Manufacturing Yogurt and Fermented Milks

Editor **Ramesh C. Chandan**

Associate Editors Charles H. White
Arun Kilara
Y.H. Hui

Blackwell Publishing

MANUFACTURING YOGURT AND FERMENTED MILKS

EDITOR Ramesh C. Chandan

ASSOCIATE EDITORS Charles H. White
Arun Kilara
Y.H. Hui

Blackwell Publishing

Manufacturing Yogurt and Fermented Milks

Blackwell Publishing

Manufacturing Yogurt and Fermented Milks

Editor

Ramesh C. Chandan

Associate Editors

Charles H. White

Arun Kilara

Y. H. Hui

Ramesh C. Chandan, Ph.D., is a consultant in dairy

Tel.: +44 (0)1865 776868

science and technology with special expertise in the

manufacture of yogurt and fermented milks. He has

Blackwell Publishing Asia

more than 40 years experience with various food com-

550 Swanston Street, Carlton, Victoria 3053, Australia

panies, including Unilever, Land OLakes and General

Tel.: +61 (0)3 8359 1011

Mills. He served on the faculty of the Department of

Food Science and Human Nutrition, Michigan State

Authorization to photocopy items for internal or per-

University, East Lansing from 1976–82.

Charles H. White, Ph.D., is professor and former

Head of the Department of Food Science, Nutrition and Health Promotion at Mississippi State University.

Danvers, MA 01923. For those organizations that have

been granted a photocopy license by CCC, a sepa-

Arun Kilara, Ph.D., is a food industry consultant spe-

rate system of payments has been arranged. The fee

cializing in dairy foods, ingredient functionality, prod-

codes for users of the Transactional

Reporting Service

uct development, and training. He has served on the

are ISBN-13: 978-0-8138-2304-1; ISBN-10: 0-8138-

faculty of Penn State University for more than 20 years.

2304-8/2006 $.10.

Y.H. Hui, Ph.D., is a food industry consultant and has

First edition, 2006

served as the author, editor, or editor-inchief of numer-

ous books in food science, technology, engineering,

Library of Congress Cataloging-in-Publication Data

and law.

Manufacturing yogurt and fermented milks /

editor, Ramesh C. Chandan ; associate editors, Charles H. White, Arun Kilara, Y. H. Hui.—1st ed.

p. cm.

Blackwell Publishing Professional

Includes bibliographical references and index.

2121 State Avenue, Ames, Iowa 50014, USA

ISBN-13: 978-0-8138-2304-1 (alk. paper)

ISBN-10: 0-8138-2304-8 (alk. paper)

Orders:

1-800-862-6657

1. Yogurt.

2. Fermented milk.

3. Dairy

Office:

1-515-292-0140

processing.

4. Food industry and trade.

Fax:

1-515-292-3348

I. Chandan, Ramesh C.

Web site:

www.blackwellprofessional.com

SF275.Y6M36 2006

Blackwell Publishing Ltd

637 .1476—dc22

9600 Garsington Road, Oxford OX4 2DQ, UK

2005017248

The last digit is the print number: 9 8 7 6 5 4 3 2 1

Contents

Contributors, vii

Preface, ix

Part I

Basic Background

1.

History and Consumption Trends, 3

Ramesh C. Chandan

2.

Milk Composition, Physical and

Processing Characteristics, 17

Ramesh C. Chandan

3.

Regulatory Requirements for Milk Production, Transportation, and Processing, 41

Cary P. Frye

4.

Regulations for Product Standards and Labeling, 57

Cary P. Frye

5.

Basic Dairy Processing Principles, 73

Arun Kilara

6.

Starter Cultures for Yogurt and Fermented Milks, 89

Ebenezer R.Vedamuthu

7.

Laboratory Analysis of Fermented Milks, 117

Robert T. Marshall

8.

Fermented Dairy Packaging Materials, 129

Aaron L. Brody

Part II

Manufacture of Yogurt

9.

Yogurt: Fruit Preparations and Flavoring Materials, 151

Kevin R. O'Rell and Ramesh C. Chandan

10.

Milk and Milk-Based Dairy Ingredients, 167

Isabelle Sodini and Phillip S. Tong

11.

Ingredients for Yogurt Manufacture, 179

Ramesh C. Chandan and Kevin R. O’Rell

12.

Principles of Yogurt Processing, 195

Ramesh C. Chandan and Kevin R.

O'Rell

13.

Manufacture of Various Types of Yogurt, 211

Ramesh C. Chandan and Kevin R. O'Rell

14.

Plant Cleaning and Sanitizing, 237

Dennis Bogart

Contents

15.

Yogurt Plant: Quality Assurance, 247

Ramesh C. Chandan and Kevin R. O’Rell

16.

Sensory Analysis of Yogurt, 265

Yonca Karagül-Yüceer and MaryAnne Drake

Part III

Manufacture of Fermented Milks

17.

Cultured Buttermilk, 279

Charles H. White

18.

Cultured/Sour Cream, 285

Bill Born

19.

Other Fermented and Culture-Containing Milks, 295

Ebenezer R. Vedamuthu

Part IV

Health Benefits

20.

Functional Foods and Disease Prevention, 311

Ramesh C. Chandan and Nagendra P. Shah

21.

Health Benefits of Yogurt and Fermented Milks, 327

Nagendra P. Shah

22.

Probiotics and Fermented Milks, 341

Nagendra P. Shah

Index, 355

Contributors

Dennis Bogart (Chapter 14)

MaryAnne Drake, Ph.D. (Chapter 16)

Randolph Associates Inc.

Department of Food Science

3820 3rd Avenue South, Suite 100

North Carolina State University

Birmingham, AL 35222 USA

PO Box 7624

Phone: 205-595-6455

Raleigh, NC 27695 USA

Fax: 205-595-6450

Phone: 919-513-4598

E-mail: dennis bogart@yahoo.com

Fax: 919-513-0014

E-mail: mdrake@unity.ncsu.edu

Bill Born (Chapter 18)

P: (919) 515-4598; F: (919) 515-7124

Dairy Consultant (Retired from Dean

Foods Company)

Cary P. Frye (Chapters 3, 4)

7254, South Main

Vice President Regulatory Affairs

Rockford, IL 61102 USA

International Dairy Foods Association

Phone: 815-965-2505

1250 H Street, N.W., Suite 900

Fax: 815-968-9280

Washington, DC 20005 USA

E-mail: blbor@aol.com

Phone: 202-737-4332

Fax: 202-331-7820

Aaron L. Brody, Ph.D. (Chapter 8)

E-mail: cfrye@idfa.org

President & CEO

Packaging/Brody, Inc.

Y. H. Hui, Ph.D (Associate Editor)

PO Box 956187

Senior Scientist

Duluth, GA 30095-9504 USA

Science Technology System

Phone: 770-613-0991

P.O. Box 1374

Fax: 770-613-0992

West Sacramento, CA 95691, USA

E-mail: aaronbrody@aol.com

Phone: 916-372-2655

Ramesh C. Chandan, Ph.D.

Fax: 916-372-2690

(Editor, Chapters 1, 2, 9, 11–13, 15, 20)

E-mail: yhhui@aol.com

Consultant

1364, 126th Avenue, NW

Coon Rapids, MN 55448-4004 USA

Phone: 763-862-4768

Fax: 763-862-4768

E-mail: Chandanrc@aol.com

Contributors

Arun Kilara, Ph.D. (Associate Editor, Chapter 5)

Isabelle Sodini, Ph.D. (Chapter 10)

Principal

Portocork America

Arun Kilara Worldwide

560, Technology Way

(An affiliate of Stratecon International Consultants)

Napa, CA 94558-6722, USA

516 Copperline Drive

Phone: 707-258-3930

Chapel Hill, NC 27516

Fax: 707-258-3935

Phone: 919-968-9322

E-mail: isodini@mac.com

Home: 919-370-9684

Cell: 603-491-5045

Phillip S. Tong, Ph.D. (Chapter 10)

www.akilara.com

Director, Dairy Products Technology Center

www.stratecon-intl.com

California Polytechnic State University

E-mail: kilara@ix.netcom.com

San Luis Obispo., CA 93407 USA

Phone: 805-756-6102

Robert T. Marshall, Ph.D. (Chapter 7)

Fax: 805-756-2998

Professor Emeritus

E-mail: ptong@calpoly.edu

Department of Food Science

University of Missouri

Ebenezer R. Vedamuthu, Ph.D.
(Chapters 6, 19)

122 Eckles Hall

332 NE Carmen Place

Columbia, MO 65211 USA

Corvallis, OR 97330 USA

Phone: 573-882-7355

Phone: 541-745-5206

Fax: 573-882-0596

E-mail: cheesetec@yahoo.com

E-mail: Marshallr@missouri.edu

Charles H. White, Ph.D.

Kevin R. O'Rell (Chapters 9, 11–13,

15)

(Associate Editor, Chapter 17)

Vice President, R&D/QA

Mississippi State University

Horizon Organic

Department of Food Science, Nutrition and

6311, Horizon Lane

Health Promotion

Longmont, CO 80503 USA

PO Box 9805

Phone 303-530-2711, ext 175

Mississippi State, MS 39762-9805 USA

Fax: 303-516-7252

Phone: (662)325-2473

Cell: 303-579-4507

Fax: (662)325-8728

E-mail: Kevin.ORell@whitewave.com

E-mail: chwhite@ra.msstate.edu

Nagendra P. Shah, Ph.D. (Chapters 20–

22)

Yonca Karagül-Yüceer, Ph.D. (Chapter 16)

Professor of Food Science and Technology

Assistant Professor

School of Molecular Sciences

C

¸ anakkale Onsekiz Mart University

Victoria University

Department of Food Engineering

PO Box 14428

Terzioglu Campus

Melbourne City Mail Centre

17020 Canakkale, Turkey

Victoria 8001, Australia

E-mail: yoncayuceer@comu.edu.tr

Phone: 61 3 9919 8289

Tel: +90 (0) 286 218 00 18, Ext. 1729

Fax: 61 3 9919 8284

Fax: +90 (0) 286 218 05 41

E-mail: Nagendrashah@vu.edu.au

Preface

Fermented dairy products other than cheeses have

and readability standpoint, an effort has been made

been consumed around the world for thousands of

to make the book reader- friendly.

years. Nevertheless, their industrial production is rel-

The book is organized into twenty-two

chapters

atively a new innovation. Yogurt has emerged as an

and divided into four parts. Part I covers the basic

outstanding new product of recent times. It has oc-

background with eight chapters. The objective is to

cupied a very significant position of consumer ac-

prepare the reader for the manufacturing of yogurt ceptance and growth in North America and through-

and fermented milks by providing relevant informa-

out the world. In the United States, yogurt, butter-

tion on product trends, regulatory aspects, dairy pro-

milk, sour cream, and probiotic drinks have become a

cessing technologies, packaging techniques, starter

multi-billion-dollar industry. The yogurt market con-

cultures use, and laboratory analysis.

tinues to grow on an annual basis.

Part II is devoted to the manufacture of yogurt. This

The literature on yogurt and fermented milks is

part also consists of eight chapters. It includes raw

vast and diverse. It encompasses the basic and fun-

materials, namely dairy and dairy-based

ingredients,

damental aspects as well as the applied and practi-

fruits and flavors, stabilizers, sweeteners (nutritive

cal facets of the industry. This book is intended to

and high intensity), principles of yogurt processing,

disseminate the applied and practical aspects. Some

types of yogurt products on the market and their man-basic science is included only to facilitate under-

ufacturing techniques, quality control procedures,

standing of the practice of manufacturing yogurt and

sensory evaluation of yogurt, and plant cleaning and

fermented milks. Overall, our objective is not to pro-

sanitizing programs. The formulation, regulatory as-

vide fundamental information. Instead,

attempts have

pects, labeling, processing equipment, and packaging

been made to deal with the application of the sci-

operations of various products have been included.

ence of yogurt and fermented milks to their manu-

Part III contains three chapters detailing the man-

facture and emphasize the practices in vogue in the ufacturing technology of cultured buttermilk, sour

industry.

cream, and miscellaneous fermented milks popular

As mentioned above, this book is dedicated to the

throughout the major regions of the world. It also in-

manufacture of yogurt and fermented milks. In view

cludes culture-containing milks that are not cultured of the multidisciplinary nature and continued fast de-

and retain the sensory characteristics of milk but con-

velopments in the technology and packaging of fer-

comitantly provide beneficial probiotic cultures to the

mented milks including yogurt, the book has multi-

consumer.

ple authors. The authors drawn from the industry and

Part IV deals with the overall health benefits of

academia are acknowledged as experts in their re-

yogurt and fermented milks. This topic has assumed

spective fields. Many authors have utilized their life-

much interest in view of consumer perception of

long experience in the product development, quality

health promotion attributed to functional foods like

assurance, and manufacture of yogurt and fermented

yogurt and fermented milks. This part brings to the

milks in their contributed chapters. Their contribution

reader a brief review of our understanding of both

to the writing of the book makes this book unique and

perceived and real benefits. A concise account of the first of its kind in the literature. From comprehension

scientific and clinical evidence associated with the

benefits of consuming yogurt and milks containing

material for plant operators, personnel performing

probiotic cultures, prebiotics, and

synbiotics has been

functions in quality control/assurance, and research

reviewed. This is a timely subject because new prod-

and development. The book should also be helpful

ucts with health claims are increasingly appearing in

for food industry personnel engaged in taking pur-

the market. We feel that this is the direction for fuchasing decisions. Since the book conveys collated

ture growth of the industry engaged in yogurt and

practical information on yogurt and fermented milks

fermented milks manufacture.

in entirety, it should be useful as a textbook to the

This book is the culmination of efforts to provide

instructors and participants of the industry-oriented a systematic and relatively simplified version of the

short courses on cultured dairy products.

information available on significant aspects of man-

We acknowledge the worldwide contribution of all

ufacturing yogurt and fermented milks. It is intended

the scientists, technologists, and engineers who have

as a textbook to be used by upper undergraduate uniestablished modern principles for the manufacture of

versity students of dairy and food science to learn

yogurt and fermented milks to provide the consumer

theory and practice of technology associated with the

with a truly functional family of foods that furnish

manufacture of yogurt and fermented milks. Gradu-

vital dairy nutrients as well as unique, wholesome,

ate students should find the book useful as a refer-

and healthy products.

ence book to obtain information on applied science

and technology of yogurt and fermented milks. The

Ramesh C. Chandan, Minneapolis, MN

industrial bias of the book should appeal to the practi-

Charles H. White, Mississippi State, MS

tioners of food science and technology in the food in-

Arun Kilara, Chapel Hill, NC

dustry. In this case, it would provide a ready reference

Y. H. Hui, Sacramento, CA

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

Part I

Basic Background

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

1

History and Consumption Trends

Ramesh C. Chandan

Overview of the World Dairy Industry

world's milk is produced in the United

States. The

Milk Production in the United States

American dairy farmer has been able to achieve the

Production of Dairy Foods in the United States

current milk output by applying scientific and mana-

Fermented/Cultured Dairy Products

gement advancements in milk production. On the

Occurrence and Consumption of

dairy farm, selection of dairy cows, their breeding,

Fermented Milks in Various Regions

and judicious use of balanced feed rations have been

Milk of Various Species

instrumental in increasing milk output per cow. In

Cultures for Production of Fermented Milks

the year 2003, milk production per cow increased

Forms of Fermented Milks

Major Commercial Fermented Milks

to 8,507 kg (18,749 lb). As a result of continuous

Fermented Milks of Scandinavia

efficiencies in milk production at the farm, milk pro-

Fermented Milks of Russia and East Europe

duction per cow has doubled in the last 30 years.

Fermented Milks of Middle East

Fermented Milks of South Asia

PRODUCTION OF DAIRY FOODS

References

Bibliography

IN THE UNITED STATES

Modern milking and milk-handling equipment, in-

OVERVIEW OF THE WORLD

cluding automated milking systems, have improved

DAIRY INDUSTRY

the speed of cleaning, sanitizing, cooling, and deliv-

ering good quality raw milk to processing plants. The

The world production of cow’s milk in the year 2003

United States has the distinction of being the largest

was 398 million metric tons (see Table 1.1). The

processor of milk and dairy products in the world.

documented number of cows was

125,490 thousand

Advanced processing and packaging technologies

heads. Individual cow milk yield varies widely in the

ensure efficient delivery and shelf life of high-quality

world. Japan was the most efficient milk producer

milk products, including yogurt and fermented milks.

with a yield of 8.71 t/cow, followed by the United

Currently, there are 800 dairy processing plants in the

States with a yield of 8.50 t/cow.

United States, where milk is transformed into more

than 300 varieties and styles of cheese, 100 flavors of

MILK PRODUCTION IN THE

ice cream and frozen yogurt, and 75 flavors of sev-

UNITED STATES

eral types of refrigerated yogurt. Dairy plants also

produce an array of flavored and white milks rang-

During the last decades, the trend indicates decrease

ing from fat-free to full fat, butter, sweetened con-

in dairy cow population (Table 1.2). Currently, nearly

densed milk, evaporated milk, dry milk, lactose, and

nine million cows produce 77.25 million metric tons whey products, as well as cultured products such as

(170,312 million pounds) of milk (USDA, 2004). As

sour cream and dips, buttermilk, yogurt, and yogurt

indicated in Table 1.2, there is a steady increase in

drinks. More recently, the industry has introduced

milk production per cow. Approximately 20% of the

packaging and marketing innovations to

compete

3

4

Table 1.1. Milk Production in the World in 2003

Country	Milk Cows (1000 head)	Milk Yield/Cow-(t)	Total Milk Produced (1000 t)

Canada

1,065

7.30

7,778

Mexico

6,800

1.00

9,784

United States

9,084

8.50

77,253

Argentina

2,000

3.98

7,950

Brazil

15,300

1.49

22,860

Peru

630

1.95

1,226

European Union

24,690

5.35

132,044

Romania

1,684

3.21

5,400

Russia

11,700

2.82

33,000

Ukraine

4,715

2.84

13,400

India

36,500

1.00

36,500

China

4,466

3.91

17,463

Japan

964

8.71

8,400

Australia

2,050

5.19

10,636

New Zealand

3,842

3.73

14,346

Total selected countries

125,490

–

398,040

Source: USDA, Service, FAS/CMP/DLP December, 2004.

http//www.fas usda.gov/dlp/circular2004/64-12Dairy/cowprod.pdf

aggressively for consumer food dollar share. Table

and sanitation officials. The PMO is a

constantly

1.3 lists the products manufactured and their volumes

evolving set of regulations to accommodate advance-

during 1997–2002.

ments and developments in science and technology

Dairy farmers and dairy processors alike abide by

related to milk production, processing, packaging, strict state and federal sanitary standards. Grade A

and distribution. From time to time, modifications in

Pasteurized Milk Ordinance (PMO) regulations are

the regulations are adopted following an agreement

the recommendations of the Public Health Service of

among the representatives of government, industry

the Food and Drug Administration of

United States

(milk producers, processors, equipment manufactur-

Department of Health and Human Services (DHHS,

ers, and suppliers), and academic and research in-

1999). The PMO is meant for voluntary adoption,

stitutions. To conform to the PMO, dairy farms and

but its importance in ensuring the quality and safety dairy plants are visited regularly by representatives of

of milk supply in the country is recognized by the

government regulatory agencies, who conduct qual-

dairy industry as well as by the state regulatory

ity assurance and safety inspections at the farms

Table 1.2. Milk Production in the United States

Milk Cows

Total Milk Production

Year

(1000 head)

Production/Cow (lb)

(million pounds)

1994

9,494

16,179

153,602

1995

9,466

16,405

155,292

1996

9,372

16,433

154,006

1997

9,252

16,871

156,091

1998

9,154

17,189

157,348

1999

9,156

17,772

162,716

2000

9,206

18,201

167,559

2001

9,114

18,159

165,497

2002

9,139

18,608

170,063

2003

9,084

18,749

170,312

Source: http//usda.mannlib.cornell.edu/reorts/nasbb/2004/mkpr0204.txt.

Table 1.3. Production of Dairy Products

in the United States During 1997–2002

Production Volume (millions of pounds)

Product

1997

1998

1999

2000

2001

2002

Butter

1,151

1,168

1,277

1,251

1,236

1,237

Natural cheese

7,330

7,492

7,941

8,258

8,260

8,599

Processed cheese,

2,210

2,278

2,425

2,288

2,207

2,155

foods and spreads

Frozen desserts *a*

1,569

1,624

1,623

1,068

1,571

1,576

Ice creams *a*

Regular

914

935

972

980

981

989

Low fat

387

407

381

373

407

362

Nonfat

41

43

40

31

21

–

Cottage cheese

Creamed

360

367

361

371

372

372

Low fat

347

361

359

364

371

370

Curd

458

466

465

461

454

–

Plain

Whole milk

18,413

18,147

18,467

18,448

18,007

17,960

Reduced and

23,709

23,449

23,571

23,649

23,630

23,610

low fat milk

Nonfat milk

9,139

9,203

8,985

8,435

8,225

8,030

Flavored milk and drinks

2,830

3,044

3,216

3,336

3,526

4,040

Half and half

883

895

960

1,008

1,146

1,140

Light cream

119

134

168

168

–

–

Heavy cream

504

515

555

743

797

720

Eggnog

102

102

109

93

105

127

Refrigerated yogurt

1,574

1,639

1,717

1,837

2,003

2,135

Frozen yogurt*

92

97

91

94

71

73

Sour cream and dips

794

817

841

914

990

1,031

Buttermilk

691

676

668

622

592

576

a Millions of gallons.

Source: IDFA, 2003.

and processing plants. These inspectors confirm herd

inspections for acceptance by another state (see

health, oversee veterinary practices, monitor sanita-

Chapter 3 for a detailed discussion on this topic).

tion of the facilities and milking equipment, and ver-

The industry has consolidated and continued to

ify that the milk is being rapidly cooled and properly

make large investments in new, state-of-the-art dairy

stored until delivered to processing facilities. They

manufacturing facilities. During the past decade,

also ensure that the processing of milk is in accor-

such developments have enabled a 45% reduction in

dance with the state and federal food laws. In some the number of manufacturing facilities while the total

instances, the state standards differ and may be even

milk output has increased by 4–5% annually. Contin-

more stringent than the federal standards. The state

ued investment will mean still lower processing costs

and in some cases local communities have jurisdic-

and higher milk output.

tion for standards for milk in their own market.

The PMO defines Grade A specifications and stan-

FERMENTED/CULTURED

dards for milk and milk products to facilitate move-

DAIRY PRODUCTS

ment of milk across state lines. Market milk, cream,

yogurt, cultured buttermilk, and sour cream are gov-

Fermented dairy foods have constituted a vital part of

erned by the Grade A standards. Reciprocity rights

human diet in many regions of the world since times

maintain that milk conforming to the PMO sani-

immemorial. They have been consumed ever since

tary standards in one state would not require further

humans domesticated animals. Evidence

showing

the use of fermented milks has been found in arche-

derivatives may constitute a staple meal, or may be

ological research associated with the Sumerians and

consumed as an accompaniment to the meal. They

Babylonians of Mesopotamia, the

Pharoes of north-

may be also used as a snack, drink, dessert, condi-

east Africa, and Indo-Aryans of the Indian subconti-

ment, or spread as well as an ingredient of cooked

nent (Chandan, 1982, 2002; Tamime and Robinson,

dishes.

1999). Ancient Indian scriptures, the *Vedas*, dating

Diversity of fermented milks may be ascribed to a

back some 5,000 years, mention *dadhi* (modern *dahi*)

number of factors: (a) Use of milk obtained from var-

and buttermilk. Also, the ancient Ayurvedic system of

ious domesticated animals, (b) application of diverse

medicine cites fermented milk (*dadhi*) for its health-

micro flora, (c) addition of sugar,

condiments, grains,

giving and disease-fighting properties (Aneja et al.,

fruits, etc., to create a variety of flavors and textures,

2002).

and (d) application of additional preservation meth-

Historically, products derived from fermentation

ods, e.g., freezing, concentrating, and drying.

of milk of various domesticated animals resulted in

conservation of valuable nutrients, which otherwise

OCCURRENCE AND

would deteriorate rapidly under high ambient

CONSUMPTION OF FERMENTED

temperatures prevailing in South Asia and Middle

MILKS IN VARIOUS REGIONS

East. Thus, the process permitted

consumption of

milk constituents for a period of time significantly

There is a diversity of fermented milks in the various

longer than possible for milk itself. Concomitantly,

regions of the world (see Table 1.4). As shown in

conversion of milk to fermented milks resulted in the

Table 1.5, the 1998 annual per capita consumption generation of distinctive viscous consistency, smooth

of various fermented fluid milks in various countries

texture, and unmistakable flavor. Furthermore, fer-

has been reported to range from 0.2 to 45 kg.

mentation provided food safety, portability, and

This variety of fermented milks in the world may

novelty for the consumer. Accordingly,

fermented

be ascribed to various factors.

dairy foods evolved into the cultural and dietary

Milk of various species

ethos of the people residing in the regions of the

world where they owe their origin.

Milk of various domesticated animals differs in com-

Milk is a normal habitat of a number of lactic acid position and produces fermented milk with a charac-

bacteria, which cause spontaneous souring of milk

teristic texture and flavor (Table 1.6). The milk of var-

held at bacterial growth temperatures for appropri-

ious mammals exhibits significant differences in total

ate length of time. Depending on the type of lactic

solid, fat, mineral, and protein content.

The viscosity

acid bacteria gaining entry from the environmental

and texture characteristics of yogurt are primarily re-

sources (air, utensils, milking equipment, milkers,

lated to its moisture content and protein level. Apart

cows, feed, etc.), the sour milk attains characteris-

from quantitative levels, protein fractions and their tic flavor and texture.

ratios play a significant role in gel formation and

Approximately 400 diverse products derived from

strength. Milk proteins, further, consist of caseins

fermentation of milk are consumed around the

and whey proteins, which have distinct functional

world. Fermentation conserves the vital nutrients of

properties. Caseins, in turn consist of
⎵s1-, NL-, and □-

the milk. Simultaneously, it modifies certain milk

caseins. The ratio of casein fractions and the ratio of

constituents enhancing their nutritional status and

caseins to whey proteins differ widely in the milks of

furnishes to the consumer live and active cultures

various milch animals. Furthermore,

pretreatment of

in significant numbers, which provide distinct health

milk of different species, prior to fermentation, pro-

benefits beyond conventional nutrition. Fermented

duces varying magnitudes of protein denaturation.

milk products may be termed as "functional foods."

These factors have a profound effect on the rheo-

They represent a significant and critical sector of the

logical characteristics of fermented milks, leading to

human diet. These products fit into the cultural and

bodies and textures ranging from drinkable fluid to

religious traditions and dietary pattern of many popu-

firm curd. Fermentation of the milk of buffalo, sheep,

lations. In addition to the main

ingredient, milk, other

and yak produces a well-defined custard-like body

food ingredients are also used in the fermented milks

and firm curd, while the milk of other animals tends

to innovate a range of nutritional profiles, flavors,

to generate a soft gel consistency.

textures, and mouth feel, thereby offering an array of

Cow's milk is used for the production of fermented

choices for the consumer. Fermented foods and their

milks, including yogurt, in a majority of the countries

Table 1.4. Major Fermented Dairy Foods Consumed in the Different Regions of the World Product Name

Major Country/Region

Acidophilus milk

United States, Russia

Ayran/eyran/jugurt

Turkey

Busa

Turkestan

Chal

Turkmenistan

Cieddu

Italy

Cultured buttermilk

United States

Dahi/dudhee/dahee

Indian subcontinent

Donskaya/varenetes/kurugna/ryzhenka/gu

Russia

Dough/abdoogh/mast

Afghanistan, Iran

Ergo

Ethiopia

Filmjolk/fillbunke/fillbunk/surmelk/taette

Sweden, Norway, Scandinavia

Gioddu

Sardinia

Gruzovina

Yugoslavia

Iogurte

Brazil, Portugal

Jugurt/eyran/ayran

Turkey

Katyk

Transcaucasia

Kefir, Koumiss/Kumys

Russia, Central Asia

Kissel maleka/naja/yaourt/urgotnic

Balkans

Kurunga

Western Asia

Leben/laban/laban rayeb

Lebanon, Syria, Jordan

Mazun/matzoon/matsun/matsoni/madzoon

Armenia

Mezzoradu

Sicily

Pitkapiima

Finland

Roba/rob

Iraq

Shosim/sho/thara

Nepal

Shrikhand

India

Skyr

Iceland

Tarag

Mongolia

Tarho/taho

Hungary

Viili

Finland

Yakult

Japan

Yiaourti

Greece

Ymer

Denmark

Zabady/zabade

Egypt, Sudan

Adapted from Chandan, 2002; Tamime and Robinson, 1999.

around the world. In the Indian subcontinent, buffalo

fermentation by bacteria transforms milk into the

milk and blends of buffalo and cow milk are used

majority of products. A combination of lactic starters

widely for *dahi* preparation, using mixed mesophilic

and yeasts are used for some products and in a few

cultures (Aneja et al., 2002). In certain countries, buf-

cases lactic fermentation combined with molds make

falo milk is the base for making yogurt, using ther-

up the flora (Table 1.7).

mophilic cultures. Sheep, goat, or camel milk is the

starting material of choice for fermented milks in

Forms of fermented milks

several Middle Eastern countries.

Fermented milks may be mixed with water to make a

refreshing beverage. Salt, sugar, spices, or fruits may

Cultures for production

be added to enhance the taste. Liquid yogurt is a prime

of fermented milks

example. Spoonable yogurt has significant commer-

Various microorganisms characterize the diversity of cial importance all over the world. It is available

fermented milks around the world. In general, lactic

in cups and tubes. To enhance its health appeal, the

Table 1.5. Consumption of Fermented Milks

Yogurt/buttermilk may be concentrated through a in Certain Countries in 1998

process that removes whey by straining through cloth

or by mechanical centrifugation to generate a cheese-

Country

Per Capita (kg)

like product. The concentrate may be mixed with

Netherlands

45.0

herbs, fruit, sugar, or flavorings to yield *shrikhand*

Finland

38.8

in India, *Quarg/tvorog/topfen/taho/kwarg* in central

Sweden

30.0

Europe, and *fromaige frais* in France. Similarly,

Denmark

27.3

cream cheese and *Neufchatel* cheese are obtained

France

26.9

from sour cream and buttermilk.

Iceland

25.3

To enhance the shelf life, fermented milks and yo-

Germany

25.0

gurt may be sun-dried or spray-dried to get a powder

Israel

24.8

form. *Leben zeer* of Egypt and *than/tan* of Armenia

Norway

19.3

are examples of concentrated yogurt without whey re-

Bulgaria

15.6

moval. In Lebanon, the concentrated yogurt is salted,

Austria

14.7

compressed into balls, sun-dried, and preserved in

Spain

14.5

oil. Another way to preserve yogurt is

the process

Czech Republic

10.0

of smoking and dipping in oil. *Labneh anbaris* and

Portugal

9.8 *a*

shanklish are partially dried yogurt products pre-

Hungary

9.4

Poland

7.4

served in oil. Spices are added to *shanklish* and the

Slovakia

7.4

balls made from this are kept in oil. In Iran, Iraq,

U.S.A.

7.4 *b*

Lebanon, Syria, and Turkey,

concentrated yogurt is

Australia

6.4

mixed with wheat products and sun-dried to get *kishk*.

Argentina

6.0

Frozen yogurt is available in the United States and

Canada

3.6

Canada as well as in several other countries.

Ukraine

3.4

South Africa

3.1

MAJOR COMMERCIAL

China

0.2

FERMENTED MILKS

a In 1997.

b In 2003.

Yogurt represents a very significant dairy product

Source: IDF, 1999, with permission.

around the world in recent times. It is a semisolid fer-

mented product made from a heat-treated standard-

trend now is to deliver prebiotics as well as probiotic

ized milk mix by the activity of a

symbiotic blend of

organisms through conventional yogurt. In many

Streptococcus thermophilus and *Lactobacillus del-*

countries, probiotic yogurt and fermented milks are

brueckii subsp. *bulgaricus*. In certain countries, the

available. They are made with defined cultures that

nomenclature yogurt is restricted to the product made have been scientifically documented to display cer-

exclusively from the two cultures, whereas in other

tain health benefits.

countries it is possible to label the product yogurt

Table 1.6. Proximate Composition of Milk of Mammals Used for Fermented Milks

Total

Total

Whey

Solids (%)

Fat (%)

Protein (%)

Casein (%)

Protein (%)

Lactose (%)

Ash (%)

Cow

12.2

3.4

3.4

2.8

0.6

4.7

0.7

Cow, zebu

13.8

4.6

3.3

2.6

0.7

4.4

0.7

Buffalo

16.3

6.7

4.5

3.6

0.9

4.5

0.8

Goat

13.2

4.5

2.9

2.5

0.4

4.1

0.8

Sheep

19.3

7.3

5.5

4.6

0.9

4.8

1.0

Camel

13.6

4.5

3.6

2.7

0.9

5.0

0.7

Mare

11.2

1.9

2.5

1.3

1.2

6.2

0.5

Donkey

8.5

0.6

1.4

0.7

0.7

6.1

0.4

Yak

17.3

6.5

5.8

–

–

4.6

0.9

Adapted from Chandan and Shahani, 1993; Chandan, 2002.

r,

r,

o

o

av

av

as

as

fl

fl

aroma,

g

,

g

Function

,

r,

,

,

,

r,

)

2)

,

r,

2

xture,

Culture

avo

avo

avo

te

aroma,

fl

probiotic

aroma

probiotic

fl

(CO

alcohol,

probiotic

alcohol,

fl

(CO

Major

of

Acidity

Acidity

Acidity

Acidity

Acidity

ime

for

hours

hours

T

hours

hours

$\circ$ C

and

2.5

24–36

12–24

for

12–14

for

for

hours

◦ C

for

◦ C/37–40

◦ C

◦ C

emperature

◦ C

8–14

Incubation

T

43–45

22

22–37

15–22

20–25

a

.casei,

.

bifidum,

Lb

Lb

oides

lactis

Milks

Lc.

marxianus

omyces

orulaspor

kefir

Acetobacter

Acetobacter

T

har

:

infantis,

mesenter

Bifidobacterium

rhamnosus,

reuteri.

lactis,

Sacc

rmented

.

omyces

2002.

e

Lb

Lb

Candida

F

Leuc.

,

Bifidobacterium

emoris

emoris

kii,

bacteria

bacteria:

cr

subsp.

cr

marxianus,

ganism(s)

Kluyver

lactis,

:

acid

acid

.

lactis,

evisiae

Robinson,

acidophilus,

lactis

.

longum,

Bifidobacterium

Lb

helveticus,

subsp.

subsp.

easts

subsp.

delbruecc

cer

aceti

aceti

and

Secondary/Optional

Microor

Lb

Leuc.

Lc.

Y

Acetic

Acetic

Commercial

of

amimeT

.

Lb

.

kii

kii

,

2001;

acture

Lb

subsp.

uf

kefir

lactis

lactis

.

.

GG,

delbruec

Lb

Frank,

Lb

ginosus,

Man

ulgaricus,

Lc.

Lc.

delbruec

.

Leuconostoc

ulgaricus,

lactis,

,

lactis

.

b

and

acidophilus,

Lb

.

Lb

the

Lc.

.

longum,

bifidus

casei,. revis,b oides,

cartila

in

Lb

subsp.b

lactis

casei,

lactis,

Lb

.

subsp

lactis

omyces

Hassan

rhamnosus

.

spp.

Lb

.

kii

diacetylactis

.

b

emoris,

Lb

kii

har

r.

ulgaricus,

L

omyces

Used

thermophilus

subsp.

cr

Lb

subsp.

cremoris.,

b

,

1995;

ganism(s)

va

.

lactis,

mesenter

anicum

Sacc: *har*

ept.

kefir.

delbruec

lactis

lactis

xtr

delbruec

.

Str

subsp.

lactis

thermophilus,

reuteri,

johnsoni,

Bifidobacterium

Bifidobacterium

subsp

subsp.

subsp

helveticus,

Leuc.

de

.

Lb

easts

Sacc

Mycoderma

Shahani,

Cultures

Primary

Microor

Lb

Lc.

S.

Lc.

Lb

Y

and

ter

Star

Chandan

utterb

1.7.

and

cream

from

leba

ogurt

milk

sour

Fermented

milks

efir

oumiss

T

Product

Y

Cultured

Probiotic

K

K

Adapted

9

10

Part I: Basic Background

Yogurt: U.S. per capita sales

8

7

6

5

4

Pounds 3

2

1

0

1982 1987 1992 1997 1998 1999 2000 2001 2002

Figure 1.1. Trends in the per capita sales of

Year

yogurt in the United States.

made with yogurt cultures and adjunct probiotic

from infections caused by food-borne microorgan-

cultures. The more common adjunct cultures are

isms, control of vaginitis, and vaccine adjuvant

Lactobacillus acidophilus, Bifidobacterium spp., effects.

Lactobacillus reuteri, *Lactobacillus casei*, and *Lac-*

Following world trends in increased consumption

tobacillus rhamnosus GG, Lactobacillus gasseri,

of fermented milks, the per capita sales of yogurt in

and *Lactobacillus johnsonii LA1* (Chandan, 1999).

the United States has also shown enormous growth.

Yogurt is produced from the milk of cow, buffalo,

The past two decades has witnessed a dramatic rise

goat, sheep, yak, and other mammals. In industrial

in per capita yogurt consumption from nearly 2.5 to

production of yogurt, cow's milk is the predominant

7.4 lbs (Fig. 1.1). The increase in yogurt consumption

starting material. To get a custard-like consistency,

may be attributed to yogurt’s perceived natural and

cow’s milk is generally fortified with nonfat dry

healthy image along with providing to the consumer

milk, milk protein concentrate, or condensed skim

convenience, taste, and wholesomeness attributes.

milk. Varieties of yogurt available include plain, fruit

In the year 2003, yogurt sales in the United States

flavored, whipped, drinking type, smoked, dried,

exceeded $2.7 billion. The total sales volume was

strained, and frozen. Details of yogurt technology

2,387 million pounds. From 1995 to 2002, as a snack

are given in various texts (Chandan and Shahani,

and lunchtime meal, yogurt consumption

grew by

1993; Chandan, 1997; Tamime and Robinson, 1999;

60%. As a breakfast food, yogurt consumption in-

Mistry, 2001; Robinson et al., 2002). This subject is

creased by 75% during the same period.

detailed in chapters 9–16 in this book.

It is interesting to note that the sale of cultured

The popularity of yogurt has increased

due to

buttermilk is on the decline (Fig. 1.2), while the

its perceived health benefits. Health-promoting

sales of yogurt and sour cream and dips are regis-

attributes of consuming yogurt containing live and

tering a significant growth. Buttermilk sales declined

active cultures are well documented (Chandan, 1989;

from 1,039 million pounds in 1987 to 592 million

Chandan and Shahani, 1993; Fernandes et al., 1992).

pounds in 2002. Yogurt drinks, on the other hand, are

The current trend of using prebiotics and probiotic

exhibiting significant growth. Sour cream and dips

cultures in the manufacture of fermented milks

sales have grown from 694 million

pounds in 1987

and yogurt products is supported by clinical trials

to 1,031 million pounds in 2002. The recent popu-

(Chandan, 1999; Ouwehand et al., 1999; Hirahara,

larity of Mexican cuisine has, in part, enhanced the

2002; Salminen and Ouwehand, 2003). The bene-

consumption of sour cream.

ficial effects documented in the numerous studies

The rise in yogurt consumption is also related to

and reviews include prevention of cancer, reduction

the choices available in the marketplace. Besides the

in diarrhea associated with travel, antibiotic therapy,

varieties of flavors, diversification in yogurt market

and rotavirus, improvement of

gastrointestinal

includes variety of textures, packaging innovations to

health, enhancement of immunity of the host, ame-

fulfill consumer expectations of health food trends,

lioration of lactose intolerance symptoms, protection

convenience, portability plus a magnitude of eating

1 History and Consumption Trends

11

1200

1000

800

600

400

Sales, million pounds

Sour cream

200

Buttermilk

0

Figure 1.2. Trends in the total sales of

1980

1985

1990

1995

2000

2005

buttermilk and sour cream and dips in the

Year

United States.

occasions. Figure 1.3 illustrates segmentation and

Generally, milk is standardized to 9–10% milk

various forms of yogurt available in the U.S. market.

solids-not-fat and < 0.5% fat and heat-treated at

Cultured buttermilk is an important fermented

85◦C for 30 minutes or at 88–91◦C for 2.5–5

milk of the United States. It is obtained from

minutes. After homogenization at 137 kPa (2,000

pasteurized skim or part skim milk cultured with lac-

psi), it is inoculated with lactic starter and ripened

tococci and aroma-producing bacteria leuconostoc.

for 14–16 hours at 22◦C. When the pH

reaches 4.5,

Fruit

flavored

Whipped

Yogurt

Lowcalorie

/ Aerated

/ Light

Yogurt

Yogurt

Hard and

Mild

Soft

Yogurt

Frozen

PLAIN

YOGURT

Yogurt

Yogurt

with

Drink/

Probiotic

Smoothie

Cultures

Long

Yogurt

Life

for

Yogurt

Yogurt

Breakfast

for

Toddlers

Figure 1.3. Segmentation of yogurt market.

the coagulum is broken and blended with 0.18% salt

Sweet acidophilus milk is an acceptable substitute and butter flakes while cooling to 4◦C. The product

for acidophilus milk of the past era. The product is

is bottled in paper/plastic containers.

made from pasteurized and chilled low-fat milk to

Buttermilk is primarily consumed as a beverage.

which a concentrate of *Lb. acidophilus* culture has

In addition, it is used in cooking, especially bakery been incorporated to deliver a minimum of one mil-

items (see Chapter 17 for a detailed discussion on

lion organisms per milliliter. It is sold in refrigerated

cultured buttermilk).

form and has a shelf life of 2–3 weeks. For more de-

Sour/cultured cream is a significant fermented

tails see Chapter 19. More recently, additional probi-milk product in North America. It is manufactured

otic organisms have been included to enhance healthy

by culturing pasteurized cream with lactococci and

connotation of the product. Among the additional cul-

aroma-producing bacteria, leuconostoc (Table 1.7).

tures are Bifidobacteria, *Lb. delbrueckii* subsp. *bul-*

It has a butter-like aroma and flavor.

Cream is stan-

garicus, S. thermophilus, and *Lb. casei*. Additional

dardized to 18% fat, 9% milk solids-not-fat, and 0.3%

details are given in chapters 20, 21 and 22.

stabilizer to get stable acid gel. The blend is heat-

treated at 72◦C for 20 minutes and homogenized at

FERMENTED MILKS

172 kPa (2,500 psi) at 72◦C, single stage, two times.

OF SCANDINAVIA

It is cooled to 22◦C, inoculated with 2–5% of the

starter, and cultured for 16–18 hours at 22◦C or until

As shown in Table 1.6, the Scandinavians have a high

pH drops to 4.7. It is packaged in cartons and cooled

per capita consumption of fermented milks. The fer-to 4◦C so that it develops thick consistency. Individid-

mented milks of Scandinavia are distinctive in flavor

ual serving cups and packages are also available. In

and texture. They are generally characterized by a

this case, fermentation is carried out by filling seeded

ropy and viscous body, and include *viili*, *ymer*, *skyr*,

base, followed by packaging and

cooling.

langfil, *keldermilk*, and several local products.

Crème fraiche is popular in France and other

viili, a fermented milk of Finland, is sold plain

European countries. This product resembles sour

as well as fruit-flavored. Its fat content ranges from

cream, except that it contains up to 50% fat as com-

2% to 12%. Milk standardized to required fat level

pared to 18% fat in sour cream and has a higher pH

is heat-treated at 82–83◦C and held at this tempera-

of 6.2–6.3.

ture for 20–25 minutes. Homogenization is avoided.

Cultured cream is used as a topping on vegetables,

It is then cooled to 20◦C and inoculated with 4%

salads, fish, meats, and fruits and as an accompani-

starter consisting of diacetyl producing *Lactococ-*

ment to Mexican meals. It is also used as a dip, as a

cus lactis subsp. *lactis, Leuconostoc mesenteroides*

filling in cakes, in soups, and in cookery items. Chap-

subsp. *cremoris*, and a fungus *Geotrichum candidum.*

ter 18 contains a detailed discussion on sour/cultured

Following packaging in individual cups, the product

cream.

is incubated at 20◦C for 24 hours, which results in

Culture-containing milks are seeded but are unfer-

acid development (0.9% titratable acidity) and cream

mented milks delivering significant doses of probi-layer on the top. The cream layer traps the fungus

otic microorganisms. In this case, the growth of the

giving a typical musty odor to the product (Mistry,

culture is intentionally avoided to preserve the fresh

2001). The fermentation process also elaborates mu-

taste of milk. Accordingly, the product is stored at

copolysaccharides imparting ropiness

and viscosity

refrigeration temperatures at all times. In the past,

to the product.

acidophilus milk was marketed by fermenting steril-

Ymer is a Danish product with characteristic high

ized milk with *Lb. acidophilus*. The inoculated base

protein (5–6%) and pleasant acidic flavor with buttery was incubated at 37◦C for 24 hours. The plain product

aroma. Protein enrichment is achieved by ultrafiltra-

developed titratable acidity of 1–2%. Consequently,

tion technology prior to fermentation. Alternatively,

it had a very harsh acidic flavor. Its popularity de-

the traditional process involves removal of whey by

clined rapidly as sweetened yogurt with

fruit flavors

draining curd after fermentation or by inducing sep-

began to dominate the market. However, *Lb. aci-*

aration of whey by first heating the curd followed by

dophilus does have a strong consumer appeal. Most

removing the whey. The standardized milk base is

of the yogurts now sold in the United States contain heated to 90–95°C for 3 minutes and cooled to 20°C.

Lb. acidophilus, which is either added after cultur-

It is then inoculated with mesophilic culture consist-

ing with yogurt culture or is cocultured with yogurt

ing of a blend of *Lc. lactis* subsp. *lactis* biovar. *di-*

culture.

acetylactis and *Leuc. mesenteroides* subsp. *cremoris*.

After incubation at 20◦C for 18–24 hours, the product

consumers, especially those with gastrointestinal

is cooled and packaged.

problems, allergy, and hypertension and ischemic

Skyr is another Scandinavian product. In Iceland,

heart diseases (Mistry, 2001). Since

mare’s milk has

this product is obtained by fermenting skim milk

only 2% protein, no curdling is seen in the product.

with yogurt culture and a lactose-fermenting yeast.

It contains 1–1.8% lactic acid, 1–2.5% ethanol, and

A small amount of rennet may be used to develop

enough carbon dioxide to give a frothy appearance to heavier body. The milk base is cultured at 40◦C until

the product (more detailed discussion on this topic is

a pH of 4.6 is achieved in 4–6 hours. It is then allowed

given in Chapter 19).

to cool to 18–20◦C and held for additional 18 hours

for further acidification to pH 4.0. Following pasteur-

ization, the mass is centrifuged using a clarifier-type separator at 35–40◦C to concentrate the solids and

achieve a protein level of around 13%. *Skyr* has typi-

Fermented milks and their products have been his-

cal flavor compounds consisting of lactic acid, acetic

torically associated with the Middle East.

acid, diacetyl, acetaldehyde, and ethanol.

Laban rayeb is prepared at home by pouring raw

whole milk in clay pots and allowing the fat to rise at

room temperature. The top cream layer is removed

FERMENTED MILKS OF RUSSIA

and partially skimmed milk is allowed to undergo

AND EAST EUROPE

spontaneous fermentation. Some variations of the

product exist. One of these is *laban khad*, which is fer-

Kefir is relatively the most popular of fermented milks

mented in a goat pelt. The other is *laban zeer*, which is

in Russia, Eastern Europe, and certain Asian coun-

distinctly fermented in earthenware pots. The organ-

tries. In addition to lactic fermentation, this product

isms responsible for fermentation are thermophilic

employs yeast fermentation as well. Thus, a percep-

lactobacilli in summer season and mesophilic lacto-

tible yeast aroma and alcohol content characterize

cocci in winter season (Mistry, 2001).

these products. Also, a fizz is noticed due to the

Kishk is obtained from *laban zeer*. Wheat grains

production of carbon dioxide as a result of yeast

are soaked, boiled, sun-dried, and ground to pow-

growth. *Kefir* preparation involves natural fermenta-

der form. The blend of wheat and *laban zeer* is al-

tion of cow's milk with *kefir* grains. *Kefir* grains are

lowed to ferment further for another 24

hours and

a curd-like material, which are filtered-off after each

portioned into small lumps and sun-dried. The dried

use and reused for inoculation of the next batch. *Kefir*

kishk has 8% moisture and 1.85% lactic acid. Af-

grains contain polysaccharides and milk residue em-

ter proper packaging, its shelf life is of the order of bedded with bacteria *Lb. kefir*, *Lb. kefirogranum*, and

several years. *Kishk* may contain spices.

species of leuconostocs, lactococci, and lactobacilli.

Labneh is prepared by concentrating fermented

Along with bacteria, the grains contain yeasts includ-

milk, after fermentation process is completed. Milk is

ing *Saccharomyces kefir, Candida kefir*, and *Torula* fermented with yogurt culture and then concentrated

species. Milk is heated to 85◦C for 30 minutes, cooled

using Quarg separator. This product contains 7–10%

to 22◦C, and incubated with *kefir* grains for 12–16

fat.

hours to obtain traditional *kefir*. Typical flavor com-

Zabady is an Egyptian product obtained by fer-pounds in *kefir* are lactic acid, acetaldehyde, diacetyl,

menting milk that has been concentrated by boiling

ethanol, and acetone.

and then fermented with yogurt culture. Further con-

In the United States, *kefir* is appearing in some

centration of milk solids is achieved by heating it and

markets. It varies from traditional *kefir* in that it is separating the whey.

fermented with a blend of species of lactococci and

lactobaclli. Some yeast is used to give only traces

of alcohol. The commercial product is blended with

FERMENTED MILKS

sugar and fruit juices/flavors.

OF SOUTH ASIA

Koumiss is obtained from mare's milk or cow's milk, using a more defined culture containing *Lb.*

The fermented milks discussed below and the prod-

delbrueckii subsp. *bulgaricus*, *Lb. acidophilus*, and

ucts derived from these are of commercial impor-

torula yeasts. This therapeutic product has per-

tance in India, Pakistan, and Bangladesh (Aneja et al.,

ceived health benefits and is

recommended for all

2002; Mathur, 2002).

Dahi, also called curd, is a semisolid product ob-

protein, 42% sugar, and 60% total solids. The acidity

tained from pasteurized or boiled buffalo or a mixture

of the product is usually between 1.10% and 1.20%, of cow and buffalo milk by souring natural, or oth-

expressed as lactic acid. Skim milk (9% solids-not-

erwise, by a harmless lactic acid or other bacterial

fat, 0.05% fat) is heated to 90◦C for 10 seconds in

culture. *Dahi* may contain cane sugar. It should have

a High-Temperature Short-Time pasteurizer, cooled

at minimum the same percentage of fat

and solids-

to 30◦C, and inoculated with 0.25–0.50% *dahi* cul-

not-fat as the milk from which it is prepared (Aneja

ture. After 8 hours of incubation period or titratable

et al., 2002).

acidity of 0.8%, the curd is ready for further process-

To prepare good quality of *dahi*, right type of culing. *Chakka* is prepared by separating the whey from

ture is essential. A mixed culture containing *Lc. lactis*

dahi employing a basket centrifuge or a desludging

subsp . *lactis, Lc. lactis* subsp. *diacetilactis*, or *Leuc.*

centrifuge. *Shrikhand* is prepared by adding sugar at

species, *Lc. lactis* subsp . *cremoris* in the ratio of 1:1:1

the rate of 80% of the amount of *chakka* and mixed in

may be used. In addition, *S. thermophilus* may be a

a planetary mixer. Predetermined amount of plastic

component of *dahi* culture or a culture composed of

cream (80% fat) is added along with sugar and fla-

Lc. lactis subsp. *lactis* and *Lc. lactis* subsp. *diacetivorings/spices to chakka to obtain at least 8.5% fat*

lactis may be employed.

in the finished product. Shrikhand is used primarily

Mild dahi is made from mesophilic lactococci.

as a snack and dessert.

Leuconostocs may be adjunct organisms for added

Lassi is a refreshing beverage derived from dahi.

buttery aroma and flavor. Sour dahi contains ad-

It is a popular drink of India, especially North India.

ditional cultures belonging to thermophilic group,

Significant advancements have been made toward

which are generally employed in the manufacture of

the industrial production of lassi through application

yogurt . These thermophilic organisms grow rapidly

of ultra high temperature (UHT) technology (Aneja

at 37–45◦C, producing dahi in less than

4 hours.

et al., 2002). Standardized milk (9–10% solids-not-

Mishti doi is a fermented milk product, having

fat and 0.5–1.0% milk fat) is heated to 85◦C for 30

cream to light brown color, firm consistency, smooth

minutes or at 91◦C for 2.5–5 minutes, cooled to 25◦C,

texture, and pleasant aroma. It contains 2–9% fat, *and cultured with dahi starter. It is then fermented at*

10–14% solids-not-fat, and 17–19% sugar. The most

25◦C to lower the pH to 4.5. The set curd is broken

common sweetener used is cane sugar. In some spe-

with the help of a stirrer and at the same time 30%

cial varieties of mishti doi fresh palm jaggery is used

sugar solution is added to get 8–12%

sugar concentra-

as a sweetener. Typically, a mix comprising 71.26%

tion in the blend. In some variations, fruit flavor may

milk (3% fat, 9% solids-not-fat), 5.32% cream (35%

be incorporated. Lassi is then homogenized at 13.7

fat), 5.42% nonfat dry milk, and 18% crystalline

kPa (2000 psi) and UHT processed at 135–145∘C *sugar is blended. Caramel (0.1%) may be added as*

for 1–5 seconds and packaged aseptically employing

a flavor. This mix is heat-treated at 85–90◦C for 15

standard equipment. See Chapter 13 for details on

min and homogenized. The heating process develops

Lassi.

light brown color in the mix. The mixture is cooled

Chapter 19 in this book contains a detailed dis-

to 42◦C. The starter is added at 1% level. Following

cussion on various fermented milks available in the

dispersion of the starter, mishti doi mix is dispensed

world.

into sanitized cups and lids are heat-sealed to make

the packaging airtight as well as to prevent leakage of *the mix. The sealed cups are then incubated at 42 ±*

REFERENCES

1◦C for about 6–8 hours until the acidity develops to

Aneja RP, Mathur BN, Chandan RC, Banerjee AK.

0.7–0.8%. The product is moved to a cold room (4◦C)

2002. Technology of Indian Milk Products. Dairy

with minimum disturbance because at this stage the

India Yearbook, New Delhi, India, pp. 158–182.

product has a weak body and unstable top layer. Ex-

Chandan RC. 1982. Fermented dairy products. In: G.

cessive shaking may result in undesirable cracks on

Reed (Ed), Prescott and Dunn’s Industrial

the top layer or in the curd mass. Mishti doi is used

Microbiology, 4th ed. AVI Publ,

Westport, CT,

as a dessert and snack in India and Bangladesh.

pp. 113–184.

Shrikhand is a dahi-based product. The cultured

Chandan RC (Ed). 1989. Yogurt: Nutritional and

milk or dahi is separated from whey to get chakka,

Health Properties. National Yogurt Association, *which is blended with sugar, color, flavor, and*

McLean, VA.

spices to reach a desired level of composition and

Chandan RC. 1997. Dairy-Based Ingredients. Eagan

consistency. The final product contains 8.5% fat, 10%

Press, St. Paul, MN.

Chandan RC. 1999. Enhancing market value of milk

Microbiology, 2nd ed. Marcel Dekker, New York,

by adding cultures. J. Dairy Sci. 82:2245–2256.

pp. 301–325.

Chandan RC. 2002. Benefits of live fermented milks:

Ouwehand AC, Kirjavainen PV, Srortt C, Salminen S.

Present diversity of products. In: Proceedings of

1999. Probiotics: Mechanisms and established

International Dairy Congress, Paris, France.

effects. Int. Dairy J. 9:43–52.

[Available in CD-ROM.]

Robinson RK, Tamime AY, Wszolek M. 2002.

Chandan RC, Shahani KM. 1993. Yogurt. In: YH Hui

Microbiology of fermented milks. In: RK Robinson

(Ed), Dairy Science and Technology Handbook, Vol.

(Ed), Dairy Microbiology Handbook. John Wiley,

2. VCH Publ, New York, pp. 1–56.

New York, pp. 367–430.

Chandan RC, Shahani KM. 1995. Other fermented

Salminen S, Ouwehand AC. 2003. Probiotics,

dairy products. In: G Reed, TW Nagodawithana *applications in dairy products. In: Encyclopedia of*

(Eds), Biotechnology, Vol. 9, 2nd ed. VCH Publ,

Dairy Sciences, Vol. 4. Academic Press, London,

Weinheim, Germany, pp. 386–418.

pp. 2315–2322.

Fernandes CF, Chandan RC, Shahani KM. 1992.

Tamime AY, Robinson RK. 1999. Yogurt Science and

Fermented dairy products and health. In: BJB Wood

Technology, 2nd ed. Woodhead Publ, Cambridge,

(Ed), The Lactic Acid Bacteria, Vol. 1. Elsevier,

England, and CRC Press, Boca Raton, FL.

New York, pp. 279–339.

U.S. Department of Health and Human Services

Hassan A, Frank JF. 2001. Starter cultures and their

(DHHS). 1999. Grade "A" Pasteurized Milk

use. In: EH Marth, JL Steele (Eds), Applied

Ordinance, 1999 revision. Publication No. 229. U.S.

Microbiology, 2nd ed. Marcel Dekker, New York,

Department of Public Health, U.S. DHHS, Food and

pp. 151–205.

Drug Administration, Washington, DC.

Hirahara T. 2002. Trend and evolution of fermented

milk. In: Proceedings of International Dairy

Congress, Paris, France. [Available in CD-ROM.]

BIBLIOGRAPHY

International Dairy Federation (IDF). 1999. World

Dairy Situation. Bulletin 339. IDF, Brussels,

International Dairy Federation. 2003. Yogurt:

Belgium.

Enumeration of Characteristic Organisms—Colony

International Dairy Foods Association (IDFA). 2003.

Count Technique at 37◦C. IDF Standard No.

Dairy Facts. IDFA, Washington, DC.

117/ISO 7889 Standard IDF, Brussels, Belgium.

Mathur BN. 2002. Using microflora in traditional milk

Tamime AY. 2002. Microbiology of starter cultures. In:

products processing. In: Proceedings of

RK Robinson (Ed), Dairy Microbiology Handbook.

International Dairy Congress, Paris, France.

Wiley-Interscience, pp. 261–366.

[Available in CD-ROM.]

U.S. Department of Agriculture (USDA). 2003.

Mistry VV. 2001. Fermented milks and cream. In: EH

National Agricultural Statistics Service. Dairy and

Marth, JL Steele (Eds), Applied Dairy

Poultry Statistics. USDA, Washington, DC, Ch 8.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

2

Milk Composition, Physical and Processing Characteristics *

Ramesh C. Chandan

Introduction

the neonate. Following parturition, milk is the secre-

Definition of Milk

tion of normally functioning mammary gland of the

Milk Composition

females of all mammals. The yield and composition

Factors Affecting Composition of Milk

of milk vary among various species to entirely meet

Physical Structure

postnatal growth requirements of the offspring. Milk,

Constituents of Milk

therefore, contains all the chemicals in the form of

Major Constituents

six major nutrients, viz., water, fat, proteins, carbohy-

Milk Fat Globule

drates, minerals, and vitamins that are ideal for nour-

Proteins

Milk Enzymes

ishment. Milk and milk products are used as compo-

Functional Attributes of Major Milk Proteins

nents of many food products around the *world.*

Lactose

Milk is an integral part of fermented milks, in-

Minerals

cluding yogurt, and considered by many as an ideal

Vitamins and Some Other Minor Constituents

vehicle to deliver beneficial cultures as well as pro-

Physical Characteristics of Milk

biotics and ingredients known to stimulate activity

Optical Properties

of the benefical cultures and the microflora of the

Flavor

human gastrointestinal tract. The conversion of milk

Acidity and pH

into fermented milks augments the nutritional value

Buffering Capacity

of inherent milk constituents. Additionally, the fer-

Electrochemical Properties

Thermal Properties

mentation process generates metabolic and cellular

Density and Specific Gravity

compounds that have positive physiological benefits

Viscosity

for the consumer.

Surface Activity

This chapter provides basic information relative to

Curd Tension

milk composition that is relevant to the processing of

Colligative Properties

yogurt and fermented milks. For detailed discussions,

References

the reader is referred to Wong et al., 1988; Jensen, *Bibliography*

1995; Swaisgood, 1996; Fox and McSweeney, 1998;

and Walstra et al., 1999.

INTRODUCTION

DEFINITION OF MILK

From a physiological standpoint, milk is a unique bi-

ological secretion of the mammary gland endowed

Chemically speaking, milk is a complex fluid in *by nature to fulfill the entire nutritional needs of*

which more than 100,000 separate molecules and

**The information in this chapter has been derived from Handbook of Fermented Foods, published by Science Technology Systems, West Sacramento, CA, C 2004. Used with permission.*

chemical entities have been found, the *levels of which*

from Jersey and Guernsey breeds would be closer to

vary with the species. In terms of physical chemistry,

a higher fat and protein range.

milk is an opaque, white heterogeneous fluid in which

various constituents are held in multidispersed phases

Factors Affecting Composition

of emulsion, colloidal suspension, or

solution.

of Milk

Worldwide, milk from cows, water buffaloes,

goats, sheep, camel, mare, and other mammals is used

Apart from the differences due to the breed, certain

for human consumption. However, cow’s milk entails

additional factors also influence the gross composi-

by far the most important commercial significance.

tion of milk: (a) individuality of animal, (b) stages

According to the Food and Drug Administration

of milking, (c) intervals of milking, (d) completeness

(FDA) of the United States, milk refers to cow's milk.

of milking, (e) frequency of milking, (f) irregular-

Milk from other species must be

labeled to indicate

ity of milking, (g) portion of milking, (h) different

the species. For instance, milk from goats must be

quarters of udder, (i) lactation period, (j) yield of

called goat's milk. Milk is the whole, clean lacteal

milk, (k) season, (l) feed, (m) nutritional level, (n) en-

secretion of one or more healthy cows properly fed *vironmental temperature, (o) health status, (p) age,*

and kept, excluding that obtained within 15 days be-

(q) weather, (r) oestrum or heat, (s) gestation period,

fore calving and 3–5 days after. This would exclude

(t) exercise, (u) excitement, and (v) administration

colostrum, the milk secreted immediately after giv-

of drugs and hormones. In general,

these variables

ing birth. The definition of Grade A milk as per FDA

tend to average out in commercial pooled milk used

standards of identity is "the lacteal secretion practi-

by dairy processors, but they do display an inter-

cally free of colostrum, obtained by complete milk-

esting seasonal pattern. The seasonal variations in *ing of one or more healthy cows, which contains not*

protein and mineral content have an important im-

less than 8.25% milk solids not fat and not less than

pact on viscosity and gel structure of yogurt and fer-

3.25% milk fat."

mented products. During late spring and early sum-

mer months, milk in some areas of the United States

MILK COMPOSITION

registers low protein and calcium content resulting

in poor viscosity in finished yogurt. During these

The chemical makeup of milk and its physicochemi-

months of low-protein milk, it is necessary to com-

cal behavior provide scientific basis for the basic pro-

pensate by raising the solids-not-fat (SNF) content *cessing of milk and the manufacture of products. The*

of yogurt mix by 0.25–0.50%. However, because of

composition of milk is generally described in terms

the current widespread use of stabilizers (modified

of its commercially important constituents, milk fat

starch and gelatin) in yogurt mix, the seasonal vari-

and nonfat solids or milk solids not fat

(MSNF). The

ations in protein content do not impact viscosity and

MSNF consists of protein, lactose, and minerals.

texture to the extent it does in natural yogurt in which

These solids are also referred to as "serum solids."

no stabilizers are used.

The term "total solids" refers to the serum solids plus *the milk fat. The major constituents of milk are given*

PHYSICAL STRUCTURE

in Table 2.1.

The ash content is not quite equivalent to the salt

Various interactive forces between the chemical con-

level in milk. In the determination of mineral con-

stituents of milk determine the technological behav-

tent, some salts like chlorides and organic salts are

ior of milk. Milk has well-defined physical equilib-

volatilized or destroyed as a result of high temper-

ria between various constituents that exist mainly in

ature exposure during routine mineral analysis by

three forms, viz., emulsion, colloidal solution, and

the ash method. The data given in

Table 2.1 refer

true solution. Milk lipids are present as an "oil-in-

to all major breeds of cows in North America. Milk

water" type of emulsion in the form of microscopic

***Table 2.1.** Composition of Bovine Milk*

Water

Fat

Protein

Lactose

Ash

Average, %

86.6

4.1

3.6

5.0

0.7

Range, average %

84.5–87.7

3.4–5.1

3.3–3.9

4.9–5.0

0.68–0.74

Source: Adapted from Swaisgood, 1996.

Table 2.2. *Physical State and Particle Size Distribution in Milk*

Compartment

Size, Diameter (nm)

Type of Particles

Emulsion

2,000–6,000

Fat globules

Colloidal dispersion

50–300

Casein–calcium phosphate

4–6

Whey proteins

True solution

0.5

Lactose, salts, and other substances

globules varying from 0.1 to 22 μm in diameter.

suspended. Water content varies from 85.4% to

The colloidal phase contains casein micelles, calcium

87.7% in different species of cows (Table 2.1). A *phosphates, and globular proteins. Whey proteins are*

small percentage of the water in milk is hydrated to

in colloidal solution and the casein is in colloidal

the lactose and salts and some is bound with the pro-

suspension. Lactose, vitamins, acids, enzymes, and

teins.

some inorganic salts are present as true solutions.

Table 2.2 gives the relative sizes of these particles in

milk.

Fat

Certain factors tend to influence the physical equi-

Milk fat, though quite bland in taste, imparts rich-

librium of milk that exists between colloidal dis-

ness/smoothness to fat-containing dairy products.

persion and salts. These factors are (a) addition of

Milk fat in freshly secreted milk occurs as micro-

polyvalent ionizable salts, (b) concentration of serum

scopic globular emulsion of liquid fat in aqueous

solids, (c) changes in pH, (d) heat treatment (which

phase of milk plasma. Fat content of milk varies from

may alter the surface charges or unfold *proteins), and*

3.4% to 5.1%, depending on the breed of the cow.

(e) addition of alcohols (which reduces bound water

Most of the milk used for yogurt production typi-

associated with the colloidal constituents). All these

cally contains an average of 3.5–3.6% fat. Variability

factors tend to destabilize colloidal systems and thus *of milk fat also depends upon the individuality of an-*

influence the technological behavior of milk during

imal, stage of lactation, feed, environmental factors,

product manufacture. In the production of cultured

and stage of milking. The composition of milk fat is

milks, as the fermentation proceeds, the colloidal cal-

given in Table 2.3.

cium phosphate gets progressively converted to ionic

The milk fat of cows consists chiefly of triglyc-

form as the pH drops from 6.6 in milk to less than

erides of fatty acids, which make up 95–96% of milk

4.6 in yogurt and fermented milks. Casein and the

fat. The remaining milk fat is composed of diglyce-

interacted whey proteins coagulate at

the isoelectric

rides, monoglycerides, free fatty acids, phospho-

point at pH 4.6, forming a gelled structure.

lipids, and cholesterol, as shown in Table 2.3.

Certain terms related to milk structure need clear

understanding. Milk plasma is the fluid portion of

milk minus fat globules, being almost similar to skim

Table 2.3. *Composition of Bovine Milk*

milk.

Fat/Lipids

Milk serum is milk plasma minus milk fat and ca-

sein micelles. Removal of casein micelles from skim

Lipid Fraction

g/l in Milk

Weight %

milk by clotting with rennet yields the *liquid called*

Triacylglycerols/

30.7

95.80

whey. It is different from milk serum because it con-

triglycerides

tains some polypeptides cleaved from casein by ren-

Diacylglycerols/

0.72

2.30

net.

diglycerides

Monoacylglycerols/

0.03

0.08

monglycerides

CONSTITUENTS OF MILK

Free fatty acids

0.09

0.28

Major Constituents

Phospholipids

0.36

1.11

Cholesterol

0.15

0.46

Water

Cholesterol esters

0.006

0.02

Water is the medium in which all the other com-

ponents of milk (total solids) are dissolved or

Total

32.056

100.05

20

Table 2.4. *Fatty Acid Profile of Milk Fat*

of fatty acids is either blood plasma lipids or they are

synthesized in the mammary gland. There is a cor-

Fatty Acids

Common Name

Weight %

relation between the fatty acid composition of feed

C4:0

Butryic

3.8

lipids and butter hardness. A seasonal effect is seen

C6:0

Caproic

2.4

as well. A softer butter is observed when the cow is

C8:0

Caprylic

1.4

on summer pasture or when the ration includes oils

C10:0

Capric

3.5

liquid at ambient temperature.

C12:0

Lauric

4.6

C14:0

Myristic

12.8

C

Cholesterol

14:1

Myristoleic

1.6

C15:0

–

1.1

The cholesterol content of milk is significantly af-

C16:0(branched)

–

0.30

fected by the species, breed, feed, stage of lactation,

C16:0

Palmitic

43.7

and season of the year. Cholesterol content is gener-

C16:1

Palmitoleic

2.6

ally lowest in the beginning of lactation period and

C17:0

–

0.34

progressively rises throughout the

lactation period,

C18:0(branched)

–

0.35

being highest toward the end of the lactation. The

C18:0

Stearic

11.3

cholesterol content of colostrum is relatively high

C18:1

Oleic

27.42

C

(570–1950 mg per 100 g fat) for the first milking af-

18:2

Linoleic

1.5

C

ter parturition and progressively declines to normal

18:3

Linolenic

0.59

levels during subsequent milking.

In general, typical cholesterol content of whole

The functional properties of milk fat are attributed

milk (3.25% fat) is 10.4 mg/100 ml or 24.4 mg per *to its fatty acid makeup. More than 400 distinct fatty*

serving of 8 fl. oz. It corresponds to 3–4 mg/g fat.

acids have been detected in milk. Typical milk fat

Fat reduction in dairy products is accompanied by

consists of 62% saturated, 29% monounsaturated,

cholesterol reduction. By separating fat from milk, an

and 4% polyunsaturated fatty acids. It *contains 7–8%*

80% reduction in cholesterol content can be achieved

short-chain fatty acids (C4—C8), which is a unique

in skim milk. Thus, nonfat milk/skim milk shows

characteristic of milk fat. The major fatty acids of

residual cholesterol level of 4.9 mg/8 oz serving. Yo-

milk fat are given in Table 2.4.

gurt and fermented milks, therefore, contain choles-

Milk fat functions as a concentrated source of en-

terol content depending on the milk fat and SNF con-

ergy as well as a source of fat-soluble vitamins A,

tent of the product.

D, E, and K and essential fatty acids, linoleic acids,

and arachidonic acids. The essential fatty acids are

Phospholipids

not synthesized by the human body. They must be

supplied by the diet. Arachidonic acid with four dou-

A number of factors influence the unique phospho-

ble bonds is present in traces. Its precursor is linoleic

lipid content of milk. The total phospholipid content

acid. Omega-3-linoleic acid and its products, eicos-

of cow's milk is approximately 36 mg/100 ml.

apentaenoic acid (EPA) and docosahexaenoic acid

(DHA), are also present in trace, but significant,

Milk Fat Globule

amounts. The positional location of individual fatty

acids in the triglycerides is not random. In fact, the

Milk fat occurs in milk as an emulsion of fat particles *syn-1 and syn-2 positions on the glycerol molecule*

suspended in aqueous phase. The spherical particles

are mainly occupied by myristic (C14:0), palmitic

are called fat globules (Fig. 2.1).

(C16:0), stearic (C18:0), or oleic acids (C18:1). The

The average size of fat globules in raw cow milk

syn-3 positions contain butanoic (C4:0), hexanoic *varies from 3.4 to 4.5 □m, depending on the breed of*

(C6:0), or oleic (C18:1) acids.

the cow. Jersey milk fat globules tend to have larger

Saturated fatty acids are solid at ambient temper-

diameters than Holstein milk fat globules. Milk lipid

ature, while unsaturated fatty acids are liquid. Their

globules fall into three overlapping size distributions.

ratio in milk fat has a profound effect on the hardness

These are shown in Table 2.5.

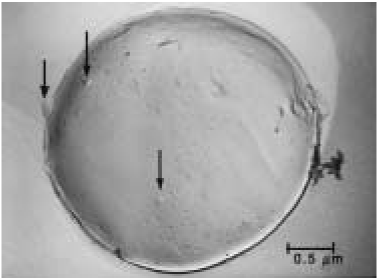
and spreadability of butter at low temperatures. The

The use of a separator in dairy plants permits frac-

balance between C4 and C18 fatty acids keeps milk fat

tionation of whole milk into skim/low-fat milk and

liquid at body temperature (Otter, 2003). The origin *cream. Fat globules are lighter (less dense) than the*



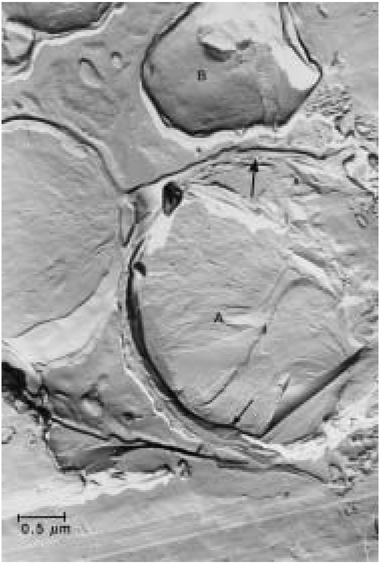

B
A
0.5 µm

Figure 2.1. *Electron micrograph of freeze-etched fat*

globule of Jersey cow milk. Note the surface is smooth

as well as uneven, and some particle-like material

protrudes out on the surface as depicted by arrows.

From: Henson et al., with permission.

surrounding water phase and rise to the surface when

milk is left undisturbed, as per Stoke's law.

V = 2 r 2(density of serum − density of fat) × g

Viscosity of milk × 9

(2.1)

where V is velocity of rise of fat globules, g is the

***Figure 2.2.** Electron micrograph of freeze-etched fat*

gravitational force, and r is the radius of the fat glob-

globule membrane isolated from the globules of Jersey *ule. From the equation, it follows that V is directly*

cow milk. Note the membrane as depicted by arrows.

proportional to g. If g is increased by centrifugal

From: Henson et al., with permission.

force, fat globules can be separated in a relatively

short time. Also, g is inversely proportional to the

viscosity of milk, which decreases as the tempera-

of 0.3–0.7 □m. The fat globules of unhomogenized

ture goes up, converting the fat into liquid state. Ac-

products like whipping cream show an average diam-

cordingly, V is increased. Thus, separation is more

eter of 4.0 □m. Skim milk has smaller fat globules

efficient at warmer temperatures. Skim milk should

left over as a result of separator action *and their di-*

contain 0.05% fat or less, if the separator is function-

ameter is around 1.3 μm. Cream layer is observed in

ing properly.

products with relatively large fat globules, while the

Processed milk products, namely homogenized

homogenized dairy products show virtually no cream *milk, ultra-high temperature (UHT) milk, ice cream,*

layer during the shelf life of such products.

yogurt, light cream, half and half, evaporated milk,

The fat globules are stabilized by a very thin mem-

and condensed milk, which have undergone homoge-

brane, closely resembling plasma membrane, only

nization have diameters of their

globules of the order

5–10 nm thick (Fig. 2.2).

Table 2.5. *Size Distribution of Milk Lipid Globules*

Proportion of the Total

Fraction of Total

Class

Diameter (□m)

Globule Population (%)

Milk Lipid (%)

Small

Below 2

70–90

< 5

Intermediate

3–5

10–30

90

Large

8–10

0.01

1–4

22

Table 2.6. *Proximate Composition of Bovine*

The neutral lipids of the membrane consist of ap-

Milk Fat Globule Membrane

proximately 83–88% triglycerides, 5–14% diglyc-

erides, and 1–5% free fatty acids. The fatty acids

Component

% (w/w) of Total Membrane

contained therein are largely long chain. In order of

Protein

41

their preponderance, they are palmitic, stearic, myris-

Phospholipids

27

tic, oleic, and lauric acids.

Neutral glycerides

14

The sterols, Vitamin A, carotenoids, and squalene

Water

13

are largely located in the fat core of the globule.

Cerebrosides

3

Cholesterol

2

Proteins

Source: Adapted from Fox and McSweeney, 1998.

Milk contains hundreds of proteins and most of them

The fat globule membrane consists of proteins,

occur in trace amounts. The major proteins of milk *lipids, lipoproteins, phospholipids, cerebrosides, nu-*

are broadly classified as caseins and whey proteins.

cleic acids, enzymes, trace elements, and bound wa-

Caseins are defined as the proteins that are insolubi-

ter, details of which are given in Table 2.6.

lized and precipitate at or above 20% when the pH

The membrane is important in keeping

the fat from

of milk is lowered to 4.6. The soluble fraction at pH

separating as free oil when it is subjected to physical

4.6 is termed as whey proteins. In addition, milk con-

abrasion during handling/processing of milk. It also

tains degradation products produced by plasmin, an

protects milk lipids against the action of enzymes, no-

inherent proteolytic enzyme. Thus, □ -casein and pro-

tably lipase, in development of rancidity. Certain en-

teose peptones owe their origin to the proteolysis of

zymes such as alkaline phosphatase and xanthine oxi-

NL*-casein. Also, proteins derived from milk fat glob-*

dase as well as certain important minerals such as iron

ule membrane are present. The

membrane proteins

and copper are preferentially attached to the fat glob-

are spilled into the milk system following mechan-

ule membrane. The membrane contains 5–25% of

ical disruption of the fat globule, such as churning

the total copper and 30–60% of the total iron content

and homogenization processing. Milk also contains *of milk. Other elements associated with membrane*

numerous enzymes and biologically active proteins.

are cobalt, calcium, sodium, potassium, magnesium,

Nonprotein nitrogen compounds like urea, uric acid,

manganese, molybdenum, and zinc. Molybdenum is

creatine, creatinine, orotic acid, and hippuric acid are

associated with the enzyme xanthine

oxidase. Activ-

also found.

ity of nearly all the enzymes of milk has been detected

Casein, the principal milk protein, makes up 80%

in the membrane.

of the total, while whey proteins make up the re-

The proteins of membrane are unique and are not

maining 20%. These fractions have

been shown

found in skim milk phase. Because of damage of the

to be heterogeneous, consisting of several proteins

globule or as a result of homogenization, the mem-

(Table 2.7).

brane proteins contain skim milk proteins (casein and

whey proteins). A hydrophobic protein, butyrophilin,

Caseins

has been isolated from the membrane, which shows

extraordinary affinity for association with lipids.

Typical of milk proteins, caseins display distinctive

The lipid fraction of the membrane constitutes

structure, charge, physical and biological properties,

about 1% of the total milk lipids. It contains phos-

as well as a nutritional role. The interaction of vari-

pholipids and neutral lipids in the ratio of 2:1.

ous caseins and calcium phosphate contributes to the

The phospholipids are phosphatidyl choline (34% of

formation of large colloidal complex particles called

total lipid phosphorus), phosphatidyl ethanolamine

casein micelles. The whitish color of

milk is ascribed

(28%), sphingomyelin (22%), phosphatidyl inosi-

to the light scattering effect of colloidal micelles. The

tol (10%), and phosphatidyl serine (6%) (Fox and

micelles are rough-surfaced spherical particles vary-

McSweeney, 1998). The major fatty acid content of

ing in size from 50 to 500 nm. Electron microscopic *phospholipids is 5% C14:0, 25% C16:0, 14% C18:0,*

picture analysis has shown that the micelles are com-

25% C18:1, 9% C18:2, 3% C22:0, and 3% C24:0. Ac-

posed of smaller particles or submicelles of 20 nm

cordingly, the unsaturated content of the membrane

diameter or less. Hydrophobic interactions with cal-

lipids is different from the rest of the *milk lipids in*

cium phosphate and submicelles seem to be involved

terms of their high unsaturated fatty acid level. Thus,

in the formation of micelles. Micelle composition

they are more susceptible to oxidative deterioration.

consists of 63% moisture and the dry matter consists

Table 2.7. *Concentration of Various Proteins*

disulfide bond formation, it can exist as polymers

and Polypeptides in Milk

of two to eight units. Similarly, ⎵S2-casein also con-

tains two cysteines and exists in a dimeric form. The

Concentration in Milk

composition and size of various caseins *are shown in*

Protein/Polypeptide

(g/100 ml)

Table 2.8.

Caseins

2.4–2.8

Casein micelles contain α_{S1}-, α_{S2}-, β-, and κ-casein

α_{S1}-Casein

1.2–1.5

in the ratio of 3:1:3:1. Most of the fractions ␣S1-, ␣S2-,

␣S2-Casein

0.3–0.4

and ␤-casein are located in the interior of micelles,

␤-Casein

0.9–1.1

with □-casein predominantly wrapped around the sur-

□-Casein

0.3–0.4

face of the micelle. Casein fractions in the interior of

Casein fragments

0.2–0.35

micelle are sensitive to calcium and become insoluble

□-Casein

0.1–0.2

in the presence of calcium. However, □-casein is not

Whey proteins

0.5–0.7

sensitive to calcium and thereby keeps the micelles

␤-Lactoglobulins

0.2–0.4

containing calcium-sensitive caseins intact and sus-

␣-Lactalbumins

0.1–0.17

pended in aqueous phase. □-Casein is

a protein with

Serum albumins

0.02–0.04

hydrophilic carbohydrate moiety (sialic acid) that ex-

Immunoglobulins

0.05–0.18

tends into aqueous phase. This arrangement further

Proteose peptone

0.06–0.17

lends stability to the micelle. Casein micelles are sta-

Milk Fat Globule

Membrane Protein

0.04

ble under most heating, homogenization, and other

Enzymes

–

dairy processing conditions.

Caseins possess certain distinctive

amino acid

makeup that impacts their processing and functional

of 92–94% protein and 6–8% colloidal calcium phos-

properties. They are rich in apolar and hydropho-

phate. Other associated salts are magnesium and cit-

bic amino acids, namely valine, leucine, isoleucine,

rate. Micelles have a porous structure with large volu-

phenylalanine, tyrosine, and proline. The apolar

minosity (approximately 4 ml/g of casein). They are

amino acids normally are insoluble in water, but

considerably hydrated, showing 3.7 g water/g casein.

their nature is balanced by phosphate groups so

Caseins are further divided into S1-, S2-, -, and

that caseins exhibit some solubility.

Methionine and

□-fractions (Table 2.7), which along with whey pro-

cysteine, the sulfur-containing amino acids, are rel-

teins, □-lactglobulin, and □-lactalbumin are gene-

atively low in caseins. This fact impacts their nu-

derived proteins synthesized in the mammary gland.

tritional deficiency. On the other hand, the essential

All these proteins are heterogeneous and exhibit

amino acid lysine content is high. In human diet, the

genetic polymorphs. There are two to eight genetic

high lysine content is helpful in complementing and

variants differing from each other in 1–14 amino

balancing the low-lysine plant proteins. The ε-amino

acids. The variants may have impact on *the protein*

group of lysine present in caseins interacts with the

concentration and processing properties of milk. The

aldehyde group of lactose at elevated temperature,

□-fraction is derived from the breakdown of NL-casein

leading to the formation of brown pigments (Mail-

by the native proteolytic enzymes of milk.

lard reaction). This also explains browning of heat-

The caseins are phosphorylated proteins, contain-

sterilized milk and nonfat dry milk during extended

ing 1–13 phosphoserine residues. □-Casein exists

storage.

in as many as nine glycosylated forms. It contains

The high prolene content results in low ⎵-helix *two cysteine molecules per molecule. As a result of*

and β-sheet in their secondary structure, giving them

Table 2.8. *Composition and Some Characteristics of Caseins*

Approx. % of

No. of Amino

Phosphate

Approx. Mol.

Casein

Total Casein

Acid Residues

Groups

Wt. (Da)

Isoelectric pH

␣S1-Casein

38

199

8

23,164

4.1

⎵S2-Casein

10

207

10–13

25,388

4.1

ᴺL-Casein

35

209

5

23,983

4.5–5.3

□-Casein

13

169

1

19,038

4.1–4.5

Source: Adapted from Spreer, 1998;

Fox, 2003; Otter, 2003.

ability for more proteolytic degradation and en-

not acid-based but is caused by enzymatic attack by

hanced digestion (Otter, 2003).

acid proteinase, chymosin contained in rennet. This

Caseins possess limited secondary and tertiary *coagulation occurs at normal pH of milk. The spe-*

structures. Accordingly, their molecular conforma-

cific cleavage of □-casein molecule occurs at amino

tion is fairly flexible, and open. The polar and apolar

acid 105 (phenyl alanine) and 106 (methionine) to

amino acids in the primary structure of caseins con-

form para-□-casein and a

macropeptide called gly-

tribute to hydrophilic and hydrophobic regions. This

comacropeptide (GMP). The GMP contains carbo-

confers surface activity and contributes to emulsify-

hydrate residues. Being hydrophilic, it is soluble and

ing and foam-forming characteristics of caseins.

ends up in the whey fraction. Since the micelles

Caseins are very heat-stable under normal protein

are stabilized by calcium-insensitive □*-casein, their*

levels, environmental pH, and ionic concentrations.

hydrolysis by chymosin results in the exposure of

Moderate heat has little or no effect on casein

calcium-sensitive ⎵ *S-casein and* ᴺᴸ*-casein to serum*

molecules since they exist naturally in *an open and*

calcium; the overall effect is coagulum formation

extended state. However, heating of milk at elevated

by aggregation of the micelles. Further hydropho-

temperature for an appreciable length of time could

bic interactions result in the expulsion of moisture

result in hydrolytic cleavage of peptide and phosphate *from the coagulated micelles, causing syneresis and*

bond, which affects the stability of the complex, con-

curd shrinkage. This coagulum is the basis of cheese

tributing to coagulation of milk.

curd formation. para-□-Casein is further degraded

Coagulation of milk is primarily a manifestation

during cheese ripening to produce numerous flavor *of micellar casein precipitation. This temperature-*

compounds and textural components.

dependent phenomenon is critical in the manufac-

ture of yogurt and fermented milks as well as in

Polyvalent Ion Precipitation.

Because of its disor-

cheese making. The precipitation/coagulation mech-

dered molecular structure, casein

fractions also pre-

anism consists of the following types:

cipitate out in the presence of di- and polyvalent ions

of various salts.

Isoelectric Precipitation.

Factors such as the pH

strongly influence the electrostatic interactions in ca-

Alcohol Precipitation.

Casein micelles become

sein. Casein becomes insoluble and precipitates out

unstable at 40% alcohol concentration at normal milk

when the milk is acidified and the pH is reduced to

pH. At lower pH, the stability becomes even less and

4.6 at or above 20◦C. At low temperature (4◦C), no

lower alcohol levels can precipitate milk. Dehydra-

visible precipitation is observed. As the *temperature*

tion of casein micelles appears to be the major cause

is raised, coagulation is observed at or above 20◦C.

of this type of precipitation.

The proteins remaining in solution are whey proteins.

The destabilization of micellar casein by added acid

Heat Coagulation.

Severe and extensive heating

or by lactic acid produced during fermentation by

of milk can cleave the calcium phosphate complexes

lactic acid bacteria starts at pH 4.9 when colloidal

with casein micelle, resulting in destabilization, ag-

calcium phosphate becomes soluble and changes to

gregation, and precipitation. Casein can withstand

ionic form. As the pH reaches 4.6,

calcium phos-

normal heating processes in dairy plants; interactions

phate is cleaved in entirety from the micelle. At the

do occur with the whey proteins.

same time, the isoelectric point of casein is reached

Among the minor caseins of milk, □ -casein is

and the micelle has no longer any charge to keep it *the C-terminal fragment of κ-casein, a product of*

suspended by repelling forces. The result is aggrega-

attack by natural proteolytic enzyme plasmin. The

tion of casein micelles leading to dense coagulum.

N-terminal residue is the proteose–peptone fraction.

This type of coagulation is relevant in all fermented

These hydrolytic products of κ-casein

occur at a

dairy products including cottage cheese and cream

range of 3–10% of the total casein content of milk.

cheese. Many textural attributes are controlled by the

The stage of lactation and the health status of the cow

temperature, quiescent conditions, pH, and rate of

affect their concentration.

acidification of milk.

Peptides derived from caseins are biologically ac-

tive and display significant extra nutritional attributes

Rennet Coagulation.

In the production of most

for maintaining normalcy of physiological functions

cheese varieties, the mechanism of coagulation is

in human subjects.

Table 2.9. *Composition and Some Characteristics of Whey Proteins*

Approx. % of

No. of

Total Whey

Amino acid

Approx. Mol.

Whey Protein

Protein

Residues

Wt. (Da)

Isoelectric pH

ᴺL-*Lactoglobulin*

7–12

162

18,277

5.2

⎵-*Lactalbumin*

2–5

123

14,175

5.1

Bovine serum albumin

0.7–1.3

582

69,000

4.8

Immunoglobulins

1.9–3.3

–

150,000–1,000,000

4.6–6.0

Proteose peptone

2–6

–

4,000–40,000

3.7

Source: Adapted from Spreer, 1998;

Fox, 2003; Otter, 2003.

Whey/Serum Proteins

containing five cysteine residues. It exists as a dim-

mer linked by 1-3 disulfide bonds. It is a fairly heat-

Whey proteins consist of -lactoglobulin and -

labile protein. Heat treatment of 60◦C results in par-

lactalbumin, bovine serum albumin, immunoglob-

tial denaturation. Differential scanning calorimetry

ulins (mainly IgG1, IgG2, and IgM), lactoferrin,

results show a peak maximum of denaturation at

proteose–peptone, and a number of diverse enzymes.

80◦C and formation of reactive sulfhydryl groups that

Table 2.9 shows some characteristics of whey pro-

can interact with □-casein and/or ⎵-

lactalbumin by

teins.

disulfide linkages. Further heating liberates hydro-

Compared to caseins, whey proteins have a rela-

gen sulfide, which is associated with "cooked" favor.

tively more ordered globular structure, which con-

-Lactoglobulin stimulates lipolysis and generation

tains disulfide linkages. Accordingly, unlike caseins,

of rancidity. It also acts as a carrier of vitamin A.

they are soluble and not vulnerable to precipitation

The large numbers of lysine residues can result in

under acidic conditions or by polyvalent ions. Like

lactosylation and accompanying changes in physical

other globular proteins, they are very *heat-labile and*

properties of the protein.

can be denatured at 90◦C, resulting in gel forma-

tion. β-Lactoglobulin complexes with κ-casein in

milk when subjected to rigorous heat treatment. All

***α-Lactalbumin.** α-Lactalbumin is the major pro-*

the whey proteins are superior in biological value as *tein of human milk, but in cow milk it is second*

compared to caseins and compare with the quality of

in preponderance to $^{N}_{L}$*-lactoglobulin. Three genetic*

egg albumins. Major differences in the behavior of

variants are reported, but Western cow contains vari-

caseins and whey proteins are summarized in Table

ant B only. This protein is rich in

tryptophan and

2.10.

sulfur amino acids cysteine and methionine. There

are four disulfides in the molecule and it exists as

NL ***-Lactoglobulin.*** *This major whey protein of*

a monomer. ⎵ *-Lactalbumin has 54 amino acid link-*

milk displays the presence of four genetic vari-

ages identical to the enzyme lysozyme. It is a gly-

ants. Besides the two genetic variants namely A

coprotein as well as a metalloprotein. One mole of

and B, variants C and D have also been re-

calcium is bound to each protein molecule, which

ported. β-Lactoglobulin is rich in sulfur amino acids,

confers heat stability on α-

lactalbumin. This protein

Table 2.10. *Major Differences in Physical and Chemical Properties of Casein and Whey Protein Casein*

Whey Protein

Strong hydrophobic regions

Both hydrophobic and hydrophilic regions

Phosphate residues

No phosphate residues

Little cysteine content

Both cysteine and cystine content

Random coil structure

Globular structure and helical structure

Very heat–stable

Heat-denatured and precipitates

Precipitates at pH 4.6

Soluble at pH 4.6

Precipitates with di- and polyvalent ions

Relatively resistant to the ions

Source: Adapted from Chandan, 1997.

has been shown to possess a physiological role in

Biologically Active Proteins and Peptides

the synthesis of lactose in the mammary gland. It is

A number of proteins and peptides derived from milk

a component of lactose synthetase

along with uri-

proteins have physiological activity. They are (1)

dine diphosphate-galactosyl transferase, catalyzing

immunoglobulins, lactoperoxidase, lactoferrin, and

the transfer of galactose to glucose to form lactose.

folate-binding protein; (2) insulin-like growth factors

(IGF-1 and IGF-2), mammary-derived growth fac-

Immunoglobulins.

There are five major classes of

tors (MDGF-I and MDGF-II), transforming growth

immunoglobulins, viz., IgA, IgD, IgE, IgG, and IgM.

factors (TGF

Their concentration is very high (100g/l) in first two

⎵*1, TGF*⎵*2, TGF*), *fibroblast growth*

factors, platelet-derived growth

factors, bombesin,

to three milkings after calf birth, but falls to 0.6–1 g/l

and bifidus factors; (3) peptides derived from milk

soon after. Immunoglobulins are antibodies synthe-

proteins, such as glycomacropeptides from □-casein,

sized in response to stimulation by specific antigens.

phosphopeptides from caseins, caseinomorphins, *These offer nonspecific humoral response to Gram-*

immunomodulating

peptides,

platelet-modifying

negative enteric and aerobic bacteria. Accordingly,

peptides, angiotensin-converting enzyme (ACE) in-

they provide passive immune protection to the newly

hibitor that lowers blood pressure,

calmodulin-

born calf. The basic structure of all immunoglob-

binding peptides, and bactericidal peptides from lac-

ulins is similar, which is composed of two identi-

totransferrin (Otter, 2003).

cal light chains (23,000 Da) and two identical heavy

chains (53,000 Da). The four chains are joined to-

gether by disulfide bonds. The complete molecule

Milk Enzymes

has a molecular weight of about 180,000 Da. The

antigenic sites are located at the NH

Milk is a repository of a variety of enzymes. Over

2-terminal of the

respective chain. Of the five immunoglobulin classes,

60 indigenous enzymes have been

reported in cow

IgG is the predominant fraction of milk, comprising

milk. They are associated either with milk fat glob-

about 90% of the total colostral immunoglobulins.

ule membrane (xanthine oxidase, sulfhydryl oxi-

Relatively smaller concentrations of IgM and IgA are

dase, and -glutamyltransferase) or with skim milk *also present in progressively decreasing amounts.*

serum (catalase, superoxide dismutase) or with mi-

celles of casein (plasmin and lipoprotein lipase).

Bovine Serum Albumin.

As the name indicates,

The partition and distribution of these enzymes is

this protein originated from blood and during synthe-

affected by the processing and storage conditions

sis in the udder spills into milk. It is a large molecule

of milk. Other enzymes present are lactate dehy-

with binding ability for fatty acids and metals.

drogenase, malate dehydrogenase, lactoperoxidase,

galactosyl transferase, alkaline phosphatase, phos-

Lactoferrin/Lactotransferrin.

This is a glyco-

phoprotein phosphatase, ribonuclease, lysozyme,

protein that displays a strong tendency to bind ionic

fructose biphosphate aldolase, and glucose phosphate

iron because of the presence of two metal binding

isomerase. The enzymes in milk come either from the

sites. The average lactoferrin content of 0.32 mg/ml *cow's udder (original enzymes) or from bacteria (bac-*

has been found for cow milk. The molecular weight

terial enzymes). Several of the enzymes in milk are

of lactoferrin varies between 73,700 and 74,000 Da.

utilized for quality testing and control. Some of the

Lactoferrin displays a very strong chelating tendency

enzymes, which are important from the

processing

for ionic iron and forms a salmon red color pigment.

point of view, are described below:

Lactoferrin is a single peptide chain, with two lobes,

each of which is capable of binding iron. Iron-free

Alkaline Phosphatase

form of lactoferrin is known as apolactotransferrin,

which is colorless in appearance.

Lactoferrin displays

This enzyme has assumed significance because of

a strong inhibitory effect toward Gram-negative en-

the association with the temperature at which it is in-

teropathogenic bacteria by virtue of its ability to bind

activated and the temperature employed for pasteur-

free ionic iron, which is essentially required for the *ization of milk. The basis of pasteurization is that*

growth of enteropathogenic microorganisms. Apart

the spore-forming pathogens, which may be present

from the antibacterial effect in the gut of calf, a nutri-

in milk, are completely destroyed by heat treatment

tional role in iron metabolism has also been ascribed

designated in the pasteurization

process. In turn, al-

to lactoferrin.

kaline phosphatase activity is also destroyed by the

pasteurization heat treatment. Thus, efficiently pas-

is stable over a wide pH range of 5.0–10.0. This en-

teurized milk should be safe from

pathogens, and

zyme has gained significance in view of its supportive

concomitantly, should not display any alkaline phos-

role for the preservation of raw milk by employing

phatase activity. Contamination of pasteurized milk

the lactoperoxidase (LP) system under ambient con-

with raw milk can also be detected by positive phos-

ditions.

phatase activity in milk. Alkaline phosphatase is dis-

tributed through milk. Its concentration is higher in

Lysozyme

the cream fraction. The optimum pH for the action of

alkaline phosphatase on p-nitrophenylphosphate is

This is a relatively small, single peptide chain protein.

9.5. The K

The variant found in bovine milk has 129–130 amino

m value for this substrate is 6.6 × 10−4 M

for skim milk enzymes, whereas for the cream al-

acid residues, with molecular weight of 14,000Da.

kaline phosphatase the corresponding value is 3.6 ×

The lysozyme cleaves the glycosidic linkage between

10^{-4} M. For details of the test, see Chapter 7.

N -acetylmuramic acid and N -acetylglucosamine of

the bacterial cell wall. Gram-positive bacteria are

generally more susceptible because they have a sim-

Lipoprotein Lipase

pler cell wall providing greater accessibility of the

This enzyme brings about hydrolytic cleavage of *substrate compared to the Gram-negative bacteria.*

glycerides, liberating free fatty acids and glycerol.

Cow milk contains about 13 □g /100 ml of lysozyme.

The volatile short-chain free fatty acids generate un-

More recently, emphasis has been focused on the

desirable rancid flavor in milk. Thus, the activity of

antibacterial role of lysozyme as a

natural defense

this enzyme can result in rancid flavor defects in

in milk. During mastitis, lysozyme levels in milk

dairy products. Lipase is activated by homogeniza-

tend to increase considerably, being in the range of

tion of fat globule membrane in raw milk. Similarly,

100–200 □g/100 ml. It has also been suggested that *lipase can degrade milk fat and develop off-flavor*

lysozyme may have an indirect effect on the defense

in a short storage period, if raw milk accidentally

systems as an immunomodulator through the stimula-

gets mixed with homogenized milk. The optimum

tion of the breakdown products of the peptidoglucan

pH for the enzymatic activity ranges

from 8.4 to 9.0,

on the immunosystem.

while optimum temperature for enzymatic activity

is 37◦C. Sodium chloride and magnesium chloride

Functional Attributes of Major

have a stimulatory effect on these enzymes whereas

Milk Proteins

calcium chloride and manganese chloride have an in-

Milk proteins are used in various foods to impart de-

hibitory effect. Residual activity of lipase remaining

sirable effects. Table 2.11 shows such characteristics

in processed milk or milk products tends to reduce

of milk proteins that are helpful in their use as func-

their shelf life.

tional ingredients.

Protease/Plasmin

Lactose

This enzyme is responsible for the hydrolytic degra-

The major carbohydrate of milk, lactose monohy-

dation of proteins. The optimum activity is observed

drate, ranges from 4.8% to 5.2%. Lactose content

at a temperature of 37◦C and a pH of 8.0. Nearly 82%

of milk is relatively constant. In colostrum and mas-

of proteolytic activity is lost when milk is pasteurized.

titic milk, its concentration is significantly lower. It

Native proteases of milk are more heat-labile com-

constitutes 52% of MSNF, nonfat dry milk, and 34%

pared to the microbial proteases, which tend to sur-

whey protein concentrate, and 70% of

whey solids.

vive even UHT processing treatment. Residual pro-

It is a disaccharide of one residue each of d-glucose

teolytic activity in processed milk and milk products

*and d-galactose. Structurally, lactose is 4- O-*NL*-d-*

leads to decrease in shelf life.

galactpyranosyl-d-glucopyranose. Fresh milk con-

tains small amounts of glucose (100 mg/100 ml),

galactose (100 mg/100 ml), and oligisaccharides

Lactoperoxidase

(10mg/100 ml). It is a reducing sugar and extensive

This enzyme catalyzes oxidation of substrate in the

heating of milk results in Maillard reaction between

presence of an oxygen donor such as hydrogen per-

lactose and proteins, creating brown pigments and a

oxide. It displays optimum activity at pH of 6.0 and

brownish color of milk.

Table 2.11. *Functional Properties of Milk Proteins*

Functionality

Casein or Caseinates

Whey Proteins

Water binding

Very high, minimum at pH 4.6

Water-binding capacity increases with

denaturation of the protein

Solubility

Insoluble at pH 4.6

Soluble at all pH levels. If denatured,

insoluble at pH 5

Viscosity

High at or above pH 4.6

Low for native protein. Higher, if denatured

Gelation

No thermal gelation except in the

Heat gelation at 70◦C (158◦F) or higher and

presence of Ca+2

influenced by pH and salts

Micelles gel with rennin

Emulsification

Excellent at neutral and basic pH

Good except at pH 4–5, if heat-denatured

Foaming

Good overrun. □-Casein best

Good foam/overrun. ␤-Lactoglobulin better

followed by ␤- and ␣S1-caseins.

than ␣-lactalbumin

Poor foam stability

Flavor binding

Good

Retention varies with degree of denaturation

Source: Adapted from Fox, 2003; Chandan, 1997.

In isolated form, lactose exists in either of the two

crystallization plays an important role. In rapid dry-

crystalline forms, ␣-hydrate and anhydrous-NL, or as

ing conditions, lactose glass (amorphous lactose) is *amorphous "glass" mixture of α- and β-lactose. In so-*

formed. This form of lactose is very hygroscopic and

lution both the forms exist in equilibrium with a ratio

causes caking in dried products containing moisture

of (α to β) 1.68 at 20◦C. Lactose has an asymmetric

levels of 8% or more. Under such conditions, the

carbon and therefore displays optical

activity. Lac-

conversion of lactose glass to ⎵-lactose monohydrate

tose anomers rotate plane-polarized light and their

crystals is responsible for binding powder particles

concentration can be assayed by polarimetric mea-

together as a “cake.”

surements. The ⎵-lactose anomer is more dextroro-

In sweetening power, lactose is only 16–33% as

tatory than the NL*-lactose anomer. If lactose crystal-*

sweet as sucrose. This makes lactose uniquely suit-

lizes from a solution like milk or whey below 93.5◦C,

able for certain food applications. Toppings, icing,

⎵*-lactose is usually formed, while above 93.5◦C,*

and various types of fillings are

examples of use

β-lactose is usually formed. During crystallization,

where its inclusion in the formulations can improve

the β-form mutarotates to α-lactose. Crystals of α-

the quality. The pharmaceutical industry has used lac-

lactose monohydrate are shaped like a tomahawk and

tose for many years for tablet or pill formation. Be-

other shapes arise as a result of cocrystallization on

ing a reducing sugar, it reacts with proteins to form a

the face of lactose crystals. The rate of crystallization,

highly flavored golden brown substance, commonly

size, and shape of lactose crystals depend on the de-

found on the crust of baked foods. Lactose contributes

gree of supersaturation of lactose

solution and the

significantly to the flavor, texture, appearance, shelf

inhibitor (β-form) level.

life, and toasting qualities of baked foods.

The α-form is less soluble (70 g/l at 15°C) than the

A compound formed from lactose in heated milk

β-form. Crystallization of lactose when milk is con-

products is lactulose. It stimulates the growth of

centrated is of importance in regard to the texture. An

Bifidobacterium bifidum and is thus beneficial in es-

equilibrium mixture of ␣- and ␤-lactose, formed by

tablishing useful microflora in the gut.

mutarotation, exhibits a solubility of about 155 g/l at

The role of lactose in yogurt and fermented milks

10◦C and 119 g/l of water at 0◦C. The relatively poor

is extremely important because the culture nutrition-

solubility at low temperatures (4◦C or below) con-

ally requires it as a substrate for growth. It is a source

tributes to sandy texture in high milk solids ice cream,

of carbon and after fermentation about 30% of the

processed cheese products, and

condensed milk prod-

lactose content is converted to lactic acid. Lactose is

ucts. As a general rule, a concentration of lactose ex-

easily hydrolyzed by NL-d-galactosidase or lactase en-

ceeding 13 g/100 ml water in a dairy product tends

zyme of the culture to glucose and galactose. Glucose

to promote crystallization of ⎵-lactose monohydrate *is readily metabolized by the Embden–Meyerhof–*

and accompanying sandy texture defect. In the manu-

Parnas pathway, while galactose tends to accumu-

facture of nonhygroscopic dry milk and whey, lactose

late. One molecule of lactose gives one molecule of *galactose and two molecules of lactic acid. Energy is*

0.90%. The percentage of salt and ash in milk varies

generated in this reaction. The acid production lowers

with the breed, feed, season, and stage of lactation

the pH enough so that the fermented food is safe from

and disease. The white residue after incineration of

most pathogens. The shelf life of

fermented milks is

a given weight of milk is used as a measure of the

significantly increased because many spoilage organ-

mineral content of milk. Ash content is not identical

isms cannot grow at their low pH.

to milk mineral level because of decomposition and

Digestion of lactose presents a problem in some *volatilization of certain minerals as a result of heat.*

individuals. These individuals lack the enzyme $^{N}{}_{L}$-

The ash contains substances derived from both the or-

d-galactosidase in their gastrointestinal tract. Con-

ganic and inorganic compounds in the milk. The CO_2

sequently, dietary lactose is not hydrolyzed and it

of the carbonates is formed mostly from *the organic*

reaches the colon intact where it is metabolized by

components; the SO3 of the sulfates is considered

colonic bacteria forming gases like methane and hy-

to be a decomposition product of the proteins. Part

drogen. It leads to discomfort caused by bloating and

of the P2O5 arises from the casein, since this pro-

diarrhea. This lactose malabsorption is alleviated by

tein contains phosphorus equivalent to about 1.62%

yogurt containing live cultures, because the culture

P_2O_5. Citric acid is completely lost. Chloride is partly

furnishes the lactose-hydrolyzing enzyme and nor-

lost (45–50%) by the high temperature employed for

mal digestion pattern is restored.

ashing. This loss can be minimized by keeping the

temperature below 600◦C. The mineral content of

milk is shown in Table 2.12.

Minerals

Mineral makeup of milk is crucial to the stabil-

Average normal milk is considered to contain 0.70%

ity of the physicochemical equilibrium in milk. The *ash and this amount represents a salt content of about*

minerals of milk exist in colloidal and soluble form.

Table 2.12. *Typical Mineral Content of Cow's Milk*

Mean (mg/100 ml)

Range (mg/100 ml)

Major Mineral

Calcium, total

121

114–130

Calcium, ionic

8

6–16

Citrate

181

171–198

Chloride

100

90–110

Magnesium

12

9–14

Phosphorus, inorganic

65

53–72

Potassium

144

116–176

Sodium

58

35–90

Mean (□g/100 g of milk)

Range (□g/100g of milk)

Trace Elements

Boron

27

–

Chromium

1

0.8–1.3

Cobalt

0.1

0.05–0.13

Copper

20

10–60

Fluoride

12

3–22

Iodine

26

–

Iron

45

30–60

Manganese

3

2–5

Molybdenum

7

2–12

Nickel

2.5

0–5

Selenium

12

5–67

Silicon

260

75–700

Zinc

390

200–600

Source: Adapted from Swaisgood, 1996; Fox, 2003.

***Table 2.13.** Partition of Major Minerals in*

Vitamins and Some Other Minor

Colloidal and Solution Phases

Constituents

Percent of Total Mineral as

The concentrations of fat-soluble vitamins A, D, E,

Major Mineral

Colloidal

Dissolved

and K, water-soluble vitamins B and C, and minor

constituents of milk are given in Table

2.14.

Calcium

67

33

Milk contains both fat-soluble (A, D, E, and K) and

Magnesium

36

64

several water-soluble vitamins. In the production of

Sodium

4

96

low-fat and skim milk, the fat-soluble vitamins get

Potassium

6

94

concentrated in the cream fraction. Whole milk is a

Phosphate

55

45

good source of vitamin A but the separation process

Citrate

6

94

leads to low vitamin A content in low-fat and skim

Chloride

0

100

milk. The FDA regulations require fortification of

Sulfate

0

100

low-fat and skim milk to restore and to make the vi-

Table 2.13 shows approximate phase compositions

***Table 2.14.** Vitamins and Some Minor*

of the minerals.

Components of Milk

They are present in a complex equilibrium con-

sisting of colloidal state and soluble state. The sol-

Per 100 g of milk

uble state exists in both ionic and nonionic form,

Vitamins

and their ratio is influenced by the pH of milk. Their

A

40 □g RE

concentration is less than 1% in milk but the techno-

D

4 IU

logical behavior of milk is affected a great deal by

E

100 □g

them. For instance, the following

characteristics are

K

5 □g

influenced:

B1

45 □g

r

B

Heat stability and alcohol coagulation of raw

2

175 □g

Niacin

90 □g

milk.

r

B6

50 □g

Preparation, quality, and storage stability of

Pantothenic acid

350 □g

products like concentrated/condensed, evaporated

Biotin

3.5 □g

milk products.

r

Folic acid

5.5 □g

Clumping of fat globules upon homogenization of

B12

0.45 □g

cream.

r

C

2 mg

The calcium content of milk influences the

firmness of curd during cheese making

and the

Nonprotein Nitrogen (NPN) Compounds

Total NPN

23–31 mg

viscosity of fermented milks. From a nutritional

Urea N

8–13 mg

standpoint, milk is an excellent source of calcium

Creatine N

0.6–2 mg

and phosphorus. Their ratio in milk is optimal for

Uric acid N

0.5–0.8 mg

bone formation and bone health.

Orotic acid N

1.2 mg

Sodium, potassium, and chloride are almost com-

Peptides N

3.2 mg

pletely (95–96%) present in true solution and in ionic

Ammonia N

4–5 mg

form and therefore diffuse freely across the mem-

Choline

4–28 mg

brane during ultrafiltration and

electrodialysis of milk

Carnitine

1–1.7 mg

and whey. Calcium and magnesium, phosphate and

N -Acetyl neuraminic acid

12–27 mg

citrate are partly in solution and partly in colloidal

Miscellaneous Compounds

suspension, depending on the pH of

milk. Approx-

Nucleic acids and nucleotides

56 mg

imately 20–30% of diffusible Ca and Mg exist as

Phosphoric esters

30 mg

free ions and the remainder as salts of citrate and

Ethanol

0.3 mg

phosphate. As the pH of milk drops in manufactur-

Lactic acid

3.5–10 mg

ing yogurt and fermented milks, the colloidal form

Citric acid

175 mg

is converted progressively to the ionic form. At pH

Acetic acid

0.3–5 mg

4.4 most of the minerals are in ionic, soluble, and

Formic acid

1–8.5 mg

diffusible form.

Source: Adapted from Goff and Hill, 1992.

tamin A content of low-fat and skim milk equivalent

Homogenization increases the number and total

to that of whole milk. The regulations require 2,000

volume of fat globules. This results in whiter color

IU of vitamin A per quart of milk. The objective is

of homogenized products than their unhomogenized

to insure essentially the same dietary *vitamin A con-*

counterparts. Lack of fat globules and the presence

tribution of all fluid milk beverages. Natural vitamin

of water-soluble pigment riboflavin produces a bluish

A activity in milk is due to retinol and the pigment

green tint in skim milk. In the absence of fat globules,

NL*-carotene. Their levels as well as those of vitamin D* *light scattering is primarily by casein micelles, which*

and E vary in milk according to the season and feed

scatter more blue (short wavelengths of light) than

profile. Vitamin D is important in bone health and

red. The color thus becomes distinctly green in whey

vitamin E is an antioxidant. Vitamin K is present in

after removal of casein particles from *skim milk. The*

milk but its dietary nutritional role is minor.

yellow color of cow milk fat in butter and cream is due

Milk is an important source of dietary B vitamins.

to the presence of the fat-soluble pigments carotene

They are stable to various heating and processing

and xanthophyll.

conditions milk is normally subjected to. Riboflavin

is vulnerable to light (wavelength < 610 nm), gener-

Refractivity

ating a sunlight flavor defect in milk. Ascorbic acid

(vitamin C) content of milk is very low and not sig-

The refraction of light by a solution is a function of the

nificant. Also, it is inactivated by heat processing.

molecular concentration of the solute in the solution.

As shown in Table 2.14, some nonprotein nitrogen

Each solute maintains its own refractivity, and the re-

compounds and several miscellaneous compounds

fractive index of a mixture is that of the total of the

are also detected in milk.

refractive indices of the substances plus that of the *solvent. The components of milk contributing to its*

PHYSICAL CHARACTERISTICS

refractive index in descending order of importance

OF MILK

are water, proteins, lactose, and minor constituents.

Specific refractive increments (in ml/g) in water at

The reader is referred to excellent reviews on the *wavelength 589.3 nm and temperature 20◦C for ca-*

subject by McCarthy (2003), Goff and Hill (1993),

sein complex, whey proteins, lactose, and other dis-

and Fox and McSweeney (1998).

solved substances are 0.207, 0.187, 0.140, and 0.170,

respectively. The fat globules do not contribute to the

Optical Properties

refractive index of milk because refraction occurs at

the interface of plasma and air.

Color

Refractive index of a substance varies with the

The color and appearance of milk has significance

wavelength of the light and the temperature at which

because the consumers perceive it as a parameter of *the measurement was taken. It is generally measured*

quality. The opaque, white or turbid color of milk is

at 20◦C with D line of sodium spectrum (wavelength

due to the scattering of light by the dispersed phase

589.3 nm) and represented as n 20d. The value of n 20d

of fat globules, casein micelles, and the colloidal cal-

of cow milk generally falls in the range *of 1.3440–*

cium phosphate. The intensity of color is directly pro-

1.3485. Refractive indices of human and goat milks

portional to the size and number of these particles.

have slightly higher values. The refractive index of

The smaller particles scatter light of shorter wave-

milk fat ranges from 1.4537 to 1.4552 at 40◦C and is *length. The creamy color of whole milk is due to*

used for verification of its authenticity.

its β-carotene content. Some breeds (for example,

Guernsey cows) have more of this pigment and their

Flavor

color is yellowish/golden. In cases of goat milk and

water buffalo milk, the pigment content is very low.

Taste and aroma are critical to the assessment of milk.

␊-Carotene is a precursor of vitamin A and in the

Flavor is a critical criterion of quality for the con-

milks of goats and water buffaloes, it is inherently

sumer. It is a sensory property in which odor and taste

converted to vitamin A. Accordingly, their milk has

interact. The sweet taste of lactose is *balanced against*

white color as opposed to the creamy color of cow's

the salty taste of chloride, and both are somewhat

milk.

moderated by proteins. This balance is maintained

Extended heating imparts a slightly brown color to

over a fairly wide range of milk composition even *milk as a result of Maillard's reaction between lactose*

when the chloride ion level varies from 0.06% to

and proteins.

0.12%. Saltiness can be detected by sensory tests in

Table 2.15. *Off-Flavors in Milk Caused by Absorption from the Feed and Environment Off-Flavor*

Description

Possible Cause

Feed

Aromatic, onion, garlic

Cows fed 0.5–3 hours before milking

Cowy

Chemical after-taste, cow's breath odor

Cows with ketosis/acetonemia

Barny

Unclean, reminiscent of barn, silage

Poor ventilation, buildup of aromatic

silage/barn odors

samples containing 0.12% or more of chloride ions

and vice versa. The titratable acidity of individual

and becomes marked in samples containing 0.15%.

cow milk varies from 0.12% to 0.18%, but in com-

Some workers attribute the

characteristic rich flavor

mercial pooled milk the range is only 0.14–0.16%.

of dairy products to the lactones, methylketones, cer-

"Developed" or "real" acidity is due to lactic acid,

tain aldehydes, dimethyl sulfide, and certain short-

formed as a result of bacterial action on lactose in

chain fatty acids.

milk. Hence, the titratable acidity of stored milk is

Although milk has a clean, pleasantly sweet flavor,

equal to the sum of natural acidity and developed

it is quite bland, and therefore, any off-flavors are

acidity. The titratable acidity is usually expressed as

readily discernible. Off-flavors result when the bal-

a "percentage of lactic acid." The

higher the serum

ance of flavor compounds is altered because of the

solids, the higher is the titratable acidity. But the pH

microbiological activity or processing treatments, or

remains relatively the same. The titratable acidity (or

chemical or biochemical reactions. The fat globules

pH measurement) is a critical parameter in yogurt *have a large surface area and tend to adsorb aromatic*

and fermented milk production. It determines the end

odors (for example, onion and garlic) readily.

point of the fermentation process. Measuring the pH

Some off-flavors in milk are shown in Tables 2.15–

is preferable because unlike titratable acidity, it does

2.18.

not vary with the total MSNF in yogurt mix.

The pH of normal, fresh, sweet milk usually varies

between 6.6 and 6.8. Higher pH values for fresh milk

Acidity and pH

indicate udder infection (mastitis) and lower values

indicate bacterial action. Skimming and dilution with

Freshly drawn milk shows a certain acidity as de-

water raise the pH of milk while sterilization usually

termined by titration with an alkali (sodium hydrox-

lowers it.

ide) in the presence of an indicator phenolphthalein

(equivalent to pH 8.3). This acidity, also called titrat-

able acidity, as determined by titration, is known as

Buffering Capacity

"natural" or "apparent" acidity. It is caused by the

presence of casein, acid-phosphates, citrates, etc., in

The pH is a measure of acidity or inverse of the loga-

milk. The natural acidity of individual milk varies

rithm of the hydrogen ion concentration in milk. The

considerably depending on species, breed, individ-

relationship of hydrogen ion

concentration and pH is

uality, stage of lactation, physiological condition

shown by the following equation. A weak acid (HA)

of the udder, etc., but the natural acidity of fresh,

dissociates as follows:

herd/pooled milk is much more uniform. The higher

$(H+)(A-)$

K

(2.2)

the SNF content in milk, the higher the natural acidity

a

(HA)

Table 2.16. *Milk Off-Flavors of Microbiological Origin*

Off-Flavor

Description

Possible Cause

Malty

Grape nut-like, caramelized burnt

Unsanitary equipment, insufficient cooling and

storage at > 10◦C

Bitter/unclean

Musty, spoiled, stale, dirty, bitter

Exposure to warm temperature, dirty utensils, weeds

Fruity/fermented

Odor resembling fruits like

Old milk, too long storage of raw milk *apple/pineapple*

Sour

Tingling acidic taste

Growth of lactic and other organisms

Table 2.17. *Off-Flavors in Milk of Biochemical Origin*

Off-Flavor

Description

Possible Cause

Rancid

Bitter, soapy, foul odor, unclean

Homogenized raw milk stored too long,

mixture of pasteurized and raw milk,

raw milk agitated vigorously

Oxidized/light-induced

Medicinal chemical taste, reminiscent

Milk in transparent plastic/glass bottles *of burnt feather or tallow*

exposed to sunlight or UV light in

refrigerated cases

Here, K a is dissociation constant, (H+) is hydrogen

culture cells is somewhat moderated for better sur-

ion concentration, and (A−) is the concentration of

vival rates in the stomach.

the anion and (HA) is the concentration of the acid

HA.

Electrochemical Properties

1

(A−)

$pH = log$

$= p K a + log$

(2.3)

(H+)

(HA)

Oxidation Reduction Potential

Here p K a equals –log10 K a.When the pH equals p K a,

The oxidation–reduction (E h) potential of milk is ex-

the weak acid is 50% dissociated and the buffering ca-

pressed in volts. It is measured relative to the po-

pacity is maximum. Proteins contain many basic and

tential of the standard hydrogen electrode, which is

acid groups in their molecule.

Generally, their max-

assigned 0 V at pH 0. E h is due to the presence of

imum buffering capacity is at their isoelectric point.

several soluble constituents capable of yielding or ac-

For milk, maximum buffering capacity is around

cepting electrons. In milk, E h is controlled by factors

pH 5.1.

such as dissolved oxygen, ascorbic acid, riboflavin,

Milk displays innate ability to resist the changes in

cystine–cysteine transformation, and pH value. Fresh

the pH or exhibits buffering capacity (dB/dpH). This

cow milk displays values of +0.2 to +0.3 V at 30◦C.

is mainly due to the presence of amino acid residues

It is due largely to dissolved oxygen, *ascorbic acid,*

of caseins and whey proteins, and colloidal salts (cal-

and riboflavin. Bacterial growth reduces the oxygen

cium phosphate complex, citrates, etc.). Caseins dis-

tension. Methylene blue reduction test, used for as-

play maximum buffering capacity at their isoelectric

sessing the microbial quality of milk, is based on this *pH of 4.6 and phosphates at around pH 7.0. Whey pro-*

phenomenon. The ascorbic acid oxidation in stored

teins show maximum buffering capacity at pH 4–5.

milk leads to the formation of singlet oxygen, which

The buffer index of milk is defined as the amount of

in turn is involved in lipid oxidative deterioration. Ri-

acid or alkali (mol/l) required in

changing the pH of

boflavin in milk exposed to light near 450 nm assists

1 liter of milk by one unit. Buffering capacity has

in photooxidation of methionine residues of whey

some significance in the survival of live cultures in

proteins to produce methional, the principal cause of

the stomach where high acid conditions are delete-

sunlight flavor defect. Heating of milk increases the

rious to the survival of yogurt cultures. Since pH of

reducing capacity of milk and heating above 70◦C

yogurt is close to its isoelectric point, the milk pro-

also causes noticeable decrease in the E h because of

teins of yogurt exercise maximum buffering capacity.

the liberation of −SH groups from

whey proteins.

Accordingly, the impact of acidic conditions on the

The increase in the reducing capacity of yogurt mix

***Table 2.18.** Off-Flavors Arising from Processing Conditions*

Off-Flavor

Description

Possible Cause

Cooked

Sulfur-like odor, caramelized, scorched

Too high pasteurization temperature and holding

time too long, Excessive heat treatment

Foreign

Non-milk-like odor/flavor

Contamination with sanitizers, cleaning

compounds

Flat

Watery

Too low milk solids, watered milk

after heat treatment is significant in promoting the

equates to 1/4186 cal/g/◦C in cgs units. Heat capac-

growth of yogurt bacteria, which are microaerophilic

ity increases linearly with increase in temperature in

in nature.

skim milk from 3906 J/kg/K at 50◦C to 4218 J/kg/K

at 140◦C, according to the following equation (Goff

and Hill, 1993):

Electrical Conductivity

Heat capacity = 2 . 814 × temperature in ◦C + 3824

Current passes through milk by virtue of the activ-

ity of its ionic mineral constituents, of which chloride

The heat capacity of milk and cream depends strongly

ions carry 60–68% of the current. There is, therefore,

upon fat content. Milk fat has a heat capacity of 2177

a close correlation between the electrical conductiv-

J/kg/K. The heat of fusion is 8.37 J/g. The heat capac-

ity of milk and its chloride content. The specific elec-

ity of milk in the range of 50–140◦C

can be estimated

trical conductivity of milk at 25◦C ranges between

according to the equation

0.004

−1 cm−1 and 0.0055 −1 cm−1, correspond-

Heat capacity of milk = 2 . 976 × temperature ◦C

ing to that of approximately 0.25% NaCl solution

(w/w). Higher values usually represent

mastitic in-

+3692

fections. Sodium, potassium, and chloride ions are

the major contributors to electrical conductance of

Specific Heat

milk. Whey and permeate from ultrafiltration have

Specific heat is the ratio between the amount of heat

higher conductivity than skim milk. The *presence of*

necessary to raise a given weight of a substance to

fat tends to decrease the specific conductance. Con-

a specified temperature and the amount of heat nec-

ductivity of milk may be used to detect added neu-

essary to raise an equal weight of water to the same

tralizers.

temperature. It is nearly identical to the heat capac-

The development of acidity by bacterial action dur-

ity figure as the heat capacity of water (1 cal/g/◦C

ing fermentation of milk increases its conductance

or 4186 J/kg/K) is fairly constant over the range of

because of conversion of calcium and magnesium to

0–100◦C. It is important in processing *for determin-*

ionic forms. Thus, measuring their electrical conduc-

ing the amount of heat or refrigeration necessary to

tance can follow the progress of fermentation dur-

change the temperature of milk. Fat content influ-

ing manufacture of yogurt and other fermented dairy

ences the specific heat of the product.

products. Electrical conductance can also be used to

Specific heat of skim milk and whole milk is ap-

follow demineralization of whey, leading to loss of

proximately 4.052 and 3.931 kj/kg/k, respectively at

ionic minerals during the manufacture of whey pro-

80◦C. The value for non fat dry milk ranges from

tein concentrates. Electrical

conductance is directly

1.172–1.340 kj/kg/k at 18–30◦C while for milk fat it

proportional to temperature. Conductance of milk in-

is 2.177 kj/kg/k.

creases by about 0.0001

−1 cm−1 C−1.

Thermal Conductivity

Thermal Properties

Thermal conductivity determines how

fast milk is

Thermal Expansion

cooled or heated. It is the rate of heat transfer by con-

duction in J/m/s/K. Thermal conductivity increases as

When warmed the volume of milk increases which

temperature increases. It decreases as the concentra-

affects the design considerations for storage and flow *tion level increases, and for a given temperature and*

rates through processing treatments. The coefficient

concentration, the higher the fat content, the lower

of thermal expansion of fresh milk (4% fat, 8.95%

the thermal conductivity. The thermal conductivity

SNF) is approximately 0.335 cm3/kg/◦C at a temper-

for milk at 20◦C is 0.53 J/m/s/K, and

0.61 J/m/s/K

ature range of 5–40◦C. (Goff and Hill, 1993).

at 80◦C. There is a marked decrease in the thermal

conductivity with increase in either fat or total solids.

Heat Capacity

Effects of Heat

Heat capacity of milk and milk products, a function

of total solids of the sample, decreases *with their in-*

Dairy plants routinely use heat processes to make

creasing contents. Heat capacity expressed in SI units

milk safe from pathogenic organisms and to extend

the shelf life of milk and milk products. The pas-

Protein composition: Various genetic variants of

teurization and sterilization temperatures and hold-

the casein fractions display variable heat stability.

ing times employed in such treatments have profound

The heat coagulation of milk is related to the ratio

effects on milk proteins, enzymes, fat globule mem-

between □-casein and ␤-lactoglobulin.

Higher heat

brane, some vitamins, and physical state of minerals

coagulation temperature is observed at higher levels

and other constituents. Caseins of milk are relatively

of $^{N}_{L}$*-lactoglobulin.*

stable to moderate heating regimes under conditions

Mineral balance: The heat stability of milk is *of normal pH and ionic balance. The serum pro-*

mainly determined by the makeup of proteins as

teins are globular proteins. They are more prone to

well as the relative concentration of various salts

denaturation to heat. At 60–65◦C, $^{\mathrm{N}}_{\mathrm{L}}$*-lactoglobulin*

present in colloidal and ionic states. The molar ra-

molecules begins to uncoil themselves

and start inter-

tios between various cations and anions (both mono-

action with □-casein located in casein micelle form-

valent/polyvalent) strongly impact the physical equi-

ing disulfide linkages. The denaturation process is

libria of milk and the heat stability. Heat stability is

complete at 90–95∘C when milk is held for 5 minutes.

maximum at the optimum salt equilibria defined by

Under this heat treatment, ⎵-lactalbumin is relatively

the relative concentration of Ca+2, Mg+2, citrate−3,

less vulnerable to heat, undergoing reversible denat-

and phosphates−3.

uration. However, the immunoglobulins are fully de-

The molar ratio between cations and anions mainly *natured. In the manufacture of yogurt, this heating*

determines whether milk will be stable at certain tem-

treatment is beneficial in increasing water-holding

perature and pH employed for processing. When milk

capacity and in reducing syneresis of the coagulum.

is heated, salts of calcium and magnesium display an

Also, the resultant viscosity increase *assists in opti-*

inverse solubility curve manifested by progressive

mizing the texture of yogurt. High heat treatment is

transition of calcium and manganese from the col-

deleterious to rennin curd formation, and should be

loidal state to the ionic state. However, the solubility

avoided in cheese manufacture.

of the salts of sodium and potassium increases with

Normal pasteurization treatment causes "cream

the rise in processing temperature.

plug phenomenon" in which some fat globules break

pH: The pH plays a critical role in determining the

down to free fat that sticks to other fat globules giv-

heat stability of milk. The pH effects both the molec-

ing rise to the plug. On homogenization, the plug

ular disassociation of casein components and the

is broken down. Exposure to higher temperatures

formation of aggregated protein complexes through

($> 135^{\circ}C$) results in partial aggregation of proteins of

protein–protein interactions. Further, pH strongly af-

milk fat globule membrane and a more

dense mem-

fects the salt equilibrium between the colloidal and

brane that is less permeable.

ionic states of the minerals of milk. Maximum heat

Severe heat treatment above 100◦C gives rise to

stability is observed between pH 6.6–6.8.

brown pigments (melanoidin polymers) in milk. The

Concentration of milk solids: In general, the heat

Maillard reaction between the ε-amino group of ly-

stability of milk decreases progressively as milk is

sine residue of proteins and carbonyl group of lactose

concentrated to higher levels of total solids. This is

gives a brown color to milk. Such heat treatment also

accompanied by concomitant shift of

salt from the

results in nutritional compromise. Cooked flavor re-

ionic state to the colloidal state as well as drop in the

sults from the production of sulfhydryl groups arising

pH values.

from the breakdown of disulfide linkages.

Homogenization: Although fat itself does not af-

fect heat stability of milk, homogenization of milk

brings about certain significant changes in the phys-

ical equilibria of milk. During homogenization of

Heat Stability

milk, the original fat globule is disrupted and sur-

In the manufacture of certain high heat-treated/

face area increases by many folds. Resurfacing of *concentrated milk products, heat stability of milk*

the newly formed fat globules takes place instantly,

plays a significant role. A number of factors interact

predominantly by the adsorption of micellar casein.

in a complex manner, which ultimately determines

A shift in the colloidal state because of the adsorption

the heat coagulation of milk. On the

basis of signif-

of caseins affects the equilibria between the colloidal

icant findings, the role of various interacting factors

and ionic states, which ultimately reduces the heat

may be summarized as follows:

stability, although only marginally.

Density and Specific Gravity

and 1.066, respectively. The specific gravity of milk

is influenced by the proportion of its constituents,

The density of milk (mass/volume) is the sum total of

each of which has a different specific gravity approx-

the densities of its constituents, their concentration,

imately, as follows: water, 1.000; fat, 0.930; protein, *and state at a particular temperature. The density*

1.346; lactose, 1.666; salts, 4.120; and SNF, 1.616.

of milk is a useful parameter to convert volumet-

As the milk fat is the lightest constituent, the more

ric measurements to gravimetric measurements and

there is of it, the lower the specific gravity will be

vice versa. Milk is purchased on weight *basis and*

and vice versa. Determination of the density of milk

is sold in volumetric packages. Yogurt is sold in

is carried out by first warming the milk to 40◦C to al-

avoirdupois/weight units, while fermented milks are

low melting of fat and then adjusting the temperature

packaged in volumetric units. Most of the dairy plants *down to the desired working temperature.*

process milk and other products in gallons, a volu-

The percentage of total solids or SNF in milk can

metric measure. Density is also useful in estimating

be roughly estimated by the following formula:

degree of concentration during condensed milk man-

ufacture by a simple hydrometer

reading.

$$\%TS = 0.25\,D + 1.22\,F + 0.72$$

Milk density at 20∘C ranges from 1.027 to 1.033

$$\%SNF = 0.25\,D + 0.22\,F + 0.72$$

with an average of 1.030 g/cm−3. Accordingly, the

weight of 1 liter of milk would range from 1.027

where D = 1000 (d− 1) is the density of sample of

to 1.033 kg. The density of milk at

15.5°C can be

milk at 20°C and F is the fat percentage of sample.

estimated according to the following formula (Otter,

The empirical formulas given above lack the accu-

2003):

racy of laboratory analysis but in field conditions are

useful as quick estimates.

$d\ 15\ .\ 5°C =$

100

g / cm−3

F / 0 . 93 + SNF / 1 . 608 + Water %

(2.4)

Viscosity

Here, d represents density, F = % fat, SNF = %

The viscosity of milk and cream creates the im-

solids-not-fat, and Water % = 100 – F – SNF.

pression of “richness” to the consumer. From an

The densities of some fluid milk products are given

organoleptic standpoint, viscosity contributes to

in Table 2.19.

mouth feel and flavor release. Fluidity is the inverse of

The specific gravity of milk is the ratio of den-

viscosity. It has a bearing on fat separation/creaming, *sity of milk to that of water at a given temperature.*

rate of heat transfer, and flow conditions during pro-

Yogurt mix and other dairy mixes containing sugar

cessing of milk. Assuming laminar flow with parallel

and added milk solids exhibit higher densities and

stream lines, viscosity may be defined as the ratio of

specific gravities than milk. For

instance, the spe-

shearing stress (force per unit area) to shear rate (ve-

cific gravity of ice cream mix is in the range 1.0544–

locity difference divided by distance, in reciprocal

1.1232, while that of fresh whole milk lies in the

seconds). In dairy industry, the common units are

range 1.030–1.035, with an average of 1.032. Milk *centipoise (cP) or (poise × 10−2).*

fat, MSNF, skim milk, and evaporated whole milk, at

Viscosity of milk and dairy products depends on

15.5◦C, have specific gravity of 0.93, 1.614, 1.036,

the temperature and on concentration and state of

***Table 2.19.** Density of Fluid Milk Products at Various Temperatures*

Density (kg/cm3) at Various Temperatures

Product

4.4°C

10°C

20°C

38.9°C

Raw milk, 4% fat

1.035

1.033

1.030

1.023

Homogenized milk, 3.6% fat

1.033

1.032

1.029

1.022

Skim milk, 8.9% SNF

1.036

1.035

1.033

1.0026

Half and half, 12.25% fat

1.027

1.025

1.020

1.010

Light cream, 20% fat

1.021

1.018

1.012

1.000

Whipping cream, 36.6% fat

1.008

1.005

0.994

0.978

Source: Adapted from Goff and Hill, 1993.

casein micelles and fat globules.

Representative val-

imperfectly pasteurized milk or contamination of ho-

ues at 20◦C for various products are as follows:

mogenized pasteurized milk with raw milk causes

whole milk, 1.9 cP; skim milk, 1.5 cP; and whey,

partial hydrolysis of milk fat, resulting in low sur-

1.2 cP. Viscosity of milk and cream increases with *face tension, bitter flavor, and rancidity of milk.*

homogenization and the increase is proportional to

the homogenization pressure. Increase in viscosity

Foaming

can be attributed to the fine state of fat globules and

Milk and milk products high in milk fat and/or milk

the formation of a coat of plasma proteins on them.

proteins interact frequently with air and form foams.

The casein micelles of milk contribute more to the

Sometimes the process is desirable as in whipping

viscosity of milk than does any other constituent. Vis-

of cream and sometimes it has a nuisance value as

cosity varies not only with changes in physical na-

in handling of skim milk. Fat globules *and free fat*

ture of fat but also with the hydration of proteins.

make foam less stable. Heating of milk to such an

Alterations in the size of any dispersed constituents

extent that whey proteins are denatured yields more

result in viscosity changes. The fat contributes less

voluminous and more stable foam on heating. How-

than caseins but more than whey proteins. When fat

ever, sterilization diminishes its foaming capacity. A

globules are greatly subdivided by homogenization,

concentrate of 30% total milk solids that has been

an increase in viscosity is observed. The viscosity of

vigorously homogenized forms very stable foam.

skim milk decreases on heating to 62◦C *after which*

Foaming of milk is minimum at 30–35◦C. At 60◦C,

it increases apparently because of changes in pro-

the foam volume is independent of the fat content.

tein hydration. An increase in temperature causes a

Below 20◦C and above 30◦C, the foaming tendency

marked reduction in viscosity. For example at 20◦C, *appears to increase. Fat tends to stabilize the foam*

milk is about half as viscous as at 0◦C, and at 40◦C,

formed below 20◦C, for instance, during churning

is approximately one third of the value at 0◦C.

for butter production. Skim milk produces slightly

Viscosity is critical in the texture development of

more stable foam above 30◦C than does

whole milk

yogurt and cultured milks. It is a crucial attribute

or light cream.

in defining mouth feel, flavor release, and refresh-

The formation of stable foam depends upon two

ing quality of the product. It forms an important pa-

main factors. First, the lowering of the surface tension *rameter in quality control programs of culture dairy*

allows the gathering and spreading of the surface-

plants. In yogurt, the viscosity is of the order of

active components into thin films. Second, the films

15,000–25,000 cP.

must be sufficiently elastic and stable to prevent the

coalescence of the gas cells. Stable foam is thus

Surface Activity

formed when the surface tension of the liquid is not

great enough to withdraw the film from between the

Surface activity is involved in adsorption phenom-

gas cells and when the stabilizing agent has great

ena and the formation and stability of emulsions. It

internal viscosity.

is relevant to creaming, fat globule membrane func-

Foaming properties affect handling of milk prod-

tion, foaming, and emulsifier use in dairy products.

ucts and how dairy-based ingredients are used in

Normal cow milk has an inherent surface activity.

other products. Foam formation and its stability con-

Its surface tension approximates 70%

of that of wa-

stitute important factors in getting the necessary over-

ter (72 dynes/cm). The surface tension of cow whole

run and texture in frozen dairy desserts, including

milk ranges from 50 to 52 dynes/cm, and for skim

frozen yogurt and whipped yogurt. Many yogurt

milk, 55–60 dynes/cm at 20◦C. For cream it is ap-

plants use antifoaming agents as processing aid to

proximately 46–47 dynes/cm. Casein, along with the

control foam formation during the preparation of

proteolysis products protease–peptones, is largely

yogurt mix. Foam control is also necessary from a

responsible for the surface activity. Whey proteins

proper pasteurization standpoint

because organisms

make little contribution. Fat reduces surface tension

suspended in foam are resistant to common heat pas-

by a physical effect. Lactose and most of the salts

teurization time–temperature regime.

tend to raise it when they are present in true solution.

Surface tension decreases as milk temperature

Curd Tension

rises. Processing treatments such as heating, ster-

ilization, homogenization, and shear tend to in-

This property is considered important in relation

crease surface tension. However, homogenization of

to the cheese making characteristics as well as the

digestibility of milk. The curd tension of milk is

is expressed in negative numbers whereas FPD is the

28–54 g. Heat treatment of milk causes a reduction of

positive version of freezing point. Accordingly,

curd tension, as does the homogenization treatment.

freezing point depression of 0.540◦H is equivalent

Addition of some of the salts such as the sodium cit-

to freezing point of −0.540◦H. On adulteration with

rate and sodium hexametaphosphate

tend to reduce

water, zero degree being the reference point, FPD

the curd tension of milk.

decreases, while freezing point registers an increase.

Milks from individual cows show a narrow range in

Colligative Properties

their FPD (0.530–0.525), but pooled milk has av-

erage of 0.543◦H. It is generally agreed *that milk*

Osmotic Pressure

of FPD higher than 0.535◦H may be presumed to

The number of molecules or particles, not the

be water-free. But readings between 0.530◦H and

weight of solute, control osmotic pressure; thus 100

0.534◦H warrant a letter to the suppliers for a check *molecules of size 10 will have 10 times the osmotic*

on their plant operation. When FPD readings are be-

pressure of 10 molecules of size 100. It follows that

tween 0.525◦H and 0.529◦H, there is a strong sus-

for a given weight, the smaller the molecules, the

picion of added water to the milk. Any time, if the

higher the osmotic pressure.

reading is 0.525◦H or less, assumption of extraneous

Milk is formed from blood, the two being sepa-

water in milk is justified.

rated by a permeable membrane; hence they have

We will now illustrate how the freezing point

the same osmotic pressure. In other words, milk is

method detects the adulteration of milk with extrane-

isotonic with blood. The osmotic pressure of blood

ous water. Let us assume milk with no added water

is remarkably constant although the composition, as

freezes at $-0.540^{\circ}C$. *When 10% water is added, its*

far as pigment, protein, etc. are concerned, may vary.

freezing point should be in the range of $-0.478^{\circ}C$. *In*

The osmotic pressure is basically a

function of salt

general, the percentage of added water is calculated

balance and lactose content of milk.

as follows:

Freezing Point

$$\% \text{ added water} = 0.540 - FPD$$

(2.5)

0 . 540

Pure water freezes at 0°C. Milk freezes at a tempera-

×(100 − total milk solids)

ture slightly lower than water because of the presence

As little as 3% water added to milk can be detected

of soluble constituents such as lactose and soluble

by this method. Fermented milks show significant in-

salts. The freezing point of milk depends on molar

crease in FPD because of the conversion of lactose *concentration of its soluble, low molecular weight*

to lactic acid and the transformation of minerals to

compounds. Lactose, potassium, sodium, and chlo-

the ionic form. The freezing point of cream, skim

ride are the principal milk constituents responsible

milk, and whey are identical with that of the milk

for 75–80% of the entire freezing point *depression*

from which they are prepared. Therefore, the freez-

(FPD). Since it is a fairly constant property of milk, it

ing point test does not detect the addition of skim

is routinely used for detecting adulteration of incom-

milk or removal of fat from milk samples. More-

ing milk with water, using a cryoscope. Adulteration *over, watered milk, which has soured, may pass the*

of milk with water lowers the molal concentration

test because souring results in increase of the FPD

of lactose and salts, and thus increases the freez-

as a result of an increase in the amount of soluble

ing point. Earlier work was done with the Hortvet

molecules. Hence, the freezing point

should be deter-

cryoscope using a mercury-in-glass thermometer and

mined in fresh samples (having no developed acidity)

results on freezing point were based on the Hortvet

for greatest accuracy.

scale. More recent work with thermistor measuring

devices has shown that the Celsius and Hortvet scales *are not identical. The following relationship has been*

Boiling Point

reported (Harding, 1995):

A solution boils at a higher temperature than does

$$^{\circ}C = 0.96418^{\circ}H + 0.00085$$

the pure solvent, according to the concentration of the

∘

dissolved substance. The milk constituents in true so-

$H = 1.03711°C - 0.00085$

lution are mainly responsible for the elevation of the

Accordingly, $-0.540°H$ is actually $-0.521°C$. Most

boiling point above 100°C. Elevation of the boiling

of the industry data is reported in °H. Freezing point

point is based on the same principles as the depression *of freezing point. However, for detecting added wa-*

Otter D. 2003. Milk: Physical and chemical properties.

ter, the freezing point method is far superior on the

In: B Cabellero, LC Trugo, PM Finglas (Eds),

grounds of accuracy and convenience. The boiling

Encyclopedia of Food Sciences and Nutrition, 2nd *point of milk is 100.17∘C.*

ed. Academic Press, New York, pp. 3957–3963.

Swaisgood HE. 1996. Characteristics of milk. In: O.

Fennema (Ed), Food Chemistry. Marcel Dekker,

REFERENCES

New York, pp. 841–878.

Walstra P, Geurts TJ, Noomen A, Jellema A, van

Fox PF, McSweeney PLH. 1998. Dairy

Chemistry and

Boekel MAJS. 1999. Dairy Technology: Principles

Biochemistry. Blackie Academic and Professional,

of Milk, Properties and Processes. Marcel Dekker,

New York, p. 95.

New York.

Goff HD, Hill AR. 1993. Chemistry and physics. In:

Wong NP, Jenness R, Keeney M, Marth

EH (Eds).

YH Hui (Ed), Dairy Science and Technology

1988. Fundamentals of Dairy Chemistry. Van

Handbook, Vol. 1: Principles and Properties. VCH

Nostrand Reinhold, New York.

Publishers, New York, pp. 1–62.

Harding F. 1995. Adulteration of milk. In: Milk

Quality. Blackie Academic and

Professional, New

BIBLIOGRAPHY

York, pp. 60–67.

Henson AF, Holdsworth G, Chandan RC. 1971.

Bylund G. 1995. Dairy Processing Handbook. Tetra

Physico-chemical analysis of the bovine milk fat

Pak Processing System, Lund.

globule membrane. J. Dairy Sci., 54:1752–1763.

Chandan R. 1997. Dairy-Based Ingredients. Eagan

Jensen RG (Ed). 1995. Handbook of Milk

Press, St. Paul, MN, p. 5.

Composition. Academic Press, New York.

Fox PF. 2003. The major constituents of milk. In:

McCarthy, DJ. 2003. Milk: Physical and physics.

G Smit (Ed), Dairy Processing. Improving Quality.

Chemical properties. In: H. Roginski, JW Fuquay,

CRC Press, Boca Raton, FL, pp. 6–41.

PF Fox (Eds). Encyclopedia of Dairy Sciences.

Spreer E. 1998. Milk and Dairy Product Technology.

Academic Press, New York, pp. 1812–1821.

Marcel Dekker, New York, p. 21.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

3

Regulatory Requirements for Milk Production, Transportation, and Processing

Cary P. Frye

History of Milk Safety

for milk-related human illness. Coxiella burnetti was

United States Public Health Grade "A" Milk Safety Program

also noted as one of the pathogens responsible for

Inspection of Milk Safety

milk-borne outbreaks of Q fever and the imposition

Farm Requirements

of more stringent pasteurization requirements (US-

Milk Transportation

DHHS PMO, 2003).

Processing Plant

The incidence of milk-borne illness in the United

HACCP

States has been sharply reduced. In 1938, milk-borne

Standards and Regulations

outbreaks constituted 25% of all disease outbreaks,

Imports

Equipments Standards

because of infected foods and contaminated water.

The 3-A Sanitary Standards Symbol

Recent information reveals that milk and fluid milk

Milk Pricing—U.S. Federal Milk Marketing Orders

products continue to be associated with less than

Background of Federal Orders

1% of such reported outbreaks. Many groups have

Classified Pricing

contributed to this commendable achievement, in-

Producer Prices

cluding public health and agricultural agencies, dairy

Milk Pricing for Fermented Milk Products

and related industries, several interested professional

Glossary

groups, educational institutions, and

the consuming

References

public.

The responsibility for insuring the ready availabil-

HISTORY OF MILK SAFETY

ity and safe supply of milk and milk products, includ-

ing yogurt and fermented milks, is the cooperative

Milk, the primary ingredient used for yogurt and fer-

effort of all engaged, including government regula-

mented milk products, is rich in nutrients but also has

tors and the industry.

the properties to readily support microbial growth and

potentially pathogenic organisms. Milk cows on the

UNITED STATES PUBLIC

farm are exposed to many sources of potential con-

HEALTH GRADE "A" MILK

tamination. Some of these may be the water, feed

SAFETY PROGRAM

sources, exposure to manure, insects, contact with

diseased animals in housing or corral areas, injuries

The U.S. Public Health Service (USPHS) branch of

to the udder, and poor milking practices.

FDA is a division of the Federal Health and Human

Early studies implicate milk as the carrier for many

Services under the Food and Drug Administration

communicable diseases to the consumer. Some of

(FDA), which has broad authority of overseeing the

the most notable outbreaks were tuberculosis, bru-

health and safety of food. USPHS

oversight began at

cellosis, salmonaelliosis, diptheria, scarlet fever, sep-

the turn of the century with studies on the role that

tic sore throat, and dysenteries of the food infection

milk plays in the spread of diseases. The findings

type. Recent outbreaks of salmonaelliosis, listeriosis,

indicated that effective public health control of milk-

yerisnia, and camplhylobacter have been responsible

borne disease requires the application of sanitation

41

42

measures throughout the production, handling, pas-

The USPHS has legal jurisdiction for the enforce-

teurization, and distribution of milk

and milk prod-

ment of milk sanitation standards, in the case of

ucts. These studies were followed by research to iden-

interstate commerce. It also serves in an advisory

tify and evaluate sanitary measures that might be used

and simulative capacity and is designed primarily to

to control milk-borne disease, including studies that *assist state and local regulatory agencies.*

led to the improvement of the pasteurization process.

To assist states and municipalities in initiating and

Inspection of Milk Safety

maintaining effective programs for the prevention of

milk-borne disease, the USPHS developed a model

State and local regulatory agencies are responsible *regulation known as the Standard Milk Ordinance*

for the enforcement of sanitation requirements on

for voluntary adoption by State and Local Milk Con-

dairy farms, in milk hauling receiving and transfer

trol Agencies in 1924. An accompanying Code was

stations, and in processing plants. The FDA's primary

published in 1927 to provide a uniform *interpretation*

function under the Federal/State Milk Safety Coop-

of this Ordinance and to establish administrative and

erative Program is to provide technical assistance to

technical details as to satisfactory compliance. This

the states in the implementation and enforcement of

model milk regulation is still used today, though now *their regulations. This assistance is provided through*

titled the Grade "A" Pasteurized Milk Ordinance

district and regional milk specialists and the Cen-

(Grade "A" PMO), 2003 Revision. This regulation

ter for Food Safety and Nutrition's (CFSAN) Milk

incorporates the provisions governing the process-

Safety Team. The inspection program is *carried out*

ing, packaging, and sale of Grade "A" milk and milk

by the state regulatory agency under the requirements

products, including yogurt, fermented milk prod-

of the Cooperative Program of the National Confer-

ucts, whey, whey products, and condensed and dry

ence on Interstate Milk Shipments (NCIMS). As a *milk products. The 25th revision of the Grade "A"*

result, there is a greater degree of reciprocity between

PMO incorporates new knowledge into public health

states on acceptance of inspections. The NCIMS Pro-

practices.

cedures document contains information for establish-

The USPHS alone did not produce the Grade "A" *ing milk sanitation standards, rating procedures, sam-*

PMO. As with preceding editions, it was developed

pling procedures, laboratory evaluation, and sample

with the assistance of Milk Regulatory and Rating

collector procedures (USDHHS Procedures, 2003).

Agencies at every level of federal, state, and local

The Procedures requires that producer

farms and

governments. All segments of the dairy industry, in-

processing facilities are inspected by the state regu-

cluding health and agriculture regulators, producers,

latory agencies on a routine basis at a minimum of

milk plant operators, equipment manufacturers, as-

twice a year, with many state regulatory agencies in-

sociations, and educational and research institutions

specting on a four-per-year schedule. These farms

assisted in producing the Grade “A” PMO.

and dairy plants are also inspected under the Inter-

The Grade “A” PMO is the basic standard used

state Milk Shipper (IMS) Program to determine the

in the voluntary Cooperative State–

USPHS Program

“rating” of all plants electing to participate in the IMS

for the Conference of Interstate Milk Shipments, a

program. State or local ratings must be conducted by

program participated in by all 50 states, the Dis-

a certified USPHS representative. These ratings are

trict of Columbia, and the U.S. Trust Territories. The *conducted no less than once every 24 months (but*

National Conference on Interstate Milk Shipments

no more than 15 days) and are based on compliance

(NCIMS), in accordance with the "Memorandum of

with the Grade "A" PMO requirements . The ratings

Understanding" with the FDA, recommends changes

provide an assessment of state and

local sanitarians'

and modifications to the Grade "A" PMO at its bien-

activities regarding public health control and milk

nial conferences.

quality control. Rating inspections are expressed

The Grade "A" PMO is incorporated by reference

in terms of percentage compliance. For example, *in Federal specifications for procurement of milk and*

if the milk plant and dairy farms comply with all

milk products. It is used as the sanitary regulation for

requirements of the Grade "A" PMO, the Sanitation

milk and milk products served on interstate carriers

Compliance Rating of the pasteurized milk supply

and is recognized by the Public Health

Agencies, the

would be 100%. However, if the plant of some of the

milk industry, and many others as the national stan-

dairy farms fails to satisfy one or more of these re-

dard for milk sanitation.

quirements, the Sanitation Compliance Rating would *be reduced in proportion to the amount of milk and*

rial is not allowed for straining milk. Strainers, if

milk products involved in the violation, and to the

used, must be of a perforated design or constructed

relative public health significance of the violated

to utilize a single-use strainer media such as paper *item(s).*

or cloth. Details for plans of mechanically cleaned

Additionally, the USPHS is obligated to conduct

milk pipeline systems must be submitted to the

periodic "check ratings" to assure validity and uni-

state regulatory agency for written approval prior to

formity with each state's ratings (USDHHS Methods, *installation.*

2003).

Utensils and equipment used for milk handling,

storage, or transportation must be cleaned after each

use, sanitized before reusing, and stored to assure

Farm Requirements

complete drainage and protection from contamina-

The Grade "A" PMO sections on raw

milk established

tion. Additionally, effective measures must be in

the requirements and standards for milk production

place to prevent contamination by insects, rodents,

and farm conditions. These require that milking ani-

and the chemicals used to control these pests.

mals are disease-free and do not show signs of secre-

Milking must be done in the milking barn, stable,

tion of abnormal milk such as blood or mastitis. Milk

or parlor. The cows' flanks, udders, bellies, and tails

from cows that have been treated with medications or

must be free from visible dirt. Udders and teats should

antibiotics must be properly separated. The milking

be cleaned and dried before milking.

Teats should be

barn, stable, or parlor must be properly constructed

treated with a sanitizing solution just prior to the time

with floors that are concrete or impervious so as to

of milking and dried before milking. However, alter-

easily maintain cleanliness. Walls and ceilings should

native udder preparation methods may be allowed *be smooth, painted, or finished, making it dust-tight*

once they are evaluated and approved by the FDA.

in order to reduce the likelihood of dust and extrane-

Milking house operations, equipment, and facili-

ous material from getting into the milk. There must

ties should be conducted to prevent any contamina-

be sufficient light during the day and *night, as well*

tion of milk, equipment, containers, or utensils. Ve-

as good air circulation to prevent condensation and

hicles used to transport the milk from the dairy farm

excess odors.

to the milk plant, receiving station, or transfer station

Milking barns must be kept clean and the cow *should be constructed in such a way so as to protect*

yard should be graded for proper drainage to prevent

the milk from sunlight, freezing, and contamination.

standing water or excess accumulation of organic

Cleaners and sanitizers used on the farm should be

waste. The milk house should be of sufficient size

properly identified. Animal drugs must *be properly*

and provide proper cooling, handling, and storage

labeled and segregated for their use on nonlactating

of milk. It should include proper facilities to wash,

animals. Unapproved drugs should not be used. Per-

sanitize, and store milk containers and utensils. Milk

sonal cleanliness of the farm employees is impor-

houses must have tight-fitting doors to the milking

tant, and therefore hand-washing facilities must be

barn and water that is piped under pressure, with

provided.

an adequate supply of hot water. The milk cooling

Furthermore, the dairy farm is responsible for as-

must be monitored by accurate accessible tempera-

suring that the raw milk for pasteurization is cooled

ture recording devices installed in the milk line, and

to 10◦C (50◦F) or less within 4 hours or less of

milk must be cooled to below 7◦C (45◦F). The milk

the commencement of the first milking, and to 7◦C

house must be kept clean to reduce the likelihood of

(45◦F) or less within 2 hours after the

completion of

contamination of the milk. Every dairy farm should

milking provided that the blend temperature after the

have at least one conveniently located toilet. Water

first milking and subsequent milking does not exceed

for the milk house must be from a supply properly

10◦C (50◦F).

located and protected to provide safe and sanitary

water quality.

Milk Transportation

Milking equipment and utensils for handling and

storage of milk on the farm must be made of smooth,

The sanitary requirements for transportation of raw

nonabsorbent, corrosion-resistant, and nontoxic ma-

milk from the farms to the processing plant are

terial and must be constructed in such a way so that

also detailed in the Grade "A" PMO . These policies

they can be easily cleaned. Multiuse woven mate-

may be found under the sections on raw milk and *regulations pertaining to raw milk receiving stations*

station are required to be marked with the name and

and transfer stations.

address of the milk plant or hauler and should be

Milk is collected and stored at the farms in a

sealed. Additionally, a statement should be prepared

cooled bulk tank and then picked up daily or every *for each shipment containing at least the following*

other day by bulk milk transportation trucks. These

information:

trucks must be made of smooth, nonabsorbent,

r Shipper’s name, address, and permit number.

corrosion-resistant, nontoxic, material that can be

Each milk tank truck containing milk should *easily cleaned, and constructed in a way to protect*

include the IMS Bulk Tank Unit (BTU)

the milk from dust or airborne contamination.

identification number(s) or the IMS Listed Milk

The bulk milk hauler is often responsible for col-

Plant Number (for farm groups listed with a milk

lecting official milk samples as well as transporting *plant) on the weight ticket or manifest*

raw milk from a farm to a receiving station, transfer

r Permit identification of hauler, if not an employee

station, or a milk processing plant. The bulk milk

of the shipper

hauler is required to have training and pass an ex-

r Point of origin of shipment

amination with a score of 70% or

greater related to

r Tanker identification number

sanitation, sampling, and weighing procedures, in-

r Name of product

cluding proper use and cleaning of equipment, and

r Weight of product

record-keeping requirements. The bulk milk hauler

r Temperature of product when loaded

is issued a permit upon successful completion of the

r Date of shipment

examination. The state regulatory agency must ob-

r Name of supervising regulatory agency at the

serve the techniques of the bulk milk hauler at one or

point of origin of shipment

more farms every 24 months for the permit to remain *r Whether the contents are raw or pasteurized, or in*

valid.

the case of cream, low-fat, or skim milk, whether

Bulk milk tank trucks are also permitted and in-

it has been heat-treated

spected by the state regulatory agency annually. If

r Seal number on inlet, outlet, wash connections, *construction or repair defects are noted, the milk tank*

and vents

truck must be removed for service until repairs and

r Grade of product

sufficient cleaning are verified. The milk tank truck

standards encompass the following areas: properly

constructed equipment to hold milk at correct temper-

Processing Plant

atures of 7◦C (45◦F) or less, adequate milk sampling

equipment, and a tag affixed to the truck's outlet valve

Manufacturing plants that process yogurt and fer-

to verify washing and sanitizing records. When bulk

mented milk products are subject to the food safety

milk haulers are responsible for obtaining and trans-

requirements in the Grade "A" PMO section on Stan-

porting milk samples for official laboratory analysis,

dards for Grade "A" pasteurized, ultra-pasteurized,

they must complete records verifying the chain-of-

and aseptically processed milk and milk products.

custody for the samples.

These requirements dictate the construction of floors, *Bulk raw milk from farms may be transported di-*

walls, ceilings, doors, and windows as well as proper

rectly to the milk or yogurt processing plants or it

lighting and ventilation. Floors in all rooms of the

may be held at a transfer station where it is pooled

processing facility where milk products are handled,

with other raw bulk milk loads. The

transfer station

processed, and sorted or in which milk containers,

unloads smaller bulk milk trucks into holding silos

utensils, and equipment are washed must be con-

and then reloads the commingled raw milk into larger

structed of concrete or other equally impervious and

over-the-road tanker trucks for delivery to processing *easily cleanable material. The floor must be properly*

plants.

sloped with trapped drains. Storage rooms for dry in-

All vehicles and milk tank trucks containing milk

gredients need not have drains and may have floors

or milk products should be legibly marked with the

constructed of wood. Walls and ceilings should be *name and address of the milk plant or hauler in pos-*

smooth, light-colored, washable, and in good repair.

session of the contents.

Doors and windows should prevent access to insects

Milk tank trucks transporting raw, heat-treated, or

and rodents and all openings to the outside must have

pasteurized milk and milk products to a milk plant solid doors or glazed windows. However, other meth-

from another milk plant, receiving station, or transfer

ods of effectively protecting openings to the outer air

such as screening, fans, air curtains, and properly

distortion under normal use

conditions; must be

constructed flaps may be used provided the entrance

nontoxic, fat-resistant, relatively nonabsorbent,

of insects and rodents are prevented.

not impart flavor or odor to the milk or milk

The processing plant must be designed so that sep-

products, and maintain their original properties *arate rooms are provided for each of the following*

under repeated use conditions

operations:

r They must be designed to permit easy cleaning,

maintained in good repair, free of breaks or

r The pasteurizing, processing, cooling,

corrosion, and must contain no dead ends of

reconstitution, condensing, drying, and *packaging*

piping in which milk or milk products may

of milk and milk products.

collect.

r Packaging of dry milk or milk products.

r The cleaning of milk cans, containers, bottles,

Equipment, containers, and utensils should have

cases, and dry milk or milk product

containers.

joints that are flush and have a smooth finish. All

r The fabrication of containers and closures for

openings to tanks, vats, and separators are pro-

milk and milk products.

tected by raised edges to prevent the entrance of sur-

r Cleaning and sanitizing facilities for milk tank *face drainage and thus condensation-diverting aprons*

trucks in milk plants receiving milk or whey.

should be provided. There must not be threaded fit-

r Receiving cans of milk and milk products in milk

tings in milk contact areas. Strainers, if used, should

plants receiving such cans.

be of a perforated design or constructed to utilize a *single-use strainer media, such as cloth or paper. Wo-*

Every milk processing plant should have toilet and

ven material may be used only where it is impractical

hand-washing facilities with hot and cold running wa-

to use perforated strainers. However, woven strainers

ter, soap, and individual sanitary towels or approved

must be thoroughly mechanically

cleaned.

hand-drying devices. The water supply must be ade-

All single-service containers, closures, gaskets,

quate, safe, and of sanitary quality. The water supply

and other articles that contact milk must be nontoxic

may be approved as safe from the State Water Control

and should be manufactured, packaged, transported, *Authority, or in the case of individual water systems*

and handled in a sanitary manner and may not be

(wells), comply with construction specifications and

reused.

bacteriological standards.

One of the most critical food safety procedures

The processing facility should be kept clean, neat, *is proper cleaning and sanitation of containers and*

and free of evidence of insects and rodents in order

equipment that are used for processing, culturing, fill-

to reduce the likelihood of contamination of the milk

ing, packaging, and storage of milk and fermented

or milk products. All piping, floors, walls, ceilings,

milk products. All multiuse containers *and uten-*

fans, shelves, tables, and nonproduct contact surfaces

sils such as tanks, lines, vessels, pasteurizers, and

should be clean. Trash and solid waste must be kept

filling equipment must be cleaned at least once a

in covered containers.

day. Storage tanks should be cleaned when emp-

All sanitary piping, fittings, connections, mul-

tied at least every 72 hours and records must be

tiuse containers, and equipment that come in con-

readily available to verify storage times. Cleaning

tact with milk and milk products should be smooth,

frequencies beyond these requirements are allowed

impervious, corrosion-resistant,

nontoxic, and easily

after review and acceptance of specific informa-

cleanable material that is approved for food contact

tion by the state regulatory agency in consultation

surfaces. All sanitary piping, connections, and fit-

with FDA. Pipelines and equipment designed for

tings must meet the following requirements:

mechanical cleaning (cleaning-in-place [CIP]) must

meet specific requirements of being equipped with

r They must be made from either of the following:

a temperature recording device that provides a con-

a. Stainless steel of the AISI 300 series

tinuous record of the time and temperature, clean-

b. Equally corrosion-resistant metal that is *ing solution velocity, and the presence, strength, or*

nontoxic and nonabsorbent

cleaning solution chemicals. For manual washing

c. Heat-resistant glass

there must be a two-compartment wash-and-rinse

d. Plastic or rubber and rubber-like materials that

vat. After cleaning, milk product containers, utensils, *are relatively inert and resistant to scratching,*

and equipment should be stored to assure complete

scoring, decomposition, crazing, chipping, and

drainage and protection from contamination.

Single-service caps, cap stock, containers, gaskets,

Table 3.1. *Pasteurization Temperature vs.*

and other articles for use in direct contact with milk

Time

and milk products must be stored in sanitary wrap-

Temperature

Time

ping or cartons and kept in a clean, dry place until

used. This category also includes the

containers and

63◦C (145◦F) a

30 minutes

lids used for yogurt and fermented milk packages.

72◦C (161◦F) a

15 seconds

Throughout the milk processing plant, ingredients

89◦C (191◦F)

1.0 second

in process product, packaging, and finished prod-

90°C (194°F)

0.5 seconds

ucts must be protected from contamination. This in-

94°C (201°F)

0.1 seconds

cludes discarding spilled, overflowed, or leaked milk

96°C (204°F)

0.05 seconds

and milk products. All poisonous or toxic materials

100◦C (212◦F)

0.01 seconds

should be properly labeled and stored in a separate

a If the fat content of the milk product is 10% or more, or if

area and used to preclude contamination. All product

it contains added sweeteners, or is

concentrated (condensed),

contact surfaces must be covered or otherwise pro-

the specified temperature shall be increased by 3◦C (5◦F).

tected to prevent the exposure to insect, dust, con-

densation, and other contamination. Many openings,

Detailed information about the design, installation,

including valves, piping attached to milk storage, *and operation of the milk pasteurizing equipment is*

milk tank trucks, pumps, and vats should be capped

also dictated by the Grade "A" PMO. The oversee-

or properly protected. Air must be free of oil, rust,

ing regulatory agency performs specific tests on the

excessive moisture, extraneous materials, and odor

pasteurizer's critical instruments and *devices upon*

when air pressure is used for agitation or the move-

initial installation and at least once every 3 months,

ment of milk. The use of steam in contact with milk

and then applies seals to specific equipment that reg-

requires it to be of culinary quality.

ulate the temperature or flow rate. All temperature

During processing, pipelines and equipment used

and flow rate pasteurization records are required to

to contain or conduct milk and milk products should

be preserved for a period of 3 years.

be effectively separated from tanks or circuits con-

Maintaining milk at proper temperatures to avoid

taining cleaning and/or sanitizing solutions. This can *bacterial growth and spoilage is critical to product*

be accomplished by physically disconnecting all con-

quality and safety. All raw milk and milk products

nection points, by separation with two automatically

should be maintained at 7◦C (45◦F) or less until pro-

controlled valves or by a single-bodied double seat

cessed. All pasteurized milk and milk

products, ex-

valve, with a drainable opening between tanks and

cept those to be cultured, should be cooled imme-

circuits containing cleaning and/or sanitizing solu-

diately prior to filling or packaging in an approved

tions from pipelines and equipment used for milk

equipment, at a temperature of 7◦C (45◦F). This ex-

or milk products. Additionally, there should be no

emption for higher temperature during culturing has

physical connection between water, nondairy prod-

also been applied to fermentation that occurs in the

ucts, unpasteurized dairy product, with pasteurized

final package, such as cup-set yogurt. All pasteurized

milk and milk products.

milk and milk products should be stored at a temper-

Pasteurization is the only practical, commercial

ature of 7◦C (45◦F) or less until further processed. To

measure that, if properly applied to all milk, will de-

verify proper refrigeration, every refrigerated room

stroy all milk-borne disease organisms. It has been

or tank in which milk or milk products *are stored*

demonstrated that the time–temperature combina-

should be equipped with an accurate indicating ther-

tions specified by this Grade "A" PMO, if applied

mometer. On delivery vehicles, the temperature of

to every particle of milk or milk products, will kill all

milk and milk products should not exceed 7∘C (45∘F).

milk-borne pathogens. Although pasteurization de-

However, aseptically processed milk and milk

stroys the organisms, it does not destroy the tox-

ins that may be formed in milk and milk prod-

ucts when certain staphylococci bacteria are present.

***Table 3.2.** Eggnog Pasteurization*

Staph toxin can result from udder infections and

Temperature vs. Time

when the milk or milk products are not properly

Temperature

Time

refrigerated before pasteurization. Such toxins may

cause severe illness. The temperature requirements

69◦C (155◦F)

30 minutes

for milk pasteurization are given in Tables 3.1 and

80°C (175°F)

25 seconds

3.2.

83°C (180°F)

15 seconds

products to be packaged in hermetically sealed con-

HACCP System was introduced to the food industry

tainers are exempt from these cooling requirements.

as a spin-off of the space program during the 1960s.

Filling, packaging, and capping of pasteurized

The National Aeronautics and Space Administration

milk products must be done at the place *of pasteur-*

(NASA) used HACCP to provide assurance of the

ization in a sanitary manner by approved mechani-

highest quality available for components of space ve-

cal equipment. The packaging equipment and sup-

hicles. This program, to develop assurance of product

ply lines must be equipped with covers to prevent *reliability, was carried over into the development of*

contamination from reaching the inside of the filler

foods for astronauts.

bowl and drip deflectors must be designed to divert

condensation away from open containers. Container

Background

in-feed conveyors to automatic bottling or packaging *machines should have overhead shields to protect the*

HACCP is a management tool that provides a struc-

bottles or packaging from contamination. Caps and

tured and scientific approach to the control of identi-

closures must be applied in a manner where they can-

fied hazards. HACCP is a logical basis for better deci-

not be removed without detection, help *to provide as-*

sion making with respect to product safety. HACCP

surance to the consumer that the milk and milk prod-

is internationally recognized as an effective means

ucts have not been contaminated after packaging. All

of controlling food safety hazards and is endorsed

packaging must be handled in a sanitary manner.

as such by the joint Food and Agriculture Organiza-

Employees working in the milk processing plant

tion (FAO) of the World Health Organization Codex

must maintain a high degree of personal cleanliness.

Alimentarius Commission. The U.S. National Ad-

Hands must be thoroughly washed before commenc-

visory Committee on Microbiological

Criteria for

ing plant functions or resuming work after visiting

Foods (NACMCF) has also endorsed it.

the toilet, eating, or smoking. Employees must wear

The HACCP concept enables those operating and

clean outer garments and adequate hair coverings.

regulating under an HACCP Plan to move to a

No persons affected with any disease capable of be-

preventive approach, whereby potential hazards are

ing transmitted to others through the contamination

identified and controlled in the manufacturing envi-

of food are not allowed to work at a milk plant in any

ronment, i.e., prevention of product failure. HACCP

capacity that brings them into direct

contact with pas-

allows for a preventive systematic approach to food

teurized milk or aseptically processed milk or milk

safety.

product contact surfaces.

All vehicles used to transport pasteurized milk and

Voluntary Participation

milk products should be constructed and operated in *such a way so that the milk and milk products are*

The NCIMS HACCP Program is a voluntary alterna-

maintained at 7◦C (45◦F) or less and are protected

tive to the traditional inspection system. Milk plants,

from contamination. Milk tank cars, milk tank trucks,

receiving stations, or transfer stations can partici-

and portable shipping bins should not

be used to

pate in the voluntary NCIMS HACCP Program only

transport or contain any substances that may be toxic

when the state regulatory agency responsible for the

or harmful to humans.

oversight of the facility agrees to participate with

The surroundings of a milk plant should be kept *them in the program. Management responsible for*

neat and clean to prevent attracting rodents, flies, and

both the state and dairy plants, receiving stations,

other insects that may contaminate the milk or milk

or transfer stations must be willing to provide the

products. Insecticides and rodenticides must be ap-

resources needed to develop and

implement a suc-

proved for use in milk plants and used in accordance

cessful HACCP System. Both parties must provide

with label recommendations.

written commitment to each other that the necessary

resources to support participation in the NCIMS

HACCP Program will be made available.

HACCP

HACCP Principles

History of HACCP

Following are the seven HACCP principles to be in-

The use of the Hazard Analysis and Critical Con-

cluded in an HACCP Plan:

trol Point (HACCP) System is not new to the dairy

industry. HACCP is a logical, simple, effective, and *r Conduct a hazard analysis*

highly structured system of food safety control. The

r Determine the critical control points

r Establish critical limits

containers and closures plants is published in the In-

r Establish monitoring procedures

terstate Milk Shipper List quarterly.

r Establish corrective actions

r Establish verification procedures

r

Labeling

Establish record-keeping and documentation

procedures

Labeling of bottles, containers, and packages con-

taining milk or milk products such as yogurt and *fermented milk are defined in applicable require-*

Prerequisite Programs

ments of the Federal Food Drug and Cosmetic Act

Prior to the implementation of a HACCP Plan, there

(FFDCA), the Nutrition Labeling and Education Act

is a requirement for dairy plants, receiving stations,

(NLEA) of 1990, and regulations developed there un-

and transfer stations to develop, document, and im-

der the Federal Code of Regulations Title 21. More

plement written prerequisite programs (PPs). These

detailed information on FDA labeling regulations can

provide the basic environment and operating condi-

be found in Chapter 4. However, in addition to federal

tions that are necessary for the

production of safe,

requirements, the Grade "A" PMO requires additional

wholesome food. Many of the conditions and prac-

labeling as follows:

tices are specified in federal and state regulations and

All bottles, containers, and packages containing

guidelines.

milk or milk products, except milk tank *trucks, stor-*

The seven principles of HACCP are also called the

age tanks, and cans of raw milk from individual dairy

HACCP Plan. When combined with the PPs, they

farms, should be conspicuously marked with the

constitute an HACCP System. The NCIMS HACCP

following:

Program combines the HACCP System and other pre-

1. The identity of the milk plant where the milk was

scribed Grade "A" PMO criteria, such as drug residue

pasteurized, ultra-pasteurized, aseptically pro-

testing and trace back, use of milk only from supplies

cessed, condensed, or dried. This may be accom-

that have been awarded a milk

sanitation compliance

plished by printing on the container the company

rating of at least 90% or from an acceptable IMS

name and its location (listing the city and state)

HACCP listed source, and labeling requirements.

or the unique identification number, which is the

When properly implemented, the HACCP Program

"IMS Listed Milk Plant Number," assigned by the

will provide assurance of milk and milk product

state to each plant.

safety that is equivalent to that provided under the

2. The words "keep refrigerated after opening" in

traditional inspection system.

the case of aseptically processed milk and milk

products.

3. The common name of the hooved mammal pro-

Standards and Regulations

ducing the milk should precede the name of the

Standards for Containers and Closures

milk or milk product when the product is or is

made from milk other than cow's milk, for exam-

Single-service containers and closures, such as plas-

ple, "Goat," "Sheep," "Water Buffalo," or "Other

tic jugs, plastic-coated paperboard milk containers,

Hooved Mammal" milk or milk products.

plastic tubs, lids, and aluminum aerosol cans, are

4. The words Grade "A" on the exterior surface. Ac-

used by the dairy industry for packing *milk and milk*

ceptable locations should include the principal dis-

products. Industry-applied quality assurance controls

play panel, the secondary or informational panel,

for manufacturing and handling of the materials have

or the cap/cover. The term Grade "A" may not

made it possible for these products to reach the point *solely appear in the ingredient statement.*

of use in a sanitary condition free from toxic ma-

5. The word "reconstituted" or "recombined" if the

terials that may migrate into milk or milk products.

product is made by milk subject to reconstitution,

Standards set forth in the Grade "A" PMO, Appendix

recombined milk, or milk ingredients.

J ensure the production of sanitary containers and

closures for milk and milk products. The standards

All labeling terms must be truthful and not

include the bacterial requirements, fabrication plant,

misleading as dictated by the FFDCA. Grade

equipment, processing, and packaging standards as

designations, such as Grade "AA"

Pasteurized,

well as materials, waxes, adhesives, sealants, and inks

Selected Grade "A" Pasteurized, Special Grade "A"

that can be used. Approval of certified single-service

Pasteurized, etc., give the consumer the impression *that such a grade is significantly safer than Grade "A."*

and the most current edition of Official Methods of

Such an implication is false because the Ordinance

Analysis of AOAC INTERNATIONAL (OMA).

requirements for Grade "A" pasteurized, ultra-

pasteurized, or aseptically processed milk when

properly enforced will ensure that this *grade of milk*

IMPORTS

will be as safe as milk can practically be made.

Traditional fermented milk such as yogurt, cultured

Descriptive labeling terms must not be false and mis-

butter milk, lactobacillus acidophilus milks, and even

leading and should not be used in conjunction with *some of the newer fermented milk products such*

the Grade "A" designation or the name of the milk

as drinkable yogurt are defined and regulated by

or milk product. If descriptive terms are used in con-

the Grade "A" PMO . This regulatory system relies

junction with attributes of the product other than milk

on a complex oversight and inspection

of raw milk

safety, i.e., "special select strawberries" for straw-

production, milk transportation, and processing de-

berry yogurt or "rich creamy texture," these labeling

scribed previously in this chapter.

terms should not be in a location immediately preced-

The United States is a signatory of the World Trade *ing or following the name of the food. Creating phys-*

Organization (WTO) agreement, which allows coun-

ical distance and employing graphic enhancements

tries to establish measures to ensure safety of food

such as distinctive type styles, bursts, and other tech-

within their countries. The measures, however, must

niques generally are effective ways of *distinguishing*

be applied in a manner so that they do not arbitrarily

optional information from the required information

discriminate between products from different coun-

(USDHHS PMO, 2003).

tries or treat domestic products more favorably than

imported products without justification. The deter-

Examination of Milk Products

mination of equivalence is made by the importing

country based on whether the exporting country's

In order to verify the quality and safety of the milk and

measures meet the level of protection deemed ap-

milk products to the Grade "A" PMO, it is required

propriate by the importing country as provided by its *that raw milk, commingled milk in the silos intended*

own measures.

for processing, and finished products be sampled and

The FDA and the NCIMS have identified and mu-

tested by state regulatory agencies at a specific fre-

tually accepted three options that are consistent with

quency. The products must meet chemical, bacterio-

NCIMS Procedures and allow states to receive PMO

logical, and temperature standards, which are given

defined Grade "A" products produced outside of the

in Table 3.3.

United States.

It is required that the state regulatory agency collect

These options are as follows:

and test official samples of at least four *times during*

any consecutive 6 months. However, many state reg-

1. A dairy firm outside of the United States could

ulatory agencies sample and test monthly. The sam-

contract with any current NCIMS member's regu-

ples must include each fat level and both plain and

latory agency to provide the Grade "A" milk safety *flavored products for finished milk and milk products.*

program in total. This would include the regula-

Therefore, if a plant produces plain low-fat yogurt,

tory licensing, dairy farm and milk plant inspec-

flavored low-fat yogurt, and flavored nonfat yogurt,

tion, sampling, pasteurization equipment tests,

all three products must be sampled. It *is not necessary*

laboratory certification, and rating/NCIMS listing

to sample each flavor monthly, but usually different

certification. To use this option, the firm would be

flavors are chosen each time the product is sampled.

required to abide by all applicable NCIMS reg-

Testing of official samples must be done in labo-

ulatory and rating requirements and the regula-

ratories that are certified under the Interstate Milk

tory/rating agency would have to agree to treat the

Shippers Program and by technicians that have

firm as if it were located within its jurisdiction

been certified to perform the specific required tests.

for all purposes including inspection

and enforce-

Requirements for laboratories are governed by the

ment. Ratings of the firm would be check-rated by

Evaluation of Milk Laboratories (EML). Sampling

the FDA.

procedures and required laboratory tests must be in

2. The importing country may become a full member *compliance with the most current edition of Stan-*

of the NCIMS subject to all NCIMS rules and en-

dard Methods for the Examination of Dairy Products

joying all privileges of a U.S. state. This would re-

(SMEDP) of the American Public Health Association

quire, among other things, that the milk regulatory

***Table 3.3.** Chemical, Physical,*

Bacteriological, and Temperature Standards

Grade "A" raw milk and

Temperature................

Cooled to 10◦C (50◦F) or less within

milk products for

4 hours or less of the commencement

pasteurization,

of the first milking, and to 7◦C (45◦F)

ultra-pasteurization,

or less within 2 hours after the

or aseptic processing

completion of milking, provided that

the blend temperature after the first

milking and subsequent milkings does

not exceed 10◦C (50◦F).

Bacterial limits..........

Individual producer milk not to exceed

100,000 per milliliter prior to

commingling with other producer milk.

Not to exceed 300,000 per milliliter as commingled milk prior to pasteurization.

Drugs......................

No positive results on drug residue detection methods as referenced in Section 6—Laboratory Techniques.

Somatic cell count a........

Individual producer milk not to exceed 750,000 per milliliter.

Grade "A" pasteurized milk

Temperature................

Cooled to 7◦C (45◦F) or less and

and milk products and

maintained thereat.

bulk shipped heat-treated

milk products

Bacterial limits b. . . ..

20,000 per milliliter or grams. c

Coliform d ....

Not to exceed 10 per milliliter. But in the

case of bulk milk, transport tank

shipments shall not exceed 100 per

milliliter.

Phosphatase e...........

Less than 350 milliunits/liter for fluid

products and other milk products by the

Fluorometer or Charm ALP or

equivalent.

Drugs b.................. . . ..

No positive results on drug residue detection methods as referenced in Section 6—Laboratory Techniques that have been found to be acceptable for use with pasteurized and heat-treated milk and milk products.

Grade "A" pasteurized

Temperature.....................

Cooled to 7◦C (45◦F) or less and

concentrated

maintained thereat unless drying is

(condensed)

commenced immediately after

condensing.

milk and milk products

Coliform.........................

Not to exceed 10 per gram. But in the case

of bulk milk transport tank shipments

shall not exceed 100 per milliliter.

Grade "A" aseptically

Temperature................

None

processed milk and milk

Bacterial limits...........

Refer to 21 CFR 113.3(e)(1) f

products

Drugs b....................

No positive results on drug residue

detection methods as referenced in Section 6—Laboratory Techniques that have been found to be acceptable for use with aseptically processed milk and milk products.

(Continued)

Table 3.3. *Continued*

Grade "A" nonfat dry milk

No more than:

Butterfat..................

1.25%

Moisture..................

4.00%

Titratable acidity.........

0.15%

Solubility index...........

1.25 ml

Bacterial estimate.........

30,000 per gram

Coliform...................

10 per gram

Scorched particles disc B................

15.0 per gram

Grade "A" whey for

Temperature................

Maintained at a temperature of 7◦C

condensing

(45◦F) or less, or 63◦C (145◦F) or

greater, except for acid-type whey

with a titratable acidity of 0.40%

or above, or a pH of 4.6 or below.

Grade "A" pasteurized

Temperature. . . . .

Cooled to 7◦C (45◦F) or less during

condensed whey and whey

crystallization, within 48 hours of

condensing.

products

Coliform limit. . . . .

Not to exceed 10 per gram

Grade "A" dry whey, Grade "A"

Coliform limit. . . . .

Not to exceed 10 per gram

dry whey products, Grade

"A" dry buttermilk, and

Grade "A" dry buttermilk

products

a Goat milk 1,000,000 per milliliter.

b Not applicable to acidified or cultured products.

c Results of the analysis of dairy products that are weighed in order to be analyzed will be reported in # per grams. (Refer to the current edition of the SMEDP.)

d Not applicable to bulk shipped heat-treated milk products.

e Not applicable to bulk shipped heat-treated milk products; UP products that have been thermally processed at *or above 138◦C (280◦F) for at least 2 seconds to produce a product that has an extended shelf life (ESL) under refrigerated conditions; and condensed products.*

f 21 CFR 113.3(e) (1) contains the definition of "commercial sterility."

Source: USDHHS PM0, 2003.

agencies of the importing countries adopt and en-

Additionally, Grade "A" milk products have re-

force rules and regulations that are the same as *strictions in the use of imported dairy ingredients un-*

those required in the United States and abide by

less the foreign ingredient facility has meet the U.S.

all applicable NCIMS regulatory and rating re-

grade "A" requirements by using one of the three

quirements. Their ratings would be check-rated by

options listed above. As specified in the

Grade "A"

FDA in the same way as state ratings. The FDA

PMO, Grade "A" dairy products must use only Grade

would certify their rating, sampling surveillance,

"A" dairy ingredients, except that small amounts of

and laboratory evaluation officers.

functional ingredients (total of all such ingredients

3. The FDA can evaluate the importing country's

should not exceed 5% by weight of the finished blend)

system of assuring the safety of dairy products

that are not Grade "A" are allowed in Grade "A" when

and compare the effect of that system with the

the finished ingredient is not available in Grade "A"

effect of the U.S. system on the safety of *dairy*

form, i.e., sodium caseinate (USDHHS PMO, 2003).

products produced domestically. The NCIMS has

adopted a procedure to accept FDA findings of

EQUIPMENTS STANDARDS

equivalence and to allow NCIMS member states

to accept products produced within the scope of

The specific requirements for milking equipment,

such a finding.

milk transportation, storage, and processing are

explained in the Grade "A" PMO. To comply with

exchangers, valves, membranes, CIP spray devices

the sanitary design and construction

standards of the

to silo tanks.

PMO, equipment manufactured in conformity with

3-A criteria are universally accepted by equip-

the 3-A Sanitary Standards must be evaluated by

ment manufacturers, fabricators, users, and sanitari-

the state regulatory agency prior to installation. The *ans. The 3-A Symbol, where authorized by 3-A SSI,*

3-Sanitary Standards for dairy equipment are promul-

is used by equipment manufacturers and fabricators

gated jointly by the Sanitary Standards Subcommit-

to indicate conformance to 3-A Standards.

tee of the Dairy Industry Committee, the Committee

In order for dairy and food equipment

manufactur-

on Sanitary Procedure of the International Associa-

ers to use the 3-A Symbol, they must file an applica-

tion for Food Protection (IAFP), and the FDA Milk

tion with the 3-A Symbol Council office signifying

Safety Branch.

that the equipment is compliant with all provisions of *that standard. A statement of quality controls in place*

must be submitted along with drawings or pictures

The 3-A Sanitary Standards Symbol

of the equipment. The Council may also request ad-

The 3-A Symbol was introduced in 1927 and is used

ditional materials to ensure compliance on complex

to identify equipment that meets 3-A Sanitary Stan-

subassemblies. The Council reviews the application

dards for design and fabrication. Use of the 3-A

and, if all areas are in compliance under that specific

Symbol is governed by 3-A Sanitary Standards, Inc.

3-A Standard, the manufacturer is permitted to use

(3-A SSI).

the 3-A Symbol.

Once a 3-A Sanitary Standard has been developed

Equipment manufacturers are required to place

and becomes effective, manufacturers may receive

the serial number of the 3-A Standard with which

authorization from the 3-A Symbol Council to use the

it complies adjacent with the 3-A Symbol on their

symbol. Voluntary use of the 3-A

Symbol on dairy

equipment.

and food equipment serves three important purposes:

A listing of authorized holders of 3-A symbol cer-

r

tification can be found on the 3-A Sanitary Standards

Assures processors that equipment meets sanitary

Web site (http://www.3-a.org). The

listing is orga-

standards;

r

nized by standards for each type of equipment and

Provides accepted criteria to equipment manufac-

provides the manufacturing company's information

turers for sanitary design; and

r

and if relevant, the model number of the piece of

Establishes guidelines for uniform evaluation and

equipment that has received authorization.

compliance by sanitarians.

3-A SSI formulates standards and practices for the

sanitary design, fabrication, installation, and clean-

ability of dairy and food equipment or systems used *to handle, process, and package consumable prod-*

ucts where a high degree of sanitation is required.

Background of Federal Orders

These standards and practices are developed through

the cooperative efforts of industry experts. Its ulti-

The Federal Milk Marketing Orders

system is a regu-

mate goal is to protect consumable products from

latory function administered by the United States De-

contamination and to ensure that all product surfaces

partment of Agriculture (USDA). The Federal Orders

can be mechanically cleaned-in-place (CIP) or easily

have evolved significantly since their first legislative *dismantled for manual cleaning.*

introduction in 1937. The objective of the Federal

3-A Accepted Practices cover a system, which is

Orders is to stabilize markets by placing certain re-

defined as a set of connected equipment and machin-

quirements on the pricing and handling of milk in the

ery that forms as a whole or works together. In ad-

area it covers, and ultimately, assure that an adequate

dition to the criteria for equipment, a practice may

supply of wholesome milk is available and will con-

also provide specifications for sanitary installation

tinue to be available at a reasonable price to con-

and legal controls.

sumers. There are 10 regions in the United States

3-A Sanitary Standards provide material specifica-

that are regulated by a Federal Order (see Fig. 3.1).

tions, design criteria, and other necessary information

Regions that are not subject to a Federal Order have

for equipment types to satisfy public health concerns.

a state milk marketing order such as in Califor-

3-A Standards are available for more

than 70 equip-

nia where the pricing system is akin to the Federal

ment types, from fittings, centrifugal pumps, heat

Orders, or they may be unregulated (USDA, 2004).

3 Regulatory Requirements for Milk Production, Transportation, and Processing

53

Consolidated

Federal Milk Marketing Order Areas

PACIFIC

NORTHWEST

UPPER

MIDWEST

NORTHEAST

MIDEAST

CENTRAL

APPALACHIAN

ARIZONA -

LAS VEGAS

SOUTHEAST

SOUTHWEST

FLORIDA

USDA

DIFFERENCES IN SHADING MERELY SERVE TO

Agricultural Marketing Service

DIFFERENTIATE BETWEEN MARKETING AREAS

Dairy Programs

Figure 3.1. *Consolidated Federal Milk Marketing Orders areas.*

The Federal Milk Marketing Orders are concerned

from weekly surveys of dairy product manufacturers

primarily with orderly marketing of raw Grade "A"

that sell specific products on a bulk, wholesale basis

milk from producer to processor. Classified pricing

(Jesse and Cropp, 2004).

and pooling are the two key elements for the Federal

Federal orders define the following four classes

Milk Orders which set minimum prices for more than

of milk, from highest to lowest value (under most

70% of the Grade "A" milk produced in the United

circumstances):

States. A major function of the Federal Orders is com-

1. Class I is milk used for beverage products. This

puting minimum prices for raw Grade "A" milk that

includes "white" whole, low-fat, and skim milk in

handlers must pay to dairy farmers. The Federal Milk

all container sizes, chocolate and other flavored

Marketing Orders system has been developed to pool

milks, liquid buttermilk, and eggnog.

the proceeds of all qualified milk sales in order to en-

2. Class II is milk used for soft manufactured prod-

sure that all producers in an area receive a uniform

ucts like yogurt and cultured dairy products, sour

price for their milk—regardless of how their milk was

cream, ice cream, and other frozen dairy desserts,

used.

cottage cheese, and creams.

3. Class III is milk used to manufacture cream cheese

Classified Pricing

and hard cheeses.

4. Class IV is milk used to make butter and dry milk

The Federal Milk Marketing Orders program uses

products—principally nonfat dry milk.

product price formulas to determine milk component *values that are combined to calculate monthly class*

prices. The factors in the formulas are dairy product

Producer Prices

prices, which change monthly, and make allowances

and product yields, which are set in the formulas. The

The Federal Orders requires milk handlers in a mar-

dairy product prices are those collected by USDA *keting area to pay dairy farmers (producers) no less*

than certain minimum prices for fluid milk. The price

r Other Solids pounds × Other Solids Price

for class II, III, and IV milk is the same under all

r Butterfat pounds × Butterfat Price

Federal Orders. Class II prices are

computed each

r Total hundredweight milk × Somatic Cell

month for each marketing area and are based on

Adjustment

National Agricultural Statistics Service (NASS) re-

Expressed in terms of hundredweights of milk,

leased prices for milk used in manufactured products.

producer prices will differ according to milk compo-

The Federal Orders also require that a plant's usage

sition, milk quality, and the location of the receiving

value for milk be combined with other plants usage

plant.

value (pooled) and each producer (or cooperative) be

paid on the basis of a uniform/blend/average price.

This blend price represents an average of the value of

Milk Pricing for Fermented

milk in all uses (fluid milk, cottage cheese, ice cream,

Milk Products

cheese, butter, etc.).

Milk pricing for fermented milk and milk products

With federal order pooling, producers receive a

is dependent on whether the final

product will be

common price for their milk components regardless

consumed as a beverage, on the level of fat, and

of how their milk is used. Total producer milk value

on milk solids. Products similar to spoonable yogurt

under the order is the sum of the following elements:

and sour cream are considered as class II under the *r Total hundredweight milk × Producer Price*

Federal Milk Marketing Orders system. Drinkable

Differential (at locations)

fermented products, such as cultured buttermilk, aci-

r Protein pounds × Protein Price

dophilus milk, kefir, and yogurt drinks that have 6.5%

Begin Here

Fluid milk

no

product

Class II

no

Class III or Class IV

yes

identification

yes

Beverage

no

yes

Distributed in less than

one-half gallon package

Less than 9%

no

yes

yes

no

butterfat

Less than

no

yes

6.5% NFMS

Distributed in larger than

one gallon package

no

yes

Infant feeding or

dietary use

Used in soft or semisolid form

Commercial

(meal replacement)

(except for spreadable

food

no

yes

no

cheese which are utilized in class II)

processing

establishment

no

yes

yes

Hermetically

yes

sealed container

no

Class I

Class II

Figure 3.2. *Flow diagram used to*

determine milk classification pricing for a product.

Source: IDFA Milk Procurement Workbook, 2005.

or greater milk solids nonfat and less than 9% milk fat

pasteurized milk indicates the milk has not been prop-

will be priced as class I. The flow chart *in Figure 3.2*

erly heated or was mixed with unpasteurized milk.

can be used to determine whether a product will be

***SINGLE-SERVICE CONTAINERS**—A container*

considered as class I or class II.

used in the storage, handling, or packaging of milk

or milk products intended for only one use.

SNF*—Solids-not-fat portion of the milk.*

GLOSSARY

SOMATIC CELL COUNT*—A numeric count of the*

AISI 300*—A quality specification for stainless steel*

dead epithelial cell and leucocytes (white blood cells)

from the American Iron and Steel Institute.

that migrate into milk from the udder of a cow.

BULK TANK UNIT*—A dairy farm or a group of dairy*

UHT

(ULTRA-HIGH

TEMPERATURE)*—Heat*

farms from which raw milk is collected.

treatment at a temperature of 135–150◦C for a

CIP (CLEANING-IN-PLACE)*—A method of clean-*

holding time of 4–15 seconds that sterilizes the *ing lines and tanks without disassembly by purging*

product for aseptic packaging to permit storage at

water and cleaning chemicals.

ambient temperatures.

***CLASSIFIED PRICING**—A system used to price raw*

***USDA**—United States Department of Agriculture.*

milk sold for processing based on the intended use in *a specific dairy product.*

REFERENCES

***COLIFORM**—A group of microorganisms found in*

the intestinal tract; their presence indicates contami-

CFSAN (Center for Food Safety and Applied

nation with fecal matter.

Nutrition). 2004. National Conference on Interstate

***FDA**—U.S. Food and Drug*

Administration.

Milk Shipments Model Documents—Milk Safety

FFD&CA (FEDERAL FOOD DRUG AND COS-

References [Online]. Available at http://www.cfsan.

METIC ACT)*—An act of the U.S. Congress that*

fda.gov/~ear/p-nci.html.

specified the basis for food safety standards.

Jesse E, Cropp R. 2004. Basic Milk Pricing Concepts

GRADE

“A”

PMO

(PASTEURIZED

MILK

for Dairy Farmers. University of Wisconsin—

ORDINANCE)*—Model milk regulations used for*

Extension, Cooperative Extension, Madison, WI.

the inspection of milk production and processing

USDA (U.S. Department of Agriculture). 2004.

facilities.

Agriculture Marketing Services Dairy Programs.

HACCP (HAZARD ANALYSIS AND CRITICAL

Federal Milk Marketing Orders [Online]. Available

CONTROL POINTS)*—A system of steps for estab-*

at http://www.ams.usda.gov/dairy/orders.h

lishing a food safety program through identification

USDHHS PMO (U.S. Department of Health and

and prevention of problems.

Human Services). 2003. Grade "A" Pasteurized Milk

IMS (INTERSTATE MILK SHIPPERS) LISTED*—*

Ordinance, 2003 Revision, Department of Public

A publication that provides a listing of farms and

Health, USDHHS, Food and Drug Administration,

plants that have successfully passed a sanitary inspec-

Washington, DC.

tion.

USDHHS Procedures. 2003. Procedures Governing

NCIMS*—National Conference on Interstate Milk Ship-*

the Cooperative State-Public Health Service/Food

ments.

and Drug Administration Program of the National

PASTEURIZATION*—A process of heating fluid milk*

Conference on Interstate Milk Shipment, 2003

products to render them safe for human consump-

Revision, Department of Public Health, USDHHS,

tion by destroying the disease-producing organisms

Food and Drug Administration, Washington, DC.

(pathogens). The process inactivates approximately

USDHHS Methods. 2003. Methods of Making

95% of all microorganisms in milk.

Sanitation Ratings of Milk Shippers, 2003 Revision,

***PHOSPHATE**—An enzyme that is deactivated in milk*

Department of Public Health, USDHHS, Food and

at normal pasteurization temperatures; its presence in

Drug Administration, Washington, DC.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

4

Regulations for Product Standards and Labeling

Cary P. Frye

U.S. Code of Federal Regulations

U.S. PRODUCT STANDARDS

U.S. Product Standards of Identity

OF IDENTITY

Fermented Milk and Milk Products

General Definitions

Food standards were established to promote fair com-

Stayed Provisions

petition among manufacturers and to eliminate con-

Proposed Changes to U.S. Standards for Yogurt and

sumer confusion. Currently there are 97 federal stan-

Fermented Milks

dards of identity for various dairy products out of a

Food Additives and Packaging

total of 262 standards for all foods including dairy.

Labeling

Many states have also promulgated standards of iden-

General Requirements

tity for dairy products. The Nutrition Labeling Edu-

Nomenclature

cation Act (NLEA) of 1990 established that where

Flavor Labeling

federal and state standards exist simultaneously, the

Ingredient Declaration

Nutrition Facts Panel

federal standard preempts the state regulation. How-

Special Labeling Requirements

ever, in the event if no federal standard exists for a

Codex Standards and Definitions for Fermented Milk *specific dairy product and a state standard has been*

Products

promulgated, the state standard is in effect. In terms of

Glossary

detailed presentation, this section only addresses fed-

References

eral standards of identity. For the most part, standards

of identity dictate the processing

procedure, compo-

sition, and allowed ingredients of the product and

U.S. CODE OF FEDERAL

often cover public safety concerns and product label-

REGULATIONS

ing. All federal standards of identity for dairy prod-

ucts are referenced in Title 21 CFR, Parts 130–135.

The U.S. Code of Federal Regulations

(CFR) pub-

The Grade "A" Pasteurized Milk Ordinance (PMO), a

lished by the U.S. government is a set of com-

model regulation for milk sanitation, adopts by refer-

prehensive documents containing all Federal Reg-

ence the federal standards of identity. These standards

ulations. Each branch of government is assigned a *of identity apply to products that are manufactured*

different numerical title. The regulations for Food and

for sale in the United States including both domesti-

Drugs are published in Title 21. These publications

cally produced and imported products.

are revised and issued yearly. The current version

can also be found online. The Title 21 Code of Fed-

Fermented Milk and Milk Products

eral Regulations Parts 1—199 lays out FDA's regula-

tions for current good manufacturing practices, food

The milk and cream standards are found in 21 CFR

labeling, standards of identity, and approved food

part 131, which include definitions of milk ingredi-

additives.

ents and specific requirements for fermented milk

57

58

Part I: Basic Background

products such as cultured milk, sour cream, and yo-

r Optional dairy ingredients include concentrated

gurts, which are listed below.

skim milk, nonfat dry milk, buttermilk, whey, *lactose, lactalbumins, lactoglobulins, and whey*

(modified by partial or complete removal of

General Definitions

lactose and/or minerals).

In addition to the standards of identity listed below,

The provision in the standard of identity for

the CFR also provides definitions of milk and cream *cultured milk limiting the sources of optional*

as ingredients in fermented milk products:

dairy ingredients has been stayed, pending the

Milk. Milk is the lacteal secretion, free from colos-

outcome of a public hearing. Other milk-derived

trum, obtained by milking one or more healthy cows.

ingredients (e.g., caseinates) may be

used to

Milk fat and milk solids nonfat (MSNF) may be "ad-

increase the nonfat solids content in cultured

justed" by removing the milk fat or adding cream,

milk.

r

concentrated milk, dry whole milk, skim milk, con-

Nutritive carbohydrate sweeteners such *as beet or*

centrated skim milk, or nonfat dry milk. Composi-

cane sugar (sucrose), inverted sugar (paste or

tionally, it must have a minimum of 8.25% MSNF

syrup), brown sugar, refiner's sugar, molasses (not

and a minimum of 3.25% milk fat.

blackstrap), high fructose corn syrup, fructose, *Cream. Cream means the liquid milk product high*

fructose syrup, maltose, maltose syrup, dried

in fat separated from milk, which may have been

maltose syrup, malt extract, dried malt extract,

adjusted by adding to it milk, concentrated milk, dry

honey, maple sugar, dextrose anhydrous, dextrose

whole milk, skim milk, concentrated

skim milk, or

monohydrate, glucose syrup, dried glucose

nonfat dry milk. Cream contains not less than 18%

syrup, lactose, cane syrup, maple syrup, and

milk fat.

sorghum.

r Flavoring.

r Color additives may be added, except that those

Cultured Milk—21 CFR §131.112

that impart butterfat or milk fat color may not be

added directly to the fluid product so that it gives

Description of Process

the appearance that the product contains more

r Prepared by culturing with characterizing

milk fat than it actually does.

r

microbial organisms with one or more of the

Stabilizers.

r

following: cream, milk, partially skimmed milk,

Butterfat or milk fat in the form of granules or

and skim milk.

flakes (which may or may not contain color

r Must be pasteurized or ultra-

pasteurized prior to

additives).

r

the addition of the microbial culture and may be

Aroma and flavor producing microbial culture.

r

homogenized.

Salt.

r

r

May contain other optional ingredients (listed

Flavor precursors (citric acid 0.15% maximum of

later below).

milk or equal the amount of sodium citrate).

Composition

Nomenclature.

The name of the food is "cultured

r Minimum of 3.25% of milk fat

milk."

r Minimum of 8.25% MSNF

r

Milk fat level

Minimum of 0.5% titratable acidity (expressed as

lactic acid)

r

r

Milk fat percentage declaration is not required.

2000 IU of vitamin A/qt (optional)

r 400 IU of vitamin D/qt (optional)

Process

r If the dairy ingredients were homogenized, then

Other Ingredients

the label may indicate "homogenized" (optional).

r Acidifying ingredients such as acetic acid, adipic

Sweetened

acid, citric acid, fumaric acid, glucono- delta

-lactone, hydrochloric acid, lactic acid, malic

r If sweetened with a nutritive carbohydrate

acid, phosphoric acid, succinic acid, or tartaric

sweetener without a characterizing flavor, then the

acid.

label must indicate “sweetened.”

4 Regulations for Product Standards and Labeling

59

Characterizing organisms

Yogurt (Includes Drinkable Yogurts) 21 CFR

r

*§**131.200***

Name of the food may declare traditional or *generic names of characterizing microbial*

Description of Process

organisms (optional) or ingredients, e.g., "kefir

r Produced by culturing with the lactic

cultured milk," "acidophilus cultured milk," or

acid-producing bacteria Lactobacillus bulgaricus

when lactic acid producing organisms are used, *and Streptococcus thermophilus (may contain*

"cultured buttermilk."

other lactic acid-producing bacteria) one or more

Flavoring

of the following: cream, milk, partially skimmed

r

milk, skim milk, or reconstituted dairy

If characterizing flavors were added, then the *ingredients.*

name should indicate the common or usual name

The standard of identity for yogurt does not

of the flavoring.

include the addition of reconstituted dairy

Sour Cream (Cultured Sour Cream) 21 CFR

ingredients as basic components in the

*§**131.160***

manufacturing of yogurt. This exclusion has been

stayed, pending the outcome of a public hearing,

Description of Process

and therefore, reconstituted dairy ingredients

r Produced from souring pasteurized cream with

could be used as a basic dairy component in

lactic acid producing bacteria.

yogurt.

r

r

May contain other optional ingredients listed

May be homogenized and must be pasteurized or

below.

ultra-pasteurized prior to the addition of bacteria

culture.

Composition

r Flavoring ingredients may be added after

r

pasteurization or ultra-pasteurization.

Minimum of 18% milk fat

r

r The product may be heat-treated to destroy viable

Minimum of 14.4% milk fat for bulky flavored *microorganisms to extend shelf life.*

sour creams

r

r May contain other optional ingredients (listed

Minimum of 0.5% titratable acidity

later below).

Other Ingredients

r

Composition

Ingredients that improve texture, prevent

r

syneresis, or extend shelf life of the sour cream.

The provision requiring the milk fat level to be a

r Flavor precursor—sodium citrate in a minimum

minimum of 3.25% before the addition of bulky

quantity of 0.1% added prior to culturing.

flavorings has been stayed, pending the outcome

r Rennet.

of a public hearing.

r

r

Salt.

Minimum of 8.25% MSNF.

r

r

Flavoring ingredients with or without coloring,

2000 IU vitamin A/qt (optional).

r

fruit or fruit juice (may be from concentrate), or

400 IU vitamin D/qt (optional).

r

natural and artificial flavoring.

The product does not have to meet the titratable *acidity requirement indicated in the standard*

Nomenclature.

The name of the food is "sour

(minimum of 0.9% titratable acidity). This

cream" or "cultured sour cream."

provision was stayed, pending the outcome of a

public hearing.

Flavoring

r If characterizing flavors were added, then the

Other Ingredients

name should indicate the common or usual name

r Optional dairy ingredients include concentrated

of the flavoring.

skim milk, nonfat dry milk, buttermilk, whey,

Sweetened

lactose, lactalbumins, lactoglobulins, *and whey*

r If the sour cream was sweetened with a nutritive

(modified by partial or complete removal of

sweetener without the addition of characterizing

lactose and/or minerals). The provision in the

flavorings, then the label must indicate

standard of identity for yogurt limiting the *"sweetened."*

sources of optional dairy ingredients has been

60

Part I: Basic Background

stayed, pending the outcome of a public hearing.

Low-Fat Yogurt (Includes Drinkable

Other milk-derived ingredients (e.g., caseinates)

Low-Fat Yogurts) 21 CFR §131.203

may be used to increase the nonfat solids content

Same as yogurt except for the following:

in yogurt.

r Nutritive carbohydrate sweeteners such as beet or

Composition

cane sugar (sucrose), inverted sugar (paste or

r

syrup), brown sugar, refiner's sugar,

molasses (not

Either 1 / 2, 1, 11 / 2, or 2% milk fat (before the

blackstrap), high fructose corn syrup, fructose,

addition of bulky flavorings).

fructose syrup, maltose, maltose syrup, dried

maltose syrup, malt extract, dried malt extract,

Nomenclature.

The name of the food is "low-fat

honey, maple sugar, dextrose anhydrous, dextrose

yogurt." Alternate spelling of the food should not

monohydrate, glucose syrup, dried glucose syrup,

serve as the name of the food (e.g., "low-fat yogourt,"

lactose, cane syrup, maple syrup, sorghum.

"low-fat yoghurt").

r Flavoring ingredients.

r

Milk fat level

Color additives.

r

r

Stabilizers.

The percentage of milk fat must be declared (not

r Preservatives as functional ingredients were not

in decimal notation) as “1 / 2% milk

fat," "1% milk

provided for in the standard of identity for yogurt.

fat," "11 / 2% milk fat," or "2% milk fat."

This exclusion has been stayed, pending the

outcome of a public hearing, and therefore,

Nonfat Yogurt (Includes Drinkable Nonfat

preservatives could be added to yogurt as a

Yogurts) 21 CFR §131.206

functional ingredient.

Same as yogurt except for the following:

Nomenclature.

The name of the food is “yogurt.”

Alternate spelling of the food should not serve as the

Composition

name of the food (e.g., “yogourt,” or “yoghurt”).

r Less than 0.5% milk fat (before the addition of

Process

bulky flavorings).

r If the dairy ingredients were heat-treated after

Nomenclature.

The name of the food is “nonfat

culturing, then the name of the food must be

yogurt.” Alternate spelling of the food should not *followed by the parenthetical phrase*

serve as the name of the food (e.g., "nonfat yogourt,"

"(heat-treated after culturing)."

r

"nonfat yogurt").

If the dairy ingredients were homogenized, then

the label may indicate "homogenized" (optional).

Stayed Provisions

Vitamins

r If vitamins are added, then the following types of

It should be noted that as part of FDA's administrative

phrases are stated as appropriate: "vitamin A" or

procedures for enacting and updating standards, any

"vitamin A added," "vitamin D" or "vitamin D

person who would be adversely affected by a change *added," or "vitamin A and D" or "vitamin A and*

in a food standard may file objections specifying the

D added."

provisions being objected to, providing the grounds

r The word "vitamin" may be abbreviated "vit."

and requesting a public evidentiary hearing. The mere

filing of the objection prevents the action from being

Flavorings

taken (the action is stayed) and the FDA must hold a

r

public hearing.

If the yogurt contains characterizing flavorings,

Some requirements listed in the CFR have been

then the common or usual name of the flavorings

stayed following the outcome of a

public hearing. At

shall be indicated in the name.

the time of printing, FDA had not acted to proceed

Sweetened

with such a public hearing. Therefore, the following

r

provisions noted as being stayed are not in effect:

If the product is sweetened with a nutritive *sweetener without any characterizing ingredients*

1. There is no restriction to those so named for the

added, then the label must indicate "sweetened."

type of milk-derived ingredients that may be used

4 Regulations for Product Standards and Labeling

61

to increase the nonfat solids content of cultured *r Acidity: Originally the petition proposed a*

and acidified milks, eggnog, and yogurts.

minimum acidity for yogurt of pH 4.6 or lower

2. Reconstituted dairy ingredients can be used as the

rather than a titratable acidity. Later, this request

basic ingredient in the manufacture of yogurts.

was modified to maintain titratable

acidity as the

3. Preservatives can be added to yogurts.

measure of lactic acid production and recommend

4. There is no set minimum titratable acidity of 0.9%,

a standard of 0.6% titratable acidity, which more

expressed as lactic acid.

closely reflects industry practice and consumer

5. The requirement that the 3.25% minimum milk

preference for less tart yogurt than the present

fat level is eliminated after the addition of one

0.9% lactic acid.

or more of the optional sources of MNSF for

r Homogenization/Pasteurization: Clarifies that the

yogurt.

standard dairy ingredients must be pasteurized or

ultra-pasteurized before culturing and that

optional ingredients may be added after

Proposed Changes to U.S. Standards

pasteurization and culturing.

for Yogurt and Fermented Milks

r Standard Dairy Ingredients: Permits the use of

reconstituted dairy ingredients as the *basic dairy*

A citizen's petition was filed in 2000 with FDA by the

ingredients used to compose the minimum 8.25%

National Yogurt Association (NYA) on behalf of its

nonfat milk solids. Restricts whey protein

members, requesting that FDA modernize the stan-

concentrate to be used as a dairy ingredient in *dards of identity for yogurt to replace the existing*

levels up to 25% of all nonfat milk solids.

yogurt standards and make conforming amendments

r Optional Ingredients: Permits any "milk-derived

to the existing cultured milk standard of identity. As

ingredients used for technical or functional

required under FDA's procedural

regulations, a citi-

purpose.” Requires that dairy ingredients

zen petition must include information regarding the

comprise at least 51% of the product’s overall

action requested, statement of grounds, environmen-

ingredients by weight. Clarifies that other

tal impact, economic impact, and certification of all *bacterial cultures, in addition to the two*

relevant information, both favorable and unfavorable.

characterizing cultures, are permitted. Also allows

The regulations also require FDA to rule on each pe-

any safe and suitable nutritive carbohydrate

tition filed with the Agency.

sweeteners or nonnutritive sweeteners; flavoring

NYA's petition provides the basis for the FDA to

ingredients; color additives; stabilizers and

consider changes that would replace the currently ex-

emulsifiers; preservatives, vitamins, and minerals;

isting fragmented standards for yogurt, low-fat yo-

and safe and suitable ingredients added for

gurt, and nonfat yogurt as these

standards contain

nutritional or functional purposes.

numerous stayed provisions. The proposed standards

r Nomenclature: Characterizes products containing

would require that yogurt contain a minimum level

more than 3.0 g of total fat per reference amount

of certain live and active bacterial cultures and allow *commonly consumed (RACC) as "yogurt."*

for more flexibility to implement advances in food

Products with at least 0.5 g, but not more than

technology.

3.0 g of total fat per RACC will be named as

The specific details of the proposed changes are as

"low-fat yogurt" and if the food is less than 0.5 g

follows:

of total fat per RACC it will be “nonfat yogurt.”

r Single Standard of Identity: Incorporates full-fat,

This change bases the identity of the product on

low-fat, nonfat standards in one standard of

the total fat quantity in the entire product rather

identity. It also suggests that a parallel *than just the milk fat of the yogurt prior to*

“cultured/fermented milk” standard be created for

addition of optional ingredients or flavorings.

similar products that do not meet the new yogurt

standard.

At the time of writing, the FDA has not yet changed

r Live and Active Characterizing Cultures: Require *the standards of identity to incorporate these sug-*

that yogurt be characterized by certain levels of

gested modifications. Under the rule-making process,

bacterial cultures of at least 107 CFU/g active

the FDA must consider public comment for inter-

cultures Lactobacillus delbrueckii subsp.

ested stakeholders before promulgating *new stan-*

bulgaricus and Streptococcus thermophilus at the

dards of identity. The first step in this process oc-

time of manufacture.

curred in early 2004 when the FDA published an

Advance Notice of Proposed Rule Making seeking

States (EAFUS). This information can be found at

comments on the proposed NYA petition. The next

http://www.cfsan.fda.gov/~dms/eafus.htm

step is for the FDA to consider the relevant comments

and publish either a Proposed Rule allowing for ad-

LABELING

ditional comments or a Final Rule Making. However, *under FDA Procedures the law requires a very bur-*

The FDA sets forth general requirements for food la-

densome process for issuance, amendment, or repeal

beling in the FDA Federal Food Drug and Cosmetic

of standards of identity if anyone objects to the pro-

Act (FFD&C Act) and more detailed regulations in

posal being considered. Since some

interested parties

the CFR Title 21 parts 100. The basic premise is

have filed support of the yogurt modernization peti-

that food labels must be truthful and not mislead-

tion and others have objected to specific provisions,

ing to consumers. The NLEA established most fed-

it is not known when proposed changes might be *eral food labeling requirements as nationally uni-*

finalized.

form standards through federal preemption of state

requirements. Under the preemptive authority of the

NLEA, no state can directly or indirectly establish

Food Additives and Packaging

or continue to enforce any requirement that is not

Ingredients and food compounds that are added to

identical to a federal requirement issued under the

milk and fermented milk products must be safe and

following provisions of the FFD&C Act.

suitable for their intended function. The FDA reviews

Any product introduced into interstate commerce

the safety of food and color additives *before manu-*

is subject to FDA regulations. The U.S. Court has

facturers and distributors can market them. To initiate

interpreted the scope of interstate commerce expan-

this review, food additive firms are required to submit

sively for this purpose so as to apply federal regula-

a petition or notification that includes appropriate test *tion to virtually all products except those for which*

data to demonstrate the safety of the intended use of

the product, including its ingredients and packaging

the substance. The agency also has a notification pro-

materials, are produced, packaged, and sold within

gram for substances that are "generally recognized as

the given state. As a result, there are *few "intrastate"*

safe" (GRAS).

products, but those that qualify are not subject to FDA

Food packaging is regulated as a food-contact sur-

regulation.

face. The FDA defines a food-contact substance as

There are several types of state food labeling re-

"any substance intended for use as a

component of

quirements that are not expressly preempted, and

materials used in manufacturing, packing, packag-

thus, may be enforced against food products in inter-

ing, transporting, or holding food if such use is not

state commerce. These include warning labels, open

intended to have a technical effect in such food.”

date coding, unit price labeling, food grading, recy-

Safety evaluations of food-contact surfaces are done

clable container deposit labeling, religious dietary la-

by an FDA notification process to authorize new uses

beling, and item price labeling.

of food additives that are food-contact substances

While federal standards of identity preempt state *based on a detailed analysis of the compounds chem-*

standards, states may continue to establish and en-

istry, toxicology, and environmental impact. An in-

force standards of identity for products for which

ventory of effective notifications for food-contact

no federal standards of identity exist, for example,

substances and additional information

regarding the

frozen yogurt or yogurt smoothies.

notification program are listed on FDA's Web page

http://www.cfsan.fda.gov/~dms/opa-fcn.html.

General Requirements

An informational database on approved food ad-

ditives is maintained by the FDA. It contains ad-

The food labeling regulations specify what informa-

ministrative, chemical, and toxicological information

tion must appear on the package label, where infor-

on thousands of substances directly added to food,

mation must be placed, the label format, and the size

including substances regulated by the FDA as di-

for mandatory labeling material such as nutrition in-

rect, "secondary" direct, color

additives, GRAS, and

formation. The part of the package that the consumer

prior-sanctioned substances. More than 3,000 total

is most likely to see during normal retail display is

substances together comprise an inventory often re-

called the "principal display panel." Information re-

ferred to as "Everything" Added to Food in the United *lated to the product name including flavoring and*

the net quantity expressed by weight or volume must

Flavor Labeling

appear in a food product's principal display panel.

Milk and milk products including yogurt and other

The "information panel" is typically located to the

fermented milks are labeled with the name of the

right of the principal display panel and must contain

food and the flavoring if added. Flavorings are de-

the full ingredient listing, name, and place of busi-

fined by the FDA as either natural or artificial. Arti-

ness of manufacturer, packer, or

distributor, nutrition

ficial flavors are compounds that impart flavor which

labeling of food, and, if applicable, specific require-

is NOT derived from a spice, fruit or fruit juice, veg-

ments related to the use of nutrient content claims,

etable or vegetable juice, yeast, herb, bark, bud, root,

food warnings, and statements of special dietary use.

leaf, or plant material, meat, seafood, poultry, eggs,

In addition to the general labeling requirements

dairy products, and fermented products. Natural fla-

of the federal regulations, the vast majority of states

vor or natural flavoring is derived from the com-

will mandate the inclusion of additional labeling as

pounds listed above in the form of an

essential oil,

required by the Grade "A" PMO discussed in Chap-

oleoresin or extract, protein, hydrolysate, distillate

ter 3. The Grade "A" PMO's labeling requirements

that is used to impart flavor.

call for all bottles, containers, and packages con-

Flavor labeling is dictated by FDA food labeling *taining milk and milk products to be conspicuously*

regulation according to the general "6-Category" fla-

marked with the term "Grade A," identity of the

vor labeling system. The 6-Category flavor labeling

plant where pasteurized, identification of processing

categories will be referred to as Category A through

if "ultra-pasteurized" or "aseptic,"

“reconstituted” or

Category F (IDFA, 2004).

“recombined” if the product is made by reconstitution

The first three categories (A, B, and C) apply when

or recombination, and the terms “keep refrigerated

a flavor, including artificial flavor, is added to a food

after opening” in the case of aseptically processed *product in fluid form or "from the bottle" (e.g., vanilla*

milk and milk products.

extract, vanillin, coffee extract).

Nomenclature

Category A

The name of the food or "statement of identity" may

be established by regulation, or it may be dictated in

When the primary characterizing flavor ingredient *the nomenclature section of the product's standard of*

is solely natural, not artificial, and is derived from

identity. If the product does not fall under a federal

the product whose flavor it simulates, resembles, or

standard or, as applicable, state standard of identity

reinforces, the name of the food is accompanied by

or does not have a common or usual

name, then an

the common or unusual name of the characterizing

appropriate descriptive name must be used that will

flavor (e.g., "Vanilla yogurt").

easily be understood by consumers. The standards of

identity for cultured milk and yogurt designate the

Category B

name of the product. Descriptive names *may only*

be used on a product that does not have a standard

When the food contains both natural flavor derived

of identity, or a common or usual name. A descrip-

from the characterizing flavor source and other natu-

tive name must be suggestive enough to reveal the

ral flavoring from a source that simulates, resembles, *basic composition of the product and alleviate any*

or reinforces the characterizing flavor, the name of

question regarding the product's identity. For exam-

the food is followed by the words "with other nat-

ple, a beverage product made of a blend of yogurt

ural flavor" (e.g., "Coffee yogurt with other natural

and juice should not solely use the

name "smoothie"

flavor").

but include that it is "a blend of yogurt and juice."

In addition, the form of the food must be stated if

Category C

it is not visible through the packaging. For example,

drinkable yogurt would not require a disclosure that

When natural flavor(s) used in the food *is not derived*

the product is a liquid rather than a semisolid if it is

from the ingredient whose flavor has been determined

packaged in a transparent container where the con-

to be the characterizing flavor or if the food contains

sumer can clearly see the viscosity or form of the

an artificial flavor that simulates, resembles, or re-

food.

inforces the declared characterizing flavor, the name

of the food must be accompanied by the words "ar-

display panel of the package or any panels where

tificial" or "artificially flavored" (e.g., "Artificially

the product name occurs. A blend of

three or more

flavored vanilla yogurt”).

distinctive artificial flavors can be described as a col-

The next two categories (D and E) apply to those

lective name, i.e., “Artificially Flavored Tutti Fruity.”

products that consumers would commonly expect to

The name of the flavoring must be in a type size not *contain the characterizing food ingredient(s) (e.g.,*

less than 1/2 the height of the letter used in the name of

strawberries, blueberries). In both of these categories,

the food and the flavor-modifying terms must not be

the characterizing food ingredient(s) is added to

less than 1/2 the height of the name of the characteriz-

flavor the finished product at a level

NOT suf-

ing flavor. Exemptions for category name declaration

ficient to independently characterize the finished

are made if the flavor name is part of a trademark such

product.

as Lemon DropTM.

Category D

Ingredient Declaration

When the food contains an insufficient amount of

An ingredient statement is required on all food pack-

the food ingredient to independently characterize the

ages intended for retail sale that contain more than

product, and it contains added natural flavor that is

one ingredient. Except where exemptions are appli-

derived from the characterizing food

ingredient, the

cable, an individual ingredient must be declared in the

food is labeled as a naturally flavored food. The fla-

ingredient statement by its common or usual name. In

vor may be immediately preceded by the word "nat-

addition, specific regulations exist for colors, sweet-

ural" and must be immediately followed by the word *eners, incidental additives, processing aids, and fat*

“flavored” (e.g., “Peach flavored yogurt” or “Natural

and/or oil ingredients. Special ingredient labeling sit-

peach flavored yogurt”).

uations include the following:

All certified colors must be included by name in the

Category E

ingredient statement.

Any beverage product purporting to contain fruit or

When the food contains an insufficient amount of

vegetable juice must declare the percent of juice

the food ingredient to independently characterize the

present in the finished product.

food and it contains other added natural flavors that

are not derived from the characterizing flavor de-

Many standards of identity address ingredient la-

clared on the label, but that simulate, resemble, or

beling, in that they allow for ingredient groupings

reinforce the characterizing flavor, the flavor may

or provide a common or usual name for a particular

be immediately preceded by the word "natural" and

ingredient. Some examples are listed in

Table 4.1.

must be immediately followed by the words "with

The ingredient listing must appear prominently

other natural flavors" (e.g., "Peach yogurt with other

and conspicuously on either the principal display

natural flavors" or "Natural peach yogurt with other

panel or the information panel. The entire list of in-

natural flavors”).

gredients must appear in one place without other “in-

Category F applies to products that contain suffi-

tervening material” and, in general, must appear in

cient amounts of characterizing food ingredients to

letters not less than 1/16 of an inch in height.

flavor the finished product (e.g., peaches, cherries).

Ingredients in multicomponent foods may be listed

by either of the following two alternatives: grouping

or dispersion. Although either method may be used,

Category F

the grouping alternative may be more helpful to con-

If the food contains sufficient levels of the food in-

sumers in identifying the ingredients used in each *gredient to independently characterize the food and*

component of the food.

contains no added artificial flavors or natural flavors

The grouping alternative for ingredient declara-

(“from the bottle”) that simulate, resemble, or rein-

tions of multicomponent ingredients may be used by

force the characterizing flavor, then the characteriz-

declaring the common or usual name of the ingredi-

ing ingredient is the flavor of the food (e.g., "Straw-

ent followed by a parenthetical listing of all ingredi-

berry yogurt").

ents contained in each of the components in descend-

The name of the flavoring as described above must

ing order of predominance by weight. For example, *accompany the name of the food on the principal*

an ingredient statement for raspberry yogurt with

Table 4.1. *Common or Usual Names for Typical Ingredients Used in Dairy Products Common or Usual*

Ingredient

Name

Skim milk, concentrated skim milk, reconstituted skim milk, and nonfat

Skim milk or nonfat milk

dry milk (21 CFR § 101.4 Food; designation of ingredients)

Milk, concentrated milk, reconstituted milk, and dry whole milk (21 CFR

Milk

§ 133.129 Dry curd cottage cheese; 21 CFR § 101.4 Food; designation of ingredients)

Bacteria cultures (21 CFR § 131.160 Sour cream; 21 CFR § 131.162

Cultured

(the blank is

Acidified sour cream; 21 CFR § 101.4 Food; designation of ingredients) filled in with the name

of the substrate)

Sweet cream buttermilk, concentrated sweet cream buttermilk,

Buttermilk

reconstituted sweet cream buttermilk, and dried sweet cream

buttermilk (21 CFR § 101.4 Food;

designation of ingredients)

Whey, concentrated whey, reconstituted whey, and dried whey (21 CFR

Whey

§ 101.4 Food; designation of ingredients)

Cream, reconstituted cream, dried cream, and plastic cream (sometimes

Cream

known as concentrated milk fat) (21 CFR § 101.4 Food; designation of

ingredients)

Butter oil and anhydrous butterfat (21 CFR § 101.4 Food; designation of

Butterfat

ingredients)

Milk-clotting enzymes (21 CFR § 133.128 Cottage cheese; 21 CFR

Enzymes

§ 133.129 Dry curd cottage cheese)

Source: IDFA, 2004.

granola may state the following:

consumed per eating occasion by

persons 4 years of

age or older as expressed by a common household

Ingredients: Yogurt (cultured milk, raspberries,

measure appropriate for the food.

sugar, gelatin, pectin, and natural flavors) and gra-

FDA has established reference amounts for over

nola topping (rolled oats, puffed rice, corn syrup, *brown sugar, raisins, and almonds).*

100 food product categories. The established refer-

ence amount is the benchmark for determining the

The dispersion alternative for ingredient declara-

serving size declared on the label and expressed as a

tions of multicomponent ingredients may be used

common household measure (e.g., cups, tablespoons, *by incorporating into the ingredient statement (in*

teaspoons). The serving size is required to be ex-

descending order of predominance in the finished

pressed on the nutrition label in common household

food) the common or usual name of every component

measure followed in parentheses by an equivalent

of the multicomponent ingredient

without listing the

metric quantity (fluid products in milliliters and all

multicomponent ingredient itself.

other foods in grams). For example, for acidophilus

For example, an ingredient statement for raspberry

milk, "Serving Size 1 cup (240 ml)." For the most

yogurt with granola may state the following:

part, the common household unit for similar products

Ingredients: Cultured milk, sugar, rolled oats, corn

will be the same, but because of the varying densities

syrup, raspberries, puffed rice, brown sugar, raisins,

among products, the metric equivalent may not be

almonds, gelatin, pectin, and natural flavors.

identical.

Unless otherwise exempted, all nutrients and food

component quantities must be declared on the ba-

Nutrition Facts Panel

sis of the serving size derived from the reference

All food packages intended for retail sale must de-

amount. FDA has established methods for convert-

clare quantitative nutritional information expressed *ing the reference amount to the "serving size" for*

in terms of a "serving" of an individual food. A "serv-

labeling purposes. The method employed is based

ing," or as it appears on the label, "Serving Size," is

on the type of container in use (i.e., multiserv-

based on the reference amount of food customarily

ing vs. single-serving container) and

the physical

66

Part I: Basic Background

characteristics of the product (discrete unit vs.

Sodium

nondiscrete fluid or bulk-type product).

Total carbohydrate

For example, manufacturers producing frozen yo-

Dietary fiber

gurt mix for retail sale must determine the amount

Sugars

of mix that will make (under normal conditions of

Protein

preparation) 1/2 cup of the product. Since air (i.e.,

Vitamin A

overrun) is incorporated into the product, less than

Vitamin C

1/2 cup of mix will be required to produce 1/2 cup

Calcium

of finished product. The following reference amount

Iron

categories have been established for milk and milk

The following table gives a list of the Daily Refer-

products:

ence Values (DRV) based on a

2,000calorie diet.

Product Category

Reference Amount

Food Component

Daily Reference Values

Cheese used as an ingredient

55 g

Total fat

65 g

(e.g., dry cottage cheese)

Saturated fat

20 g

Sour cream

30 g

Cholesterol

300 mg

Milk and cultured or acidified

240 ml

Sodium

2,400 mg

milk

Potassium

3,500 mg

Yogurt

225 g

Total carbohydrate

300 g

Dairy-based dips

2 tbsp

Dietary fiber

25 g

Dairy and nondairy whipped

2 tbsp

Protein

50 g

topping

Juices, juice drinks, and juice

240 ml

milk blend drinks

The percent DV is calculated by

dividing the un-

Shakes or shake substitutes

240 ml

rounded (actual amount) or rounded amount of the

(e.g., dairy shake mixes)

nutrient present in the food per serving by the es-

tablished DRV and multiplying by 100, except that

the DRV for protein must be calculated from the un-

Nutrition information is presented to consumers

rounded amount. The DV is expressed to the nearest

"in the context of a total daily diet," which is man-

whole percentage. The percentage of DV is mandated

dated by regulations as a diet of 2,000 calories per

for total fat, saturated fat, cholesterol, sodium, total

day. From this theoretical 2,000

calorie per day diet,

carbohydrates, and dietary fiber, and is voluntary for

recommended intake levels or "daily values" (DV)

potassium and protein. There has been no DV set for

of individual nutrients have been developed based on

trans fat and so a percentage of DV declaration should

current dietary guidelines. As a result, information *not be made.*

on individual nutrients is required to be expressed

in most cases by a quantitative declaration (grams,

milligrams, etc.) and a percentage of a DV for the

Nutrient

RDI a Value

nutrient.

Nutrient labeling information is referred to as the

Vitamin A

5,000 IU

Nutrition Facts box. The explicit amount (quantita-

Vitamin C (ascorbic acid)

60 mg

tive declaration) and, as applicable, the percentage of

Calcium

1,000 mg

the DV must be included in the

Nutrition Facts box

Iron

18 mg

for each of the following nutrients and food compo-

Vitamin D

400 IU

nents:

a Reference daily intake.

Total calories

Calories from fat

Depending on the size of the package, FDA allows

Total fat

different graphic formats for nutritional information.

Saturated fat

The most common is the Full Vertical format (see

Trans fat

Fig. 4.1) used on all packages with greater than 40

Cholesterol

in.2 of available labeling space.

4 Regulations for Product Standards and Labeling

67

They have chosen the "REAL r " seal to indicate this

Full Vertical Format

distinction. Use of the "REAL r " seal must be in

conjunction with the "REAL r " Seal Certified User

Nutrition Facts

Agreement. Information about the seal may be ob-

Serving Size 1 cup (228g)

tained at http://www.dairyinfo.com.

Servings Per Container 2

Live and Active Cultures Seal

Amount Per Serving

***Calories** 260*

Calories from Fat 120

To help identify yogurt products that contain live

% Daily Value*

and active cultures, the National Yogurt Association

***Total Fat** 13g*

20 %

(NYA) has established a special Live & Active Cul-

Saturaled Fat 5g

25%

tures seal. The NYA is a national nonprofit trade or-

ganization whose purpose is to sponsor health and

Trans Fat 2g

medical research for yogurt with live and active cul-

***Cholesterol** 30mg*

10%

tures and serve as an information source to the trade

***Sodium** 660mg*

28%

and the general public. The Live & Active Cultures

Total Carbohydrate *31g*

10%

seal, which appears on refrigerated and frozen yogurt

Dielary Fiber 0g

0%

containers, helps identify those products containing

Sugars 5g

significant amounts of live and active cultures. The

***Protein** 5g*

seal is a voluntary identification available to all man-

ufacturers whose refrigerated yogurt contain at least

Vitamin A 4%

Vitamin C 2%

100 million cultures per gram at the time of man-

Calcium 15%

Iron 4%

ufacture, and whose frozen yogurt contains at least

**Percent Daily Values are based on a 2,000 calorie*

diet.

10 million cultures per gram at the time of manufac-

Your Daily Values may be higher or lower depending

ture. Since the seal program is

voluntary but not all

on your calorie needs.

yogurt products carry the seal. More information can

Calories

2,000

2,500

be found at http://www.aboutyogurt.com.

Total Fat

Less than 65g

80g

Sat Fat

Less than 20g

25g

Kosher Symbols

Cholesterol

Less than 300mg

300mg

Observance of the biblical kosher laws can be facili-

Sodium

Less than 2,400mg

2,400mg

Total Carbohydrate

300g

375g

tated by kosher foods being certified by a rabbinical

Dielary Fiber

25g

30g

organization and labeled with an identifying symbol.

The Jewish teachings written in the Jordon lists cer-

Calories per gram:

tain basic categories of food items that are not kosher.

Fat 9

Carbohydrate 4

Protein 4

These include certain animals, fowl, and fish (such as

pork and rabbit, eagle and owl, catfish and sturgeon)

***Figure 4.1.** Full Vertical format for nutritional*

information used for packages with greater than 40 in.2

and any shellfish, insect, or reptile. In addition, kosher

of available labeling space.

species of meat and fowl must be slaughtered in a *prescribed manner and meat and dairy products may*

not be manufactured or consumed together. Kosher

Packages with less than 40 in.2 of labeling space

food labeling regulations are not preempted by the

can use a smaller tabular format (see Fig. 4.2).

implementation of the NLEA and, therefore, state

regulatory officials can enforce their *own state regu-*

Special Labeling Requirements

lations. Although FDA does not discuss the criteria

by which these terms, "kosher" and "kosher style"

Food labeling often has additional nonmandatory in-

may be used, they do indicate that these terms should

formation used for marketing purposes. These are *be used only on products that meet the religious di-*

listed below:

etary requirements.

More information on kosher certification can be

Real Seal

obtained by contacting the following organizations:

Dairy Management, Inc. has established a voluntary

the Union of Orthodox Jewish

Congregations in New

program to promote dairy products and to distinguish

York at http://www.oukosher.org or the OK Kosher

between authentic and simulated dairy products.

Certification at http://www.okkosher.com.

Tabular Format

Nutrition

Amount/serving

%DV*

Amount/serving %DV*

Figure 4.2. *Tabular*

Facts

Total Fat *2g*

3%

Total Card. *0g* ***0%***

Serving Size 1/3 cup (56g)

Sat. Fat 1g

5*%*

Fiber 0g

0*%*

format for

Servings about 3

nutritional

Trans Fat 0.5g

Sugars 0g

Calories *90*

information used

Cholest.

Protein

Fat cal. 20

10mg

3%

17g

for packages with

Sodlum *200mg*

8%

less than 40 in.2 of

**Percent Daily Values (DV) are*

available labeling

based on a 2,000 calorie diet

Vitamin A 0% = Vitamin C 0% = Calcium 0% = Iron 6%

space.

Universal Product Bar Codes

partame in a food product require that the label state

on either the principal display panel or *the informa-*

The Uniform Code Council was originally created

tion panel the following: "Phenylketonurics: Con-

by the food industry in an effort to place a code and

tains Phenylalanine."

scanner-readable symbol on the package of contain-

ers sold through retail outlets using automatic check-

out equipment. The primary purpose of the Univer-

CODEX STANDARDS AND

sal Product Code (UPC) bar code system is to reduce

DEFINITIONS FOR FERMENTED

retail store costs by providing an automatic comput-

MILK PRODUCTS

erized checkout system, to establish better inventory

control and ordering systems, and to

provide more

The Food and Agriculture Organization (FAO) and

valuable marketing information about products. A

the World Health Organization (WHO) developed the

UPC manufacturer identification number for use in

Codex Alimentarius Commission—the body charged

the bar code may be obtained by contacting the Uni-

with developing a worldwide food code. All im-

form Code Council, Inc. in Dayton, OH, or Web site

portant aspects of food pertaining to the protection

http://www.uc-council.org.

of consumer health and fair practices in the food

trade have come under the Commission's scrutiny,

including international food standards, also known

Code Dating

as Codex Standards. The Codex Web site lists more

information on the Codex Alimentarius and official

Code dating, such as "sell by" or "best if used by"

Codex Standards.

dating, is a requirement promulgated under the state

The Codex Standard for Fermented Milk (243-

regulations and laws and enforced by state regulatory

2003), recently updated in 2003, applies to all fer-

officials. There are no federal regulations addressing

mented milk including heat-treated fermented milks,

code dating or "sell by" dating. Often a code date

concentrated fermented milks, and composite fer-

printed on the food label is used for

tracking and iden-

mented milks (fermented milks with flavoring or

tifying the food by the date of production, plant loca-

other added nondairy ingredients) that are both di-

tion, filling line, or production vat. This information

rectly consumed or used for further processing (see

may be used for inventory purposes, product rotation

Table 4.2). The Codex fermented milk standard

in storage, display, and, if necessary, retrieval from

also provides that certain fermented milk must be

the market. Therefore, it is important that the code

characterized by specific starter cultures (Codex,

date or identifying information be legibly printed on

2004).

each container and shipper.

Concentrated fermented milk such as strained yo-

gurt, Labeneh, Ymer, and Ylette require that the pro-

tein be increased to 5.6%. Flavored fermented milk

Food Warning Statements

must contain not more than 50% (mass/mass) of

FDA regulations require food warning statements to *nondairy ingredients, such as sweeteners, fruits, veg-*

appear in the labeling of certain food products. For

etables, juices, purees, cereals, nuts, spices, and other

example, the regulations pertaining to the use of as-

natural flavorings.

Table 4.2. *Culture Characterization for Codex Standard for Fermented Milk*

Yogurt

Symbiotic cultures of Streptococcus thermophilus and Lactobacillus

delbrueckii subsp. bulgaricus

Alternate culture yogurt

Cultures of Streptococcus thermophilus and any Lactobacillus species
Acidophilus milk

Lactobacillus acidophilus

Kefir

Starter culture prepared from kefir grains, Lactobacillus kefiri, species of

the genera Leuconostoc, Lactococcus, and Acetobacter growing in a strong specific relationship. Kefir grains constitute both lactose

fermenting yeasts (Kluyveromyces marxianus) and

non-lactose-fermenting yeasts (Saccharomyces unisporus,

Saccharomyces cerevisiae, and Saccharomyces exiguus)

Kumys

Lactobacillus delbrueckii subsp. bulgaricus and Khuyveromyces marxianus Note: Microorganisms other than those constituting the specific starter culture(s) specified above may be added.

Source: Codex Standard for Fermented Milk (243-2003).

Raw materials allowed in the Codex Standard for

shelf life on products that have been stored under

Fermented Milks are limited to milk and/or milk *normal conditions and temperatures.*

products obtained from milk and potable water used

Allowable food additives are specified in Table 4.4.

for reconstitution. Additional permitted ingredients

Labeling of the product is also specified by the

include starter cultures and sodium chloride. Gelatin

Codex Standard for Fermented Milks. It allows for *and starch are only allowed in heat-treated fermented*

names to be replaced by designations such as Yo-

milks, flavored fermented milks, and plain fermented

gurt, Kefir, and Kuyums and provide for alternative

milk if permitted by the regulations in the country of

spelling of the name to be appropriate in the coun-

sale to the final consumer.

try of retail sale. Additionally, the qualifying labeling

Composition requirements for various Codex Fer-

terms "milk" or "tangy" can be used. If the fermented

mented Milks are listed in Table 4.3.

milk product is subject to heat treatment after cultur-

The microbial criteria apply to the fermented milk

ing, it must be labeled as "Heat-Treated Fermented *portion only for flavored fermented milks. Compli-*

Milk"; unless the consumer would be misled by this

ance to the microbial criteria is verified though ana-

name, the product shall be named as permitted by

lytical testing of the product through the end of the

the regulations in the country of retail sale. Flavor

***Table 4.3.** Composition Requirements*

for Codex Standard for Fermented Milk

Yoghurt, Alternate

Fermented

Culture Yoghurt, and

Milk

Acidophilus Milk

Kefir

Kumys

Milk protein a(% m/m)

Min. 2.7%

Min. 2.7%

Min. 2.7%

Milk fat (% m/m)

Less than 10%

Less than 15%

Less than 10%

Less than 10%

Titrable acidity, expressed

Min. 0.3%

Min. 0.6%

Min. 0.6%

Min. 0.7%

as % lactic acid (% m/m)

Ethanol (% vol./w)

Min. 0.5%

Sum of microorganisms

Min. 107

Min. 107

Min. 107

Min. 107

constituting the starter

culture defined in section

2.1 (cfu/g, in total)

Labeled micororganisms b

Min. 106

Min. 106

(cfu/g, total)

Yeast (cfu/g)

Min. 104

Min. 104

a Protein content 6.38 multiplied by the total Kjeldahl nitrogen determined.

b Applies where a content claim is made in the labeling that refers to the presence of a specific microorganism (other than those specified in Table 4.2 for the product concerned) that has been added as a supplement to the specific starter culture.

Source: Codex Standard for Fermented Milk (243-2003).

Table 4.4. *Allowable Food Additives*

for Codex Standard for Fermented Milk

Fermented Milks Heat-Treated

Fermented Milks

After Fermentation

Additive Class

Plain

Flavored

Plain

Flavored

Colors

–

X

–

X

Sweeteners

–

X

–

X

Emulsifiers

—

X

—

X

Flavor enhancers

—

X

—

X

Acids

–

X

X

X

Acidity regulators

–

X

X

X

Stabilizers

X1

X

X

X

Thickeners

X1

X

X

X

Preservatives

—

—

—

X

Packaging gases

—

X

X

X

Note: X = The use of additive

belonging to the class is technologically justified. In the case of flavored products, the additive is technologically justified in the dairy portion; – = the use of additives belonging to the class is not technologically justified; and 1 = use is restricted to reconstitution and recombination and if permitted by national legislation in the country of sale to the final consumer.

Source: Codex Standard for Fermented Milk (243-2003).

designations and the term "sweetened," if appropri-

coordination of all food standards

work undertaken

ate, shall also be included on the label. A declaration

by international governmental and nongovernmental

on milk fat content either in percentage or in grams

organizations.

per serving should be provided if the consumer would

***COMMON OR USUAL NAME**—The name of a food* *be misled by its omission.*

that is not set by law or regulation, but either through

common usage or through expert opinion (such as

that of the FDA).

GLOSSARY

DAILY REFERENCE VALUES (DRV)*—An amount*

set by the CFR as the recommended level of in-

ASEPTICALLY PROCESSED*—When*

used to de-

take for certain nutrients (fat, saturated fat, choles-

scribe a milk product, the product has been subjected

terol, total carbohydrate, fiber, sodium, potassium,

to sufficient heat processing and packaged in a her-

and protein) based on a 2,000 calorie per day

metically sealed container, to conform to the applica-

diet.

ble requirements of the CFR and the Grade A PMO

FDA—*U.S. Food and Drug Administration.*

and to maintain the commercial sterility of the prod-

FFD&CA (FEDERAL FOOD DRUG AND COS-

uct under normal nonrefrigerated conditions.

METIC ACT)—*An act of the U.S. Congress that*

CERTIFIED COLORS*—Color additives manufac-*

specified the basis for food safety standards.

tured from petroleum and coal sources listed in the

GRADE

“A”

PMO

(PASTEURIZED

MILK

CFR for use in foods, drugs, cosmetics, and medical

ORDINANCE)*—Model milk regulations used for*

devices.

the inspection of milk production and processing

CFU/G

(COLONY

FORMING

UNITS

PER

facilities.

GRAM)*—An*

expression

of

measurement

for

HOMOGENIZATION*—The mechanical process of*

determining the number of live microorganisms on a *shearing milk fat globules via pressure to reduce the*

volume basis.

size of the fat globules and reduce the separation of

CODEX ALIMENTARIUS COMMISSION*—An in-*

the cream portion of the product.

ternational body, created by FAO and WHO, to de-

IDFA

(INTERNATIONAL

DAIRY

FOOD

velop food standards, guidelines, and related texts

ASSOCIATION)*—A*

trade

association

repre-

such as codes of practice. The main purposes are

senting dairy processors that provides *information*

protecting health of the consumers, ensuring fair

and publications on dairy product regulations and

trade practices in the food industry, and promoting

standards.

4 Regulations for Product Standards and Labeling

71

IU (INTERNATIONAL UNITS)*—A*

unit of measure-

REFERENCES

ment for certain vitamins (Vitamins A, D, and K) for

labeling purposes.

CFSAN (Center for Food Safety and Applied

***MSNF**—Milk solids nonfat portion of milk or milk*

Nutrition). 2004. National Conference on Interstate

products.

Milk Shipments Model Documents—Milk Safety

***PASTEURIZATION**—A process of heating fluid milk*

References [Online]. Available at http://www.cfsan

products to render them safe for human consump-

.fda.gov/~ear/p-nci.html.

tion by destroying the disease-producing organisms

CFSAN (Center for Food Safety and Applied *(pathogens). The process inactivates approximately*

Nutrition). 2004. Food Additive Inventory of

95% of all microorganisms in milk.

Effective Notifications for Foods Contact Substances

RDI (REFERENCE DAILY INTAKE)*—A value set*

[Online]. Available at http://www.cfsan.fda.gov/

by the CFR as the recommended level of intake

~dms/opa-fcn.html.

for vitamins and minerals essential for human nu-

CFSAN (Center for Food Safety and Applied

trition for adults and children 4 or more years of

Nutrition). 2004. Everything Added to Food in the

age.

United States (EAFUS) [Online]. Available at

REFERENCE

AMOUNT

(REFERENCE

http://www.cfsan.fda.gov/~dms/eafus.htm

AMOUNT CUSTOMARILY CONSUMED)—

Code of Federal Regulations. 2004. Title 21 Food and

Values set by the CFR to reflect the amount of a

Drugs [Online]. Available at

particular food usually consumed per eating occasion

http://www.access.gpo.gov/cgi-bin/cfrassemble.

by people 4 years of age or older, based on the major

cgi?title=200321.

intended use of that food.

Codex Alimentarius. 2004. Codex Standard for

TITRATABLE ACIDITY*—The measurement of the*

Fermented Milk (243-2003) [Online]. Available at

extent of growth of acid-producing bacteria by de-

http://www.codexalimentarius.net/web/i en.jsp.

termining the lactic acid present in a food through

IDFA (International Dairy Foods Association). 2004.

reacting the lactic acid with a standard solution of

MIF Labeling Manual, 2004 Revision,

MIF,

alkali.

Washington, DC.

UHT

(ULTRA-HIGH

TEMPERATURE)*—Heat*

USDHHS (U.S. Department of Health and Human

treatment at a temperature of 135–150◦C for a

Services). 2003. Grade "A"

Pasteurized Milk

holding time of 4–15 seconds that sterilizes the

Ordinance, 2003 Revision, Department of Public

product for aseptic packaging to permit storage at

Health, U.S. DHHS, Food and Drug Administration,

ambient temperatures.

Washington, DC.

Manufacturing Yogurt and Fermented

Milks

Edited by Ramesh C. Chandan

5

Basic Dairy Processing Principles

Arun Kilara

Introduction

products may have internal standards for insuring the

Overview of Processing Equipment in a

Dairy Plant

quality of the products important to the consumer.

Fluid Transfer Operations

Such attributes may include taste, texture, odor, fla-

Heat Transfer Operations

vor, mouthfeel, color, and keeping quality. These as-

Mixing Operations

pects are covered in detail in Chapters 1, 9, 14, and 15.

Separation

The processing steps may involve one or more op-

Microbial Transformation

erations in combination, and the most common op-

From farm to Factory

erations involve pumping or transfer of fluids, heat

Storage of Raw Milk

Centrifugal Operations

transfer (cooling and heating), mixing of ingredients,

Thermal Processing Systems

separation (fat standardization), and microbial trans-

Homogenization

formation of milk (acid gel formation). These aspects

Membrane Technology

are discussed in the next section of this chapter.

Bibliography

OVERVIEW OF PROCESSING

INTRODUCTION

EQUIPMENT IN A DAIRY PLANT

Milk is a highly perishable biological fluid. The com-

Fluid Transfer Operations

position of milk and the factors that contribute to

variability in the composition have been discussed in

Fluid transfer processes involve transferring milk

Chapter 2. Milk from many farms are collected in

from the receiving tankers to storage silos and then for

tankers two to three times a week and delivered to

further transfer to appropriate unit operations. These

a processing facility. At this facility (also known as

transfers are achieved by means of pumps. There are

a dairy plant or factory) the milk is

stored and pro-

two main categories of these transfer agents used in

cessed further to make the appropriate products for

the dairy industry called centrifugal and positive dis-

which the dairy plant is designed for.

placement pumps. Within each category there are dif-

The safety of products is of major concern in dairy *ferent types of pumps.*

processing. Hence the regulations for the production

The selection of the right type of pump for use

and storage of milk at the farm, for the transporta-

in an operation is dependent upon a number of fac-

tion from the farm to the factory, and for the holding

tors including flow rate, product to be handled by the *and processing required on the factory premises have*

pump, viscosity, density, temperature, and pressure

been promulgated, and these have been discussed

in the system. Pumps should be installed as close

in Chapter 3. Regulations also apply for standard-

to the tanks from which process liquids are being

ized food products that have to meet

compositional

transferred with as few valves and bends in the line

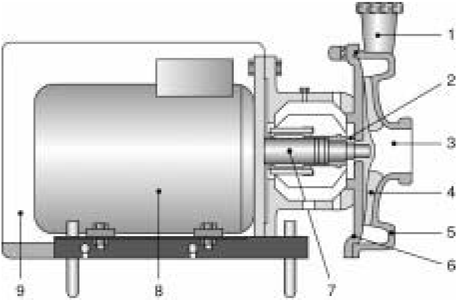
requirements as well as the use of approved ingre-

as feasible. Any devices to restrict flow should be

dients and processes. These aspects have been dis-

placed at the exit or discharge side of the pump. Cav-

cussed in Chapter 4. In addition, manufacturers of itation is a problem in pumping caused by too low a



pressure at the inlet end of a pump relative to the vapor

Positive Displacement Pumps

pressure of the fluid being transferred. As cavitation

These pumps work on the principle of positive dis-

progresses, pumping efficiencies decrease and even-

placement in which in each rotation or reciprocat-

tually the pump ceases to transfer the fluid. The ap-

ing movement a finite amount of fluid is pumped re-

propriate size of the pump required for the transfer de-

gardless of the manometric head. The main types of

pends upon flow rate and head, required motor power,

positive displacement pumps have been called rotary

and the net positive suction head. Engineers using

and reciprocating pumps. These pumps are useful for

charts and formulas easily calculate

these parameters.

higher viscosity fluids and at lower viscosities may

exhibit some slip as the pressure increases. The net

result is a reduction in volumetric flow on each stroke.

Centrifugal Pumps

Throttling by flow control valves at the discharge end

A motor drives an impeller that has vanes (Fig. 5.1).

of the pump should be avoided and these pumps have

The motion is circular and the liquid being pumped

to be fitted with a pressure relief valve. Flow control

enters to the center of the impeller that imparts a

in positive displacement pumps is achieved by con-

circular motion to the liquid. The liquid exits the

trolling the speed of the motor or by

adjusting the

pump at a higher pressure than the pressure at the

volume of reciprocating pumps. Positive displace-

inlet. Centrifugal pumps are useful for transferring

ment pumps must be placed as close to the feed tank

liquids that are not very viscous. Because of the

as possible, and the diameters of the pipes should be *lower costs (when compared with positive displace-*

large relative to those of centrifugal pumps. If pipe

ment pumps) of these pumps, they are widely used

diameters are too small the pressure drop may be high

in most applications in a dairy factory. These pumps

enough to cause cavitation in the pump.

are not suitable for high-viscosity liquids or those

Positive lobe pumps generally have two rotors and

items requiring care in handling, for example fluids

on each rotor there are three lobes (Fig. 5.2). A vac-

where structures should not be disturbed or ingre-

uum is created when the lobes move causing the pro-

dients whose identity is critical to product appeal.

cess fluid to be inspired into the

cavities of the lobes.

Flow control is achievable by three different means.

The process fluid is then moved along the outer walls

The first is by throttling. This procedure is expensive

of the pump toward the discharge end. The rotors

but offers the greatest flexibility. The second means

are driven independently by a reducing gear motor.

of achieving flow control is by changing the impeller

And the lobes do not touch each other or the walls

diameter. This method is the most economical but

of the pump casing. These pumps are used when

the least flexible. A third means is to install an elec-

the viscosity of the process fluid exceeds 300 cP,

tronic speed controller, which is both *economical and*

as is the choice for transferring cream and cultured

flexible.

products.

***Figure 5.1.** Centrifugal pump: (1) delivery*

line, (2) shaft seal, (3) suction line, (4)

impeller, (5) pump casing, (6) back plate, (7)

motor shaft, (8) motor, (9) stainless steel shroud and sound insulation. Reproduced

with permission from Tetra Pak.

important parameters defining the physical properties

of the fluids. Temperature program is dependent on

the legal requirements and temperature differentials

between the medium being heated and

the heating

medium. Temperature changes (often referred as

t)

depend upon the inlet temperatures of the medium

being heated and the heating medium. Design of the

heat exchanger refers to the flow of the fluid being

heated in relation to the flow of the heating medium.

Such flows can be countercurrent (Fig. 5.3) or con-

current (Fig. 5.4), meaning the fluid being heated

flows against the flow of the heating medium or in

the same direction as the heating medium, respec-

tively. Design also refers to the physical nature of the

heating apparatus and can be done by using plate heat

exchangers or tubular heat exchangers

and in some

Figure 5.2. *Lobe rotor principle. Reproduced with*

cases scraped surface heat exchangers. The ability to

permission from Tetra Pak.

effectively clean and sanitize food contact surfaces

is vital in the food industry and therefore the design

of a heat exchanger has to take this into considera-

tion. The necessary operational time is the length of

Eccentric screw, piston, and diaphragm pumps are

time for which the equipment can be operated with-

also positive displacement pumps used for special-

out cleaning and is dependent on a number of fac-

ized purposes in dairy plants.

tors. The operational time cannot be predicted and *will vary from factory to factory.*

Heat Transfer Operations

Heating and cooling are two common operations in

any dairy plant. Collectively these operations involve

the transfer of heat from one medium to another.

°C ti2

Transfer of heat can be routinely achieved through in-

t

direct contact of a hot medium against a cool medium.

o1

In the case of heating of dairy fluids, the hot medium

to2

is hot water. In the case of cooling, a cold medium re-

moves heat from a dairy fluid. This cool medium

may be incoming cold raw milk (as is the case of re-

ti1

generation section of a pasteurizer) or chilled water.

Boilers produce steam that is directly injected into

Time

the water and the result is hot water. Chilled water

is produced by contacting water with a refrigerant

to1

ti1

(commonly ammonia in the United States). The ap-

paratus in which heating or cooling takes place is

generically called a heat exchanger.

t

t

i2

o2

Calculating the heat transfer area required for a *particular operation is a complex process involving*

product flow rate, physical properties of the fluid be-

***Figure 5.3.** Temperature profile for a product in a*

ing heated and the heating medium, temperature pro-

countercurrent heat exchanger. Red Line/ fill is the

heating medium and Blue line/fill is the product flow. t

gram necessary for the operation,

allowed pressure

i

is inlet temperature and t o is outlet temperature.

drops, design of the heat exchanger, sanitary require-

Subscripts 1 and 2 refer to product and heating

ments, and necessary operational time. The product

medium, respectively. Reproduced with permission *flow rate depends on the operating capacity of the*

from Tetra Pak.

dairy factory. Density, specific heat, and viscosity are

dairy industry, refrigeration is commonly achieved by

°C

chilled water or polyethylene glycol in some cases.

ti2

The water is chilled by contacting it with a refrigerant

such as ammonia or other fluorocarbon gases.

Δ

t

t

o2

m

to1

Mixing Operations

t

In the manufacture of many dairy products, certain

i1

ingredients have to be mixed into milk. For exam-

ple, in the manufacture of flavored milks, sweeten-

Time

ers, stabilizers, and flavorings are added to milk prior

t

t

to processing. To fortify solids in certain types of

i1

o1

yogurts, milk solids are added to milk prior to pas-

teurization. In other instances storage of raw milk

in silos necessitates periodic agitation of the con-

t

t

i2

o2

tents of the silo. In batch pasteurization, the milk is

heated in a tank and the tank has an agitation system

Figure 5.4. *Heat transfer in a concurrent heat*

to insure uniform heat transfer. In all these instances *exchanger. Red line/fill indicates heating medium and*

mixing is required and is achieved by a number of

blue line/fill indicates product. t i is inlet temperature

means.

and t o is outlet temperature. Subscripts 1 and 2

For the incorporation of solid ingredients into

represent product and heating medium, respectively.

milk, batch and continuous processes are available.

Reproduced with permission from Tetra Pak.

The simplest batch blending system is a funnel

or hopper to feed the dry material to a closed-

circuit circulation of the process fluid. A centrifugal

Another aspect of cooling involves refrigeration.

pump is involved in circulation of the *process fluid*

Refrigeration involves the removal of heat from a

(Fig. 5.5).

product and in this process the product cools down

The tank is filled with the process fluid and circula-

and the medium removing the heat warms up. In the

tion is initiated. The centrifugal pump can be placed

SMP

Water

4

6

3

3

5

Powder

8

Reconstitution with Tri-Blender

Electrically

controlled shut-off

valve

Water from

recirculating line

Impeller

Reconstituted mix

Belt drive

Figure 5.5. *Mixing dry ingredients using a triblender.*

Duplex

filter

Recirculation line

Reconstituted

Agitator

milk to the chiller

Water

Powder

Water meter

Screen

Hopper

Reconstitution

Isolating

tank

valve

Powder

Venturi

Tangential

Recirculation

unit

inlet

pump

Water

milk

Reconstituted

Venturi unit (schematic)

Figure 5.6. *Reconstitution in a system with a venturi, with the dry ingredients being added at the discharge side of*

the pump.

at either the suction or the discharge side of the hop-

Separation

per. If the hopper is on the suction side of the pump

rapid dispersal of powders are efficiently achieved as

It is necessary to separate the fat from the milk. Prin-

a result of the mixture of powder and fluid coming *ciples used to separate fat from milk are also applied*

in contact with the impeller of the pump. The disad-

to remove fine extraneous material from milk and to

vantage is that frequent blockages may occur in the

reduce the bacterial content of milk. Separation of

hopper. If the hopper is placed on the discharge end

fat from milk is called cream

separation, the removal

of the pump the problem of blockage is avoided. This

of fine extraneous particles is termed clarification,

configuration requires the presence of a venturi to fa-

and the reduction in microbial numbers is obtained

cilitate the mixing of powder and the process fluid

through bactofugation. All of these processes rely on

(Fig. 5.6).

centrifugal force to achieve their objective. The fac-

Another type of batch mixing occurs in tanks and

tors that affect the efficiencies of these processes are

silos. The tanks are equipped with agitators. The ag-

diameter of the particle (d □m), density of the par-

itator systems can be paddle, propeller, and scraped *ticle (□ p kg/m3), density of the continuous phase*

surface. The agitators can be positioned at the top or

(□l kg/m3), viscosity of the continuous phase

bottom, perpendicular or centrally mounted. Besides

(□kg/ms), and the gravitational force (g = 9 . 81 ms2).

these factors, the speed of agitation, tank geometry,

For example a 3-□m diameter fat

globule will rise

vortex creation, air incorporation, and shearing ef-

at a velocity of 0.6 mm/h. To speed up this process

fects impact on the mixing efficiency.

centrifugal force is applied and the sedimentation ve-

In continuous mixing systems, also called in-

locity is increased 6,500-fold. In order to achieve this *line mixers, many types of devices are available. In*

separation under a centrifugal force field, a specially

blenders such as Tri-Blender and Breddo Likwifier,

designed equipment called a cream separator is used.

a high-speed blender, the powder and process liquid

Another centrifugal operation in the dairy industry

are contacted and sheared in the mixer.

Another in-

is a variant of cream separation and is used to remove

line mixer is Silverson. This mixer operates at high

solid impurities from milk. This piece of equipment

speeds and its action is somewhat similar to homog-

is called a clarifier. The principal difference between

enization.

clarification and separation is in the design of the

disc stack in the centrifuge bowl and the number of

can alter the viscosity of the milk. Some lactic acid

outlets. In a clarifier the disc stack has no distribution

bacteria metabolize citric acid to produce aroma *holes and has only one outlet. In a separator the disc*

volatiles such as diacetyl.

stack has distribution holes and there are two outlets,

Fermentation of milk is necessary for the manu-

one each for cream and skim milk.

facture of yogurt, buttermilk, kefir, and cheese, while

A third application of centrifugal force in dairy *the fermentation of cream is essential for the manu-*

processing is bactofugation. This is a process in

facture of sour cream, cream cheese and other types

which centrifugal force is used to reduce the bac-

of cheese, and for the manufacture of cultured cream

terial content of milk. Spore formers are effectively

butter. Some of these aspects are

discussed in greater

reduced by this process. It is more commonly used

detail in other chapters (Chapters 11, 12, 16, 17, and

in treating milk for milk powder and cheese manu-

18). With these basic operations understood, the next

facture.

sections will describe the milk processing steps com-

monly employed.

Microbial Transformation

Among the methods of preserving milk are drying,

FROM FARM TO FACTORY

condensing, and fermentation. Fermentation is the

controlled acidification of milk and cream. By con-

Milk production on the farm is done under strict

trolled acidification, it is meant that *the type of mi-*

guidelines that determine its grade (see Chapter 3).

croorganisms growing and the conditions for their

In 2002 the total milk production in the United States

growth are carefully monitored and stopped. The

was 75.47 billion kilograms (170 billion pounds).

characteristics of the microorganisms used in fer-

Farms with 200–500 milch animals accounted for ap-

menting milk and cream are discussed in greater de-

proximately 17.5% of the total milk produced. Farms

tail in Chapter 6. Here the main concepts of this trans-

with 50–100 cows and > 2000 cows accounted for

formation are outlined. Lactic acid bacteria are the

17.4% and 15% of the total milk

production, respec-

prime agents of fermentation. Morphologically these

tively. Also in 2002, 9.14 million cows were tended

are rods and cocci. They stain Gram positive. The op-

by 91,900 production units, which means an average

timal temperatures for their growths are either in the

of 99 cows per farm. The general trend in this area is *mesophilic range (20–30◦C) or thermophilic range*

toward less number of farms with larger herd sizes.

(35–45◦C). Lactic acid bacteria utilize lactose to pro-

Farms use milking parlors of various designs and

duce lactic acid. The transport of lactose into the cells

the milking interval is unequal. Cows are milked

is facilitated by two enzyme systems;

first the phos-

twice a day, with a small minority milking three

phoenol pyruvate dependent phosphotransferase sys-

times a day. The milk from each animal is weighed

tem while the second mode of lactose transport into

and then mixed with milk from other animals in the

the cell is via an ATPase-dependent system. Lactic *batch of cows being milked. Milk temperature im-*

acid bacteria are also classified as homofermentative

mediately after milking is approximately at the body

or heterofermentative. Production of lactic acid only

temperature of the cow (38◦C/101◦F). At this tem-

from lactose, as is the case with most mesophilic lac-

perature many mesophilic

microorganisms can grow

tic acid bacteria, leads to such bacteria being labeled

and therefore to minimize microbial growth the warm

homofermentative. One molecule of lactose results

milk is cooled rapidly. Cooling is commonly achieved

in four molecules of lactic acid. Heterofermentative

by plate heat exchangers. Milk is thus collected in *lactic acid bacteria including Leuconostocs lack the*

insulated tanks called farm bulk milk tanks. Milk

enzymes called aldolases and cannot ferment lac-

from several days of milking is collected in this tank

tose via the glycolytic pathway. This class of bacteria

(Fig. 5.7).

ferments one molecule of lactose to two molecules

As the number of cows in the herd grows and the

each of lactic acid, ethanol and carbon dioxide. Ho-

number of dairy farms shrinks, milk collection oc-

mofermentative lactic acid bacteria do not produce

curs more frequently on the farm. For example, in

ethanol or carbon dioxide. Heterofermentative lac-

an Arizona dairy farm milking 7,000

cows two times

tic acid bacteria do. Lactic acid production is not the

a day dispatches a tanker every 45 minutes to their

only change taking place in milk during fermentation.

dairy. Smaller farms may use ice bank building tanks.

Caseins are also being modified by proteolytic en-

For achieving the best grade of milk (Grade A), milk *zymes; others may produce polysaccharides, which*

has to be cooled to below 4◦C (40◦F) within time

5 Basic Dairy Processing Principles

Figure 5.7. *Milk from the cow is measured*

in-line and then sent to a bulk cooling tank.

Reproduced with permission from Tetra Pak.

limits, e.g., 2 hours post-milking. For further details

the tanker. Presence of air can cause foaming and

refer to Chapter 3.

churning of milk. When the tanker has collected milk

At the time of collecting the milk, the tanker driver

from several farms and is full it arrives at the dairy

obtains a sample for milk from each farm. This sam-

factory.

ple is the basis for quality determination and for pay-

ment based on milk composition.

STORAGE OF RAW MILK

The tanker itself is made of sanitary

stainless steel

and is fitted with baffles to prevent milk from be-

Upon arrival of the milk tanker at the dairy, it enters a

ing vigorously shaken during transportation. Thus,

covered special reception area. A technician from the

churning of milk and the possibility of churning the

quality assurance department checks the temperature *cream into butter are avoided. At the back end of the*

of the milk and draws a representative sample. During

tanker is a pump with a volumetric meter and an air-

this procedure, the technician also checks the odor of

eliminating device. The tanker pulls up to the milk

the milk and records if any off-odors are detected. The

shed and the driver attaches a sanitary *hose to the*

representative sample collected from each tanker is

farm milk storage tank and pumps the milk from the

analyzed for sediments, antibiotic residues, somatic

storage tank to the milk transport tanker (Fig. 5.8).

cell count, bacteria count, protein and fat content,

When the farm bulk tank is empty the pump is *and freezing point. Some dairies may also conduct*

turned off to prevent air from mixing with milk in

a direct microscopic count of the bacteria present in

***Figure 5.8.** Collection of milk on the farm. The tanker is pumping milk from the farm bulk milk tank for transport to the dairy factory. Reproduced with permission from Tetra Pak.*

milk. The normal bacteria count and Coliform count

take 24–48 hours. The results of the

remaining tests

are available within 15–20 minutes. If all tests meet

standards set by the dairy, the milk is then unloaded

from the tanker.

The significance of the reception dock tests is

as follows. Sediment tests point to the quality of

milk production at the farm. Antibiotic tests indi-

cate if milk from sick animals were commingled with

milk from healthy cows. If such commingling occurs

the entire tanker load of milk is rejected. Presence

of antibiotics in milk poses a 2-fold danger. First,

antibiotic-sensitive individuals can suffer from con-

suming tainted milk. Second, in the manufacture of

cultured milk products, the presence of *antibiotics*

may pose a barrier for acidity development by inhibit-

ing the starter culture growth. Somatic cell counts

are indicative of general animal health. If they are

< 500,000 per milliliter of milk the animal herd health

is considered good. If however, the count exceeds

1,000,000 per milliliter it suggests the presence of *mastitis in one or more animals in the herd. Mastitic*

cows are often treated with antibiotics and while re-

ceiving the treatment and for a period after the treat-

ment the milk from such animals is generally dis-

carded on the farm. Protein and fat contents are used

to determine payments and to gain full accounting of

***Figure 5.9.** Schematic of a milk silo*

with a propeller

raw materials received. This is important for material

agitator. Reproduced with permission from Tetra Pak.

balance calculations and for determination of losses

occurring during processing and packaging. Freezing

point of milk is another important test to determine

adulteration with water, whether accidental or inten-

The raw milk is stored in large vertical tanks known

tional. Adulteration of milk is a prosecutable offence.

as silos (Fig. 5.9). These silos can have capacities of

The most common procedure is to record the vol-

25,000–150,000 liters (6,000–37,000 U.S. gallons).

ume of milk delivered by a tanker. However, in some

The silos are placed outside the dairy *with an inside*

dairies the tanker may be weighed prior to emptying

outlet bay. The silos have a double-wall construction

and after discharging its load. Volumetric measure-

with an outside welded sheet metal within which a

ments involve a volumetric flow meter fitted with an

stainless steel tank is contained. The silos have meth-

air eliminator. Presence of air can distort readings of

ods of agitating milk so as to prevent gravitational fat

the volume of milk. The milk passes through the air

separation.

eliminator and a filter into the metering device prior

The agitation must be very smooth to avoid rup-

to going to storage silos.

ture of the milk fat globule membranes, which can

The tanker after discharging its load of milk is

cause lipolysis of milk fat. Lipolysis generates off-

cleaned in the reception bay or in a special cleaning

flavors and odors. The most common agitation sys-

bay. The inside of the tanker is washed by a cleaning-

tem is to use a propeller agitator. In *the tanks there are*

in-place system, which rinses the tanker, cleans it

instruments that include a thermometer, level indica-

with detergents, and rinses the detergent followed by

tor, low level protector, overflow protector, and an

sanitizing the tanker. While the inside of the tanker

empty tank indicator. Modern dairies have electroni-

is being cleaned, the exterior is also often washed so

cally transmitted data on temperature, levels of milk

that the tankers always look clean on the road. After

in the silos, and the protection devices. Redundant vi-

cleaning and sanitizing, the tanker goes to its next

sual (nonelectronic) systems may also be employed

round for milk collection.

in some dairies.

Milk storage silos are cleaned in place and visual *inspections of the interior surfaces for any problems*

are also conducted periodically. Since silos are con-

3

sidered to be confined spaces, entry into a silo has to

be strictly according to the standards recommended

by the Occupational Safety and Health Administra-

tion of the U.S. Government.

The temperature of the milk in the silo has to be

2

maintained at $4^{\circ}C$ *or below* $(< 40^{\circ}F)$. *Even at these*

temperatures psychrotrophes can cause proteolysis

1

and lipolysis if milk is stored for long periods of time.

Therefore, it is recommended that the silos be emp-

tied and cleaned and sanitized at regular intervals.

The raw milk in the silo is further processed and the

main elements in the processing are centrifugal oper-

ations, thermal treatment, homogenization, cooling,

and packaging.

CENTRIFUGAL OPERATIONS

Centrifugal operations deal with removing some or *most of the fat, a step called standardization. One*

method of standardization is to completely remove

all the fat as cream leaving skim milk, then the cream

***Figure 5.10.** Paring disc separator with manual*

and skim milk can be recombined in desired ratios to

controls. (1) Skim milk outlet with regulator, (2) cream

obtain low, light, and whole milk with

1%, 2%, and

throttling valve, (3) cream flow meter. Reproduced with

3.25% fat, respectively. More often this standardiza-

permission from Tetra Pak.

tion is performed in a continuous manner.

The separation of cream from milk is achieved in

a cream separator. Often the separator has the abil-

ity to remove sediments from milk as well as sep-

device. The art of balancing the cream flow and the

arate the cream from milk. Depending on the de-

skim milk pressure leads to obtaining the desired fat

sign of the separator/clarifier, the sediment collected

content in the cream.

can be manually or automatically removed. Typi-

In the more common hermetically sealed separa-

cally milk can have 1 kg of sediment per 10,000

tors, milk is supplied to the bowl through the bowl

liters (1 lb/1,100 U.S. gallons). Automatic discharg-

spindle. It is accelerated to the same speed as the

ing separators/clarifiers are hermetically sealed and

rotation of the bowl and continues

through the dis-

are cleanable in place. This is less cumbersome than

tribution holes in the disc stack. The bowl of a her-

opening up the bowl assembly and cleaning manually

metic separator is completely filled with milk during

both the sediment and the disc stacks of a separator.

operation. There is no air in the center, hence the

Control of fat content in the cream is possible by a

name hermetic separator. It is a part of the closed

paring disc in conjunction with a cream flow meter.

piping system of the dairy. The pressure generated

A throttle valve at the cream discharge side controls

by the external product pump is sufficient to over-

the volume of cream leaving the

separator. This is

come the resistance to flow through the separator

counterbalanced by controlling the pressure of the

to the discharge pump at the cream and skim milk

skim milk outlet and is dependent on the make of the

outlets.

separator and the throughput of the separator.

An automatic constant pressure unit in a hermetic

In paring disc separators the volume of cream dis-

separator is controlled by a diaphragm valve. The

charged is controlled by a cream valve with a built-in

pressure on the valve is controlled by compressed air

flow meter (Fig. 5.10). The size of the valve aperture

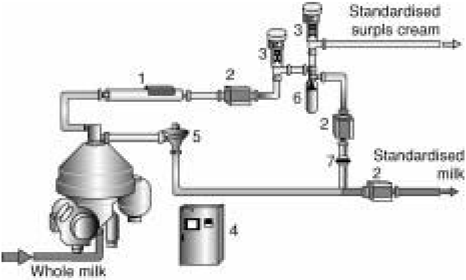
above the diaphragm (Fig. 5.11).

is controlled by a screw and the throttled flow passes

Direct in-line standardization of the fat content of

through a graduated glass tube with an indicating

milk is based on the principle of keeping the pressure



on-line. A schematic of an in-line standardization unit

is shown in Figure 5.12.

Separation temperature is also an important vari-

able. Cold separation of milk ($< 4^\circ$C or 40°F) de-

creases the efficiency of fat recovery. Therefore, com-

monly, warm separation is used where

the efficiency

of fat removal is greater because the fat is in a fluid

state at temperatures of around 50◦C (122◦F). Warm-

ing of the milk can take place during the regeneration

phase of heat transfer (see below).

THERMAL PROCESSING

SYSTEMS

Figure 5.11. *Hermetic separator bowl with an*

The standardized milk is thermally processed as re-

automatic pressure unit on the skim milk outlet.

quired by law. This treatment renders the milk free

Reproduced with permission from Tetra Pak.

from pathogens. The term pasteurization describes

this process. Pasteurization can be a batch process

or a continuous process. Batch

processes are used

of the skim milk constant. This pressure has to be

by small processors and is not common in modern

maintained regardless of flow fluctuations or pres-

dairies. The batch process is called Long Time Low

sure drop caused by the equipment after separation.

Temperature (LTLT) pasteurization. In this process, *This is done by a constant pressure valve at the skim*

standardized milk is heated to 62.5∘C (145∘F) and

milk discharge side of the separator. Precision stan-

held at that temperature for 30 minutes. The process-

dardization is also dependent upon fluctuations in fat

ing tanks used for such purposes should have certain

content of the incoming milk, in

throughput, and in

characteristics defined in the Pasteurized Milk Or-

preheating temperatures. Centrifugal operations may

dinance (PMO). Homogenization takes place post-

also be used in some countries for the manufacture

pasteurization, followed by cooling. Homogeniza-

of cultured dairy products. In yogurt manufacture, *tion may also take place after the regeneration section*

skim milk (with 0.05–0.1% fat content) or milk hav-

and prior to entering the heating section. If the tem-

ing different fat contents (1%, 3.25%, etc.) is often

perature of the milk is around 40◦C (104◦F), lipoly-

used and in the more indulgent types of yogurt, milk

sis can be enhanced by

homogenization. Therefore,

having higher fat contents up to 8% may be used.

homogenization temperature has to be above 45∘C

All these different fat contents are arrived through

(113∘F). At this temperature milk lipase and many

centrifugal operations involving standardization

microbial lipases are rendered ineffective.

Figure 5.12. *The complete process for*

in-line standardization of milk and cream.

(1) Density transmitter, (2) flow transmitter,

(3) control valve, (4) control panel, (5)

constant pressure valve, (6) shut-off valve,

and (7) check valve. Reproduced with

permission from Tetra Pak.

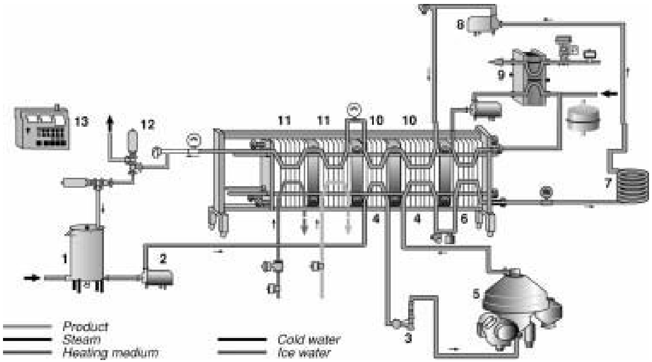


Figure 5.13. *A complete pasteurizer plant. (1) Balance tank, (2) feed pump, (3) flow controller, (4) regenerative preheating sections, (5) centrifugal clarifier, (6) heating section, (7) booster pump, (8) holding tube, (9) hot*

water heating, (10) regenerative cooling sections, (11) cooling sections, (12) flow diversion valve, (13) control panel, A.

temperature transmitter, B. pressure gauge. Reproduced with permission from Tetra Pak.

The continuous pasteurization process is termed

stored pasteurized milk, further tests are often con-

High Temperature Short Time Pasteurization (HTST)

ducted to determine the cause of this

positive test.

and entails heating milk to 71.5◦C (161◦F) and hold-

In the HTST pasteurization process (Fig. 5.13),

ing the milk for a minimum time of 15 seconds prior

cold milk enters a balance tank with a float valve.

to cooling and storage. Yogurt manufacture necessi-

The purpose of the balance tank (also known as a *tates the holding of milk for longer periods of time in*

constant level tank) is to maintain a constant level of

order to denature the whey proteins and thus improve

milk in the plate heat exchanger as the pasteurizer

the gel strength of yogurt. Therefore, in yogurt man-

should be filled at all times during operation to pre-

ufacture milk may be held at 71◦C for

30 minutes

vent the product from burning onto the plates. The

or it may be heated to 90◦C (194◦F) and held for

balance tank may be fitted with an electronic sensor

10 minutes (see Chapters 11 and 12 for further

that transmits a signal to the flow diversion valve.

details). The HTST process involves plate heat

If the level in the balance tank goes below a certain

exchangers and the PMO has prescribed various

level and fresh milk is not coming in to raise the level,

controls and requirements for the equipment.

this electrode transmits a signal for the flow diversion

The effect of heat treatment on milk is to reduce

valve to open and to return the milk in *the system to*

the rate of deterioration due to microbial and enzy-

the balance tank. The milk is replaced by water if

matic action. In addition, the milk may look whiter

circulation has continued for a certain predetermined

and appear more viscous, with appreciable flavor

time.

changes and a decrease in nutritive value. The effec-

Milk is pumped from the balance tank to the plate

tiveness of pasteurization is estimated by assaying

heat exchanger. The pump is fitted with a flow con-

for an enzyme called phosphatase. In fresh properly

troller to ensure that a constant flow is maintained at a

pasteurized milk, no phosphatase

activity is detected.

predetermined value. This value is dependent on the

Upon storage sometimes microbial phosphatases or

characteristics of the pump and the heat exchanger

the milk phosphatase itself can regain some of its ac-

capacity. The flow control device also guarantees a

tivity. If the presence of phosphatase is detected in *stable temperature and constant length of holding.*

The flow control device may also be located after the

to the flow diversion valve to open. Therefore, two

first regeneration section.

different causes for flow diversion are temperature

Regenerative preheating is an energy-

saving step

falling below preset values and the pressure differen-

in pasteurization. Cold untreated milk is heated by

tial between raw and cold milk falling below a certain

the outgoing pasteurized milk. Thus, cold milk is

preset limit. The milk is not considered pasteurized

preheated and the hot milk is cooled simultaneously.

if either of these events occurs. For milk to be des-

The regeneration section is divided into two sections.

ignated as pasteurized, every drop of milk has to be

After the cold milk is preheated in the first regener-

heated to and held at the specified minimum temper-

ation section, it is separated and homogenized and

ature for a specified amount of time.

then the standardized, homogenized milk enters the

Pasteurized milk in the regeneration section is

second regeneration section where it is further heated

cooled giving off its heat to the cold incoming raw

by the hot pasteurized milk. Heating is accomplished

milk. This cools down the milk but not to the desired

by using hot water as the medium. The

hot water, in

4◦C (40◦F) or below. The final step in pasteurization

turn, is produced by injecting culinary steam into the

is to cool the milk to below 4◦C in the cooling section.

water. The steam is generated in boilers of the dairy

Cooling is achieved by chilled water or cold glycol

factory.

as the refrigerant. The water is chilled by a refrig-

After this regeneration section the milk enters the

eration system that commonly uses ammonia as the

pasteurization section where it is heated to the re-

refrigerant. Other hydrocarbons may also act as re-

quired temperature. The heated milk exits the heat-

frigerants. Since the pasteurized milk *transmits con-*

ing section and enters an external holding tube. The

siderable heat to the cold raw milk, less refrigeration

flow rate of hot milk determines the residence time in

capacity is required to cool the milk to below 4◦C.

this holding tube. The flow rate in turn is controlled

In yogurt manufacture the cooling system may not *by the flow controller referred to earlier. After the*

be used. Once the pasteurized milk has been cooled

transit through the holding tube the exiting milk tem-

to around 43–45◦C it may be pumped to the fer-

perature is measured and transmitted to a temperature

mentation tanks for further processing. It is obvious

controller and a recording chart.

that reheating cold pasteurized milk to the incubat-

A sensor at the exit of the holding tube transmits

ing temperatures of 43–45◦C will require a greater

a signal to the temperature monitor. As soon as the

consumption of energy than avoiding this step in the

temperature falls below a preset minimum value the

first place.

monitor switches the flow diversion valve to "diverted

flow." In diverted flow, the hot milk returns to the

HOMOGENIZATION

balance tank as it is not considered pasteurized. The

reason for the fluctuation is determined and corrected

Homogenization is a process of reducing the size

and if the correct temperature is maintained at the *of fat globules. Homogenization prevents creaming*

exit point of milk from the holding tube, further flow

(separation of a fat enriched layer from the aque-

is continued past the flow diversion valve. Often a

ous phase). Reduction in the globule size is achieved

booster pump may be added after the milk exits the

through a combination of turbulence

and cavitation.

holding tube. The hot pasteurized milk enters the re-

The apparatus in which such particle size reduction

generation section of the pasteurizer to heat the in-

occurs is called a homogenizer.

coming raw milk.

Cold milk cannot be homogenized efficiently be-

In the regeneration section

unpasteurized milk

cause the milk fat still is solid. Therefore, homog-

flows on one side of the plate and hot pasteurized

enization occurs best at temperatures greater than

milk flows on the other; if there are pinholes in the

37◦C (99◦F). Another necessity for efficient homoge-

plates of the heat exchanger, unpasteurized milk can *nization is the presence of protein. A suggested min-*

commingle with pasteurized milk. This violates the

imum value of 0.2 g of casein per gram of fat is

integrity of the pasteurized milk and the fluid is not

recommended.

considered pasteurized. To avoid such a problem, the

Homogenizers are manufactured as single-stage *pasteurized milk is always at a higher pressure than*

and dual-stage machines. In single-stage homoge-

the raw milk. To measure the pressures a pressure dif-

nization the whole pressure drop is used over one

ferential meter is often installed on the control panel.

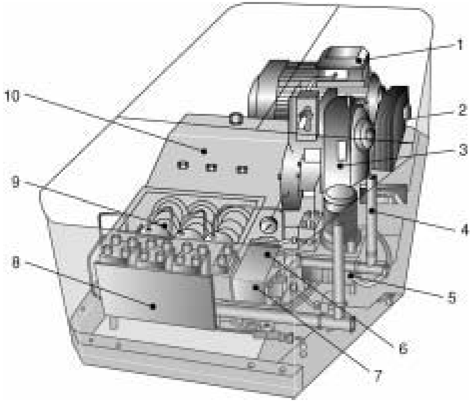
device. It is used for products with low fat content

If the pressure differential between raw *and pasteur-*

and in products requiring a high viscosity (e.g., sour

ized milk drops below a preset value, a signal is sent

cream, coffee cream, whipping cream). Dual-stage


1
2
3
4
5
6
7
8
9
10

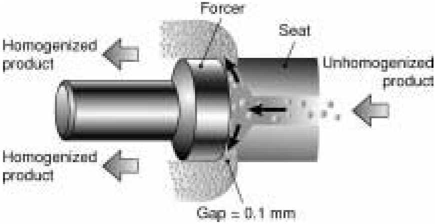

Forcer
Seat
Homogenized product
Unhomogenized product
Homogenized product
Gap = 0.1 mm

Figure 5.14. *The homogenizer is a large*

high-pressure pump with a homogenizing

device. (1) Main drive motor, (2) V-belt

transmission, (3) gear box, (4) damper,

(5) hydraulic pressure setting system,

(6) homogenizing device, second stage,

(7) homogenizing device, first stage, (8) solid

stainless steel pump block, (9) pistons, *(10) crank case. Reproduced with*

permission from Tetra Pak.

homogenizers are used in breaking down the fat glob-

is called the homogenizer valve. There are many

ule in two stages. This is effective for products with

designs for the homogenizer valve all of which have

high fat content, high solids content, or for products *a similar effect on the fat globule (Fig. 5.15).*

where low viscosity is desired (Fig. 5.14).

When a large fat globule is disintegrated to a num-

The effects of homogenization are smaller fat glob-

ber of small droplets, a tremendous increase in sur-

ule size (prevention of creaming), whiter and more

face area of the fat occurs. Onto the

surfaces of these

appetizing color, reduced sensitivity to fat oxidation,

newly created droplets casein adsorbs and stabilizes

and a fuller bodied flavor and mouthfeel. In cultured

the droplet. If this step does not occur, the fat droplets

milk products a better stability is also achieved. Ho-

could recombine to form a larger globule. The adsorp-

mogenizers are high-pressure machines in which re-

tion time has been estimated to be around 0.25 □s,

ciprocating pistons create the pressure. Pressurized

the encounter time between the protein and fat is es-

milk is passed through a narrow aperture. When the

timated to be 015 □s, and the deformation time is

pressurized milk exits into atmospheric *pressure cav-*

around 0.3 □s for 4% fat milk being homogenized

itation is created, which results in large fat globules

at 20 MPa. In this process, the average fat glob-

being reduced to smaller ones. The narrow aperture

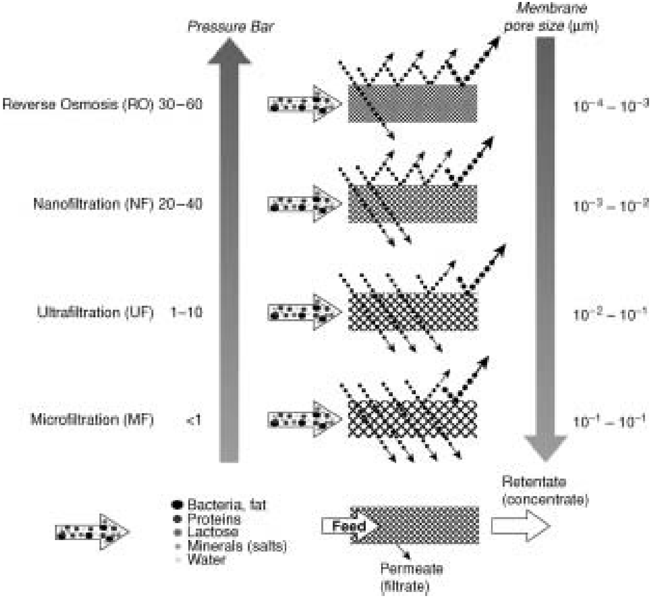
ule diameter of 9 □m for 4% fat milk is reduced to

Figure 5.15. *The milk is forced through a narrow*

gap, which results in the fat globules splitting into

smaller sized droplets. Reproduced with

permission from Tetra Pak.



1.6 □m. The protein that is adsorbed

onto the newly

consists of four distinct processes. Reverse osmosis

formed surfaces is casein. Approximately 75% of the

(RO) is useful in concentrating solids by removal of

surface area is covered with casein. Larger micelles

water. Nanofiltration (NF) can concentrate organic

are preferentially adsorbed over smaller ones. Pro-

components by removal of monovalent ions like

tein adsorption is greatest on smaller globules. The

sodium and chloride thereby resulting in deminer-

surface concentration of protein has been measured

alization. Ultrafiltration (UF) is the process in which

at 10 mg/m2.

macromolecules are concentrated. The major macro-

Single-stage homogenization uses only one stage

molecules in milk are fat and proteins. The fourth

to reduce the fat globule size. In dual-stage homog-

membrane process is microfiltration (MF). This pro-

enization two stages for pressure reduction are used.

cess removes bacteria and it can also separate macro-

First a low-pressure treatment is

followed by a second

molecules.

higher pressure treatment. A two-stage homogenizer

These techniques utilize cross flow membrane in

is useful with low-viscosity fluids.

which the feed solution is forced through the mem-

brane under pressure (Fig. 5.16). The solution flows

MEMBRANE TECHNOLOGY

over the membrane and solids are retained (retentate)

while the removed materials are present in the perme-

Membrane technology is useful in selectively en-

ate. The membranes are classified according to their

riching certain components. Membrane technology

molecular weight cutoff, supposedly the molecular

***Figure 5.16.** Different membrane*

processes and their characteristics. Reproduced with permission from Tetra Pak.

weight of the smallest molecule that cannot pass

membrane reducing capacity and making cleaning

through the pores of the membranes.

necessary.

The filter modules themselves are

available in var-

Membrane operations can be batch or continuous.

ious geometries. Spiral wound is the most common

In dairy plants continuous processes are more desir-

but others available are plate and frame, tubular, and

able. Process temperatures are maintained at around

hollow fiber. Tubular filters can be made out of ce-

50◦C to minimize microbial growth and to improve

ramics or polymers.

membrane flux.

Membrane separation capacity depends on a num-

The use of membrane processing in the cultured

ber of factors. Foremost among them is membrane

dairy products area is restricted to concentration of *resistance, which is determined by membrane thick-*

skim milk for fat-free yogurt manufacture. Some of

ness, surface area, and the pore diameter. Next is

the lactose and minerals are removed from skim milk

transport resistance (also known as fouling effect).

thereby increasing the protein content. This process

This effect occurs on the membrane

surface as filtra-

can concentrate skim milk with 9% solids to 12%

tion proceeds. The formation of a layer of deposit

solids. There is still enough lactose in the retentate

leading eventually to membrane fouling is due to

to facilitate fermentation. A higher protein content in

the flow of macromolecules at right angles to the

the concentrated milk results in a firmer acid gel in

direction of flow. A concentration gradient leads to

yogurt.

diffusion in the opposite direction. Parallel to the

membrane the macromolecules present in the layer

close to the membrane move at varying velocities

BIBLIOGRAPHY

dependent on the axial flow rate. The concentra-

Tetra Pak. 1995. Dairy Processing Handbook. Tetra

tion polarization is not uniformly distributed, espe-

Pak Processing Systems, Lund, Sweden.

cially when the pressure drop gives different trans-

Walstra P, Geurts TJ, Noomen A, Jellema A, van

membrane pressures along the membrane surface.

Boekel MAJS. 1999. Dairy Technology—Principles

The upstream end of the membrane clogs first and

of Milk, Properties and Processes. Marcel Dekker,

gradually spreads across the whole surface of the

New York.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

6

Starter Cultures for Yogurt

and Fermented Milks

Ebenezer R. Vedamuthu

Introduction

peroxide, a powerful oxidizing agent unless detoxi-

Starter Functions

fied, would be detrimental to cell

viability. In aerobic

Factors Affecting Starter Performance

microorganisms, hydrogen peroxide is transformed

Intrinsic Factors

into nontoxic components, water, and oxygen by the

Extrinsic Factors

enzyme catalase. In fermentation, the final hydrogen

Miscellaneous Factors

acceptor is a truncated molecule of the substrate. To

Microorganisms Used in Starters for Cultured Dairy Products

a large measure respiration involves the oxidation of

Genus Lactococcus

carbohydrates, which yields energy in the form of

Genus Leuconostoc

Genus Streptococcus

high-energy chemical bonds, as well as *short-chain*

Genus Lactobacillus

carbon compounds needed for cellular synthesis. In

Genus Bifidobacterium

the fermentation of sugars, the truncated intermedi-

Starter Culture Production

ate, pyruvate, is the final hydrogen acceptor resulting

Bulk Starter Production

in the formation of lactic acid. In certain other fer-

Commercial Starter Culture Production

mentations, acetaldehyde derived from pyruvate is

Bibliography

the final hydrogen acceptor yielding ethyl alcohol as

Books

the final product. In mixed fermentations, both lactic

Chapters in Books

acid and ethyl alcohol are formed. In terms of energy

Review Articles and Research Papers

yield, fermentation yields only substrate-level phos-

phorylation, which is much less than complete aero-

INTRODUCTION

bic respiration. Fermentative microorganisms gener-

ally do not possess catalase, and hence *cannot tolerate*

Starter culture is at the heart of cultured dairy product

aerobic conditions.

manufacture. With the exception of certain probiotic

Cultured dairy product manufacture largely in-

milks, the centerpiece of cultured dairy product man-

volves lactic acid fermentation. And, the microor-

ufacture is fermentation. Fermentation is a biological

ganisms fomenting the change are lactic acid bacteria

process. In the context of cultured dairy products, the

(LAB). In mixed lactic acid – alcohol fermentations,

agents of fermentation are microorganisms. Fermen-

as in Kefir and Koumiss, in addition to LAB, yeasts

tation in the physiological sense is

anaerobic respira-

are also associated. Yeasts are the agents of alcohol

tion. In microbial metabolism, the oxidation of sub-

formation in these products. Certain LAB in cultured

strates involves a series of transfers of hydrogen via

dairy products impart flavor attributes through the

carriers (coenzymes) to a final acceptor. In aerobic *fermentation of citric acid or citrates.*

respiration the final hydrogen acceptor is molecu-

Starter culture, or starter for short, consists of se-

lar oxygen. Depending on the electron (hydrogen)

lected microorganism(s) deliberately added to milk

transfer system, the final transfer of the hydrogen to

or a dairy mix to bring about desired changes that *oxygen would result in the formation of water and*

result in the production of a specific cultured dairy

molecular oxygen or hydrogen peroxide. Hydrogen

product with the desired attributes. The term "starter"

89

90

in this context is entirely appropriate, *because the*

composed of different microorganisms with different

starter initiates and carries through the necessary

growth requirements. In such operations, associative

changes in the starting material to yield the cultured

action by components in the starter mixtures may be

dairy product. The entire cultured dairy product man-

desired, and in other cases, the conditions need to

ufacture is dependent upon the activity of the starter.

be manipulated to curtail the growth and activity of

It is very similar to the ignition switch (which acti-

one component, but favor the other or promote a bal-

vates the starter) in an automobile. Unless the starter

anced growth and activity of both

components. All

is activated or operating in an automobile, the car

those events have to be carefully controlled to obtain

will have no mobility and will be useless in getting

consistently superior end products. Yogurt manufac-

one from point A to point B. That somewhat portrays

ture exemplifies a process where synergism between *the role of the starter culture in cultured dairy prod-*

two different starter components is desired. In cul-

uct manufacture. The parallel between the function

tured buttermilk, conditions are manipulated to pre-

of the starter in a car and that in the production of

vent dominance by acid-producing bacteria, so that

cultured dairy products relates only to *the initiation*

the flavor-producing component(s) in the starter mix-

of the process and does not adequately represent the

ture can function, assuring a balanced growth and

full gamut of the roles the starter culture plays in cul-

activity of both components.

tured dairy product manufacture and quality. Starter

Because of the complex interactions between mi-

cultures not only initiate, but also carry through every

croorganisms, and complex substrates in which the

change to attain the desired body, texture, and flavor

starter flora have to function, even a slight devia-

in the cultured dairy product. Furthermore, starters

tion from standard operating

procedures could cause

play a preservative function in suppressing spoilage

problems in the fermentation industry. The quality

flora, thus increasing shelf life. Another vital function

of materials being transformed through fermenta-

relates to their protective role in retarding or inhibit-

tion in some cases could be detrimental to starter *ing pathogenic flora, and the formation of entero-*

functions. The physical and chemical properties (for

toxins in the finished culture dairy product. In short,

example, the concentration of solids contributing to

starter culture determines the shelf life and the safety

osmolarity, presence of toxic substances like antibi-

of cultured dairy products. In probiotic *products, the*

otics, residual sanitizers, or mastitic milk, etc.) or

added cultures impart health-promoting properties to

variability in the quality of the milk or dairy mix

the consumer.

would result in malfunction of starter flora and poorer

Because of the aforementioned vital functions of *quality end products. Another complicating factor*

starter cultures in fermented and nonfermented dairy

in cultured dairy product manufacture is the infec-

products, the selection, propagation, and handling

tion of starter bacteria by bacterial viruses or bac-

of starter cultures are of paramount importance in

teriophages, or phages for short. Starters infected

successful cultured dairy product manufacture and

with phages are either killed or functionally crip-

merchandizing. That holds true in the industrial pro-

pled. Economic consequences of phage-related fail-

duction of starter cultures, which

would entail an

ures of dairy fermentations are manyfold. Firstly,

additional burden in using the most optimum har-

there could be complete failure of the desired fermen-

vesting and preservative techniques that would en-

tation(s). Secondly, slowing down of the process may

sure optimum functionality of the starter during *disrupt daily schedules and result in erratic turnover*

application.

of equipment, overtime wages, overall loss in the fi-

As mentioned earlier, starter cultures are com-

nal quality of the products, undergrade products, and

posed of living entities. Living organisms require

loss in value. Most importantly, there is likelihood *proper environmental conditions to thrive and per-*

of unchecked development of chance contaminants

form their functions. Environmental conditions com-

such as spoilage flora and pathogenic or toxigenic

prise optimum temperature ranges, proper nutrition,

flora in the product.

and optimum pH range, absence of toxic substances

Fermentation failures may be caused either by

or by-products, and careful handling procedures.

technological or microbiological factors or by a com-

Some of the manufacturing processes for cultured

bination of the two. Troubleshooting in the fermen-

dairy products require sequential operations, which

tation industry thus requires good

knowledge of both

would involve manipulations that favor or retard

technological and microbiological facets involved in

the growth and biochemical activities of starter cul-

any specific fermentation. Using yogurt as an exam-

tures. Some fermentations require the use of starters

ple, some of these aspects can be illustrated. Yogurt *today is a multifaceted product. In the United States*

In terms of flavor, "mildness" both in terms of acid-

yogurt is available as "plain yogurt," which is the

ity and "greenness or acetaldehyde flavor" is highly

product obtained after fermentation without any ad-

desired by manufacturers. Mildness allows the manu-

ditions. Within the "plain yogurt" category, in addi-

facturers to use a wide assortment of single and com-

tion to the solid product, there is also liquid, drinkable

plex flavors, for example, chocolate and coffee fla-

plain yogurt. Another variation within this group is

vors. The selection of starter strains *becomes critical*

the solid or drinkable yogurt with probiotic cultures

in obtaining mildness. To obtain a smooth texture

comprising one or more species or different strains of

without whey separation, starters containing strains

the same species. Subgroups in the plain yogurt vari-

that produce exopolysaccharides (EPS) are neces-

ety are made up of products with different fat contents

sary, but there is a fine line between the smoothness

(fat-free, low fat, and full fat). Plain yogurt is, how-

desired and the stringiness or "ropiness." Here, too,

ever, not very popular because of its acid taste, and

starter selection and cultural conditions are critical.

shunned by most consumers. Most

customers pre-

Use of EPS-producing strains also helps to give yo-

fer the flavored and sweetened products. Within the

gurt a heavy body that would hold in suspension fruit

flavored category, there are varieties with added fla-

pieces within the yogurt matrix. Bleaching or fading

vor essences only, such as vanilla, chocolate, coffee, *of the natural hues of fruits and fruit juices is often en-*

lemon, lime, orange, banana, etc; others with fruit

countered in fruit yogurts. The bleaching or fading of

pieces and fruit flavors/syrups exemplified by straw-

fruit pigments (anthocyanins) is caused by pH and ox-

berry, raspberry, blueberry, apple, etc; and special-

idation/reduction changes introduced

by starter bac-

ized flavors and combinations like nuts and cereals,

teria. Starter selection, proper cultural conditions and

pina colada, apple-cinnamon, etc. Then there are vari-

choice of stabilizers, and fruit preparations are impor-

ations based upon how the fruit is distributed—fruit

tant in controlling the quality of the finished product.

at the bottom/sundae style and the blended style in

The need for viable starter bacteria in the product till

which the fruit is uniformly distributed. Within the

the "open date" and the complexity introduced by the

flavored yogurts, there are the solid and drinkable

inclusion of probiotic strains add another dimension

types, as well as classes distinguished *by different fat*

to the difficulties in yogurt fermentation and yogurt

levels. Flavored yogurts are also available with added

systems. The foregoing illustration using yogurt in

probiotic cultures. There are yogurt varieties targeted

a nutshell shows the importance of starter culture

for youth and children, special dietary yogurts con-

and the need for "holistic" analyses of both tech-

taining artificial sweeteners, and yogurts packaged in

nological and microbiological aspects in successful

squeezable containers for people "on-the-go."

fermentations.

All the foregoing yogurt products need to meet

certain basic criteria in body, texture, color, flavor,

STARTER FUNCTIONS

fruit distribution, and resilience to handling through

marketing channels. Various operations in the man-

The primary starter function is to generate lactic acid

ufacture of the wide variety of yogurt products exert

by the fermentation of the major sugar in milk or

stresses on the starter organisms. For example, the *dairy mixes, lactose. The rate at which the acid de-*

addition of fairly high concentrations of sugar (su-

velopment is desired depends upon the cultured dairy

crose or high fructose corn syrup or corn syrup) be-

product, the turnover desired in the manufacturing

fore culturing increases the osmotic pressure of the

plant, the starter flora used, the

temperature of fer-

mix; the addition of fruit preparations preserved in

mentation, the flavor generation needed in the cul-

sugar syrups after culturing also has the same effect.

tured product (need for balanced growth of the mixed

There are trade requirements that specify that yo-

starter flora), and the body characteristics (in terms *gurt should have a certain level of live starter organ-*

of EPS generation) desired in the cultured product.

isms present throughout the prescribed shelf life of

As acid accumulates during fermentation of sugar,

the product. Agitation of coagulated curd, pumping

the pH progressively decreases. When the pH drops

through pipelines, and other related

processes intro-

to the isoelectric point of casein, the colloidal disper-

duce air into the product, which also cause stress con-

sion of casein micelles collapses, and the acid casein

ditions. Such stress conditions cause cell destruction

precipitates forming the curd. Thus, the acid gener-

or injury. These stresses affect the viability of yo-

ated from the fermentation of lactose not only im-

gurt starter bacteria as well as other probiotic strains

parts a pleasantly acid flavor to the cultured product,

added to the yogurt.

but also transforms the starting liquid milk or dairy

mix into a semisolid-to-solid curd.

Within the solid

bacteria consist of selected, compatible strains of

casein matrix, the whey and other soluble compo-

Leuconostoc spp. and citrate-fermenting Lactococ-

nents of milk and milk fat are entrapped. Unless the

cus lactis subsp. lactis. Among the two, Leuconostoc

curd is unduly disrupted by rough handling or ex-

spp. are preferred over citrate-fermenting L. lactis

cessive pumping, the entrapped components are held

subsp. lactis organisms in cultured buttermilk and

fairly intact with the casein network. Excessive acid

sour cream starters. The citrate-fermenting lactococci

generation by starter organisms because of uncon-

accumulate fairly high concentrations

of acetalde-

trolled fermentation (failure to arrest fermentation by

hyde, which introduces unwanted harsh, "green,

prompt and proper cooling at the desired acid level or

yogurt-like" flavors in cultured buttermilk and sour

improper temperature control during fermentation)

cream. Dairy Leuconostoc spp. on the other hand *will result in the shrinkage of the curd and the ex-*

scavenge undesirable acetaldehyde, converting the

pulsion of whey and soluble components. Excessive

aldehyde to ethanol, which provides a complemen-

acid concentration also imparts a harsh, acrid flavor

tary flavor to the overall characteristic flavor bou-

and masks the delicate dairy flavor

notes like diacetyl

quet of cultured buttermilk and sour cream. The rel-

desired in cultured buttermilk, sour cream, and a few

atively high alcohol dehrydrogenase activity of dairy

other cultured dairy products.

leuconostocs plays a vital part in the scavenging of

The acid generated and the gradual lowering of *acetaldehyde. To obtain a characteristic cultured but-*

the pH facilitate the transport of citrate present in

termilk flavor, a balanced ratio of diacetyl to acetalde-

milk or dairy mixes into the cells of "flavor bacteria"

hyde is necessary. The desirable ratio of diacetyl to

efficiently, resulting in the formation of the primary

acetaldehyde falls between 3.2:1 and

4.4:1. In dahi,

flavor compound, diacetyl. Transport of citrate into

the presence of slightly higher concentrations of ac-

the cells of flavor bacteria is facilitated by an enzyme,

etaldehyde is not considered a defect. The flavor bac-

citrate permease, which functions optimally below

teria are heterofermentative, and from lactose pro-

pH 6.0 (the initial pH of milk is around 6.6, and in

duce fairly high amounts (about 30%) of metabolic

dairy mixes, the pH may range from 6.3 to 6.4).

end products other than lactic acid. The non lactic

Another important function of lactic acid is its

acid metabolites include acetic acid, ethanol, and car-

preservative effect. Undissociated

lactic acid is in-

bon dioxide. The fermentation of citrate in addition

hibitory to many spoilage and pathogenic bacteria,

to diacetyl and its reduction products also yields car-

and the lowered pH is an additional stabilizing factor.

bon dioxide. Carbon dioxide plays a role in the flavor

In most cultured dairy products, the maximum acidity *perception of cultured buttermilk, very similar to the*

attained ranges between 1.3% and 1.5%, expressed as

effervescence or the "lift" imparted by carbonation

lactic acid. To yield 1 lb of lactic acid, 1 lb of lactose

in "soft drinks."

is consumed. Milk contains around 4.8% lactose, and

In yogurt, on the other hand, acetaldehyde is a key *to yield 1.5% lactic acid, only about 30% of the total*

component in furnishing the desirable "green apple"

lactose content is consumed, leaving a large portion

flavor. Although for typical plain yogurt a fairly high

of the lactose intact at the end of fermentation.

concentration of acetaldehyde is needed, the present

The secondary functions of the starter *culture in*

trend as mentioned earlier is to select starter strains

cultured dairy products include flavor generation,

that produce low amounts of the aldehyde to give a

special body and texture production, and the elab-

mild-flavored yogurt, compatible for the addition of

oration of miscellaneous inhibitory metabolites that *a wide variety of flavors.*

impart preservative effects. In cultured buttermilk,

In Kefir and Koumiss, ethyl alcohol and carbon

dahi (an Indian cultured milk), sour cream, and re-

dioxide provide essential flavor notes. The yeasts as-

lated products, the nutmeat-like "buttery" flavor is

sociated with the Kefir grains and the starters used *desirable. Diacetyl is the key compound that imparts*

for Koumiss generate the needed alcohol and carbon

the buttery flavor. Diacetyl is a diketone, derived by

dioxide. In dahi, in certain areas, a slight "yeastiness"

the fermentation of citrate present in milk and dairy

is preferred. Yeasts acquired through chance contam-

mixes. Flavor bacteria included in

starters for such

ination and carried over by "back slopping" practice

products possess the enzymatic pathways to convert

are attributable to the yeastiness in dahi. The starters

citrate to diacetyl and other closely related reduced

used in Viili contain a mold, Geotrichum candidum,

derivatives of the diketone. The reduced forms of di-

that forms a layer or mat on the surface of the prod-

acetyl do not possess the desired buttery notes prized

uct (aerobic growth). The mold metabolizes lactic

in the aforelisted cultured dairy products. Flavor

acid, and induces a “layered mildness” to the product *and also imparts a "musty" aroma. The exact role of*

functions are a reflection of the genetic infor-

molds associated with certain Koumiss starters is still

mation encoded in the nuclear materials (DNA—

undefined.

chromosomal and extrachromosomal) contained within

Starters additionally impart special body and tex-

the cells. Metabolic functions of the cell are carried

ture characteristics to certain cultured dairy prod-

out via various catabolic and synthetic enzymatic

ucts. In Viili and closely related Scandinavian cul-

pathways. Enzymes are biological catalysts that drive

tured milks, a viscous and a ropy or stringy body and

the catabolic and synthetic reactions.

Enzymes are

texture is caused by EPS-producing strains included

proteins made up of amino acids strung together in

in the starters. As described earlier, EPS-producing

specific sequences, which are encoded in the DNA of

starter strains in yogurt starters provide the heavy

the cells. The specific folding of the amino acid se-

body to hold fruit pieces in suspension. Lately, the

quences, and the specific reactive sites thus formed,

use of EPS-producing starter strains is widespread in

facilitates the reactivity of enzymes. The structure

cultured buttermilk and sour cream production. With

and the reactive site(s) of enzymes determine their

the ever-increasing price of milk

solids, these strains

specificity for substrates.

provide cost-effective means to impart a heavy body

The genetic materials in the cell could be altered

to these products. The cost savings are realized ei-

by mutations. Mutations (spontaneous or induced) in

ther by reducing the amount of milk powder forti-

enzymatic pathways would profoundly affect cellular

fication or by complete elimination of fortification.

metabolism. Such mutations in carbohydrate utiliza-

During filling operations for cultured buttermilk, the

tion would affect acid production, a primary function

EPS-induced texture in the finished product prevents

of starters. Similarly, other functions *could also be*

foaming, and allows easy filling of bottles to the re-

affected.

quired level.

As mentioned earlier, the genetic material of the

LAB used as starters produce other metabolites

cell could be organized in the chromosome or in

that are inhibitory to spoilage flora.

These metabo-

extrachromosomal elements. Plasmids, transposons,

lites contribute to shelf-life extension of cultured

and introns represent some of the extrachromoso-

dairy products. The secondary metabolites that are

mal elements found in starter bacteria. Nuclear mate-

significant include hydrogen peroxide, which is in-

rial of bacteriophages (or phages) specific for starter

hibitory to spoilage bacteria such as Pseudomonas

bacteria sometimes exist as extrachromosomal en-

spp. Hydrogen peroxide in combination with the

tities within starter cells. Many of the vital starter

lactoperoxide system of milk exerts suppressive ef-

functions are encoded on plasmid DNA.

During cell

fect on spoilage flora. Certain starter bacteria pro-

division, extrachromosomal DNA replicate in syn-

duce benzoic acid as a metabolite. Benzoic acid has

chrony with the chromosomal DNA. But, errors dur-

a bacteriostatic and fungistatic effect. Starter LAB

ing replication occur more frequently in plasmids.

produce bacteriocins such as nisin, acidophilin, bul-

And, failures in the transfer of plasmids to daugh-

garicin, and other uncharacterized inhibitory pep-

ter cells are also more frequent. This phenomenon

tides. Nisin is active against spore-forming bacteria.

is often referred to as "plasmid loss." Loss of plas-

Citrate-fermenting L. lactis subsp .

lactis strains exert

mids in starter cells results in loss of specific starter

an inhibitory action against Gram-negative spoilage

functions. Loss of plasmids among Lactococcus spp.

bacteria as well as pathogens. Some of the inhibitory

is quite prevalent. Repeated transfer of starter cul-

peptides elaborated by that Lactococcus subspecies *tures, sudden thermal shocking during propagation,*

have recently been described.

or exposure to overacidic environment increases the

frequency of plasmid loss in lactococcal starters.

FACTORS AFFECTING STARTER

Lactose utilization (Lac+) is one of the plasmid-

PERFORMANCE

encoded traits in dairy lactococci. The *loss of Lac-*

plasmid results in the inability of the strain to

The factors influencing starter performance may be

efficiently ferment lactose. Such a phenotype is des-

classified under two headings, namely intrinsic and

ignated as Lac−. Another important plasmid-encoded

extrinsic.

trait is the ability to break down protein(s). This trait

is designated as Prt+. Proteolytic ability is closely

Intrinsic Factors

linked with efficient lactose utilization. Milk con-

Among the intrinsic factors, the genetic makeup of

tains only traces of free amino acids. To synthesize

the starter cells is vital in starter functions. Cellular *enzymes involved in lactose utilization, free amino*

acids are needed. Breakdown of milk proteins would

depends upon how the culture was propagated, han-

yield the necessary amino acids for synthesizing the

dled, and preserved. Many of the enzyme systems *needed enzymes for lactose fermentation. So the*

vital in acid and flavor production are inducible.

Prt+ phenotype is critical for lactose fermentation.

Enzyme induction is a control mechanism that op-

In short, for efficient acid production in milk or dairy

erates at the genetic level. An inducible enzyme is

mixes, Lac+/Prt+ phenotype is

mandatory.

expressed only when the specific substrate is present.

Another important functional trait that is plasmid-

Enzymes that cleave lactose among starter LAB

encoded is the transport of citrate into the cell. Cit-

(NL-galactosidase and phospho-NL-galactose galacto-

rate present in milk and dairy mixes is converted by *hydrolase) are inducible. Starter bacteria that have*

citrate-utilizing lactococci to diacetyl, which is the

been propagated in the absence of lactose (using sug-

key flavor component in cultured dairy products such

ars like glucose) when added to milk have to un-

as cultured buttermilk and sour cream. The citrate in

dergo an adaptive lag for induction. In *other words,*

the environment first has to be transported into the

the cells are not "primed up" to use lactose. Citrate

cells before it can be converted into diacetyl. Cit-

permease involved in flavor production is inducible

rate transport is mediated by the enzyme citrate per-

in both citrate-fermenting Lactococcus lactis subsp.

mease. Cells possessing active citrate permease, and

lactis and Leuconostoc cremoris. The enzyme that

hence capable of citrate conversion to flavor com-

cleaves citrate leading to diacetyl production is in-

pounds, are designated Cit+. The loss of Cit-plasmid

ducible in Leuconostoc cremoris. Thus, for efficient

renders the cell Cit–, which is

incapable of diacetyl

flavor generation, starter cultures need to be prop-

production.

agated with the inducer (citrate) in the propagation

Some of the genes connected with EPS synthesis in

medium.

dairy lactococci are plasmid-encoded. So EPS pro-

Lack of essential factors in

propagation medium

duction is an unstable trait in those bacteria. Also,

significantly affects cellular integrity of certain

efficient EPS synthesis in LAB is favored at tem-

starter LAB. A good example is Lactobacillus del-

peratures lower than optimum for growth. Loss of

brueckii subsp. bulgaricus (hereto referred to as Lac-

plasmids encoding some of the genetic information

tobacillus bulgaricus for convenience). Availability

for EPS synthesis results in the inability to produce

of Ca++ in the propagation medium affects the in-

the viscosity and "ropiness" desired in specific cul-

tegrity of the cell walls of those bacteria; Lb. bulgar-

tured dairy products, where

lactococcal starters are

icus cultures propagated in media lacking free Ca++

used. The entire genetic material that codes for EPS

display distorted cell morphology, and fragility to cell

production in lactococci has been unraveled. And,

harvesting and preservative processes.

genetic probes to identify EPS-producing lactococci

In commercial production of starter cultures, the

have been described.

starter strains are grown in a relatively clear medium

Among the dairy lactococci, the production of

or one that contains low, undissolved suspended

wide-spectrum bacteriocins known as lactacins is

solids. Dairy starter cultures that need to function in *plasmid-encoded. The genes for another broad-*

milk should preferably be grown in milk containing

spectrum bacteriocin, nisin, are encoded on a transpo-

medium with lactose as the carbon source. Exces-

son, a highly mobile genetic element. The loss of such

sive use of protein hydrolysates should be avoided.

extrachromosomal elements throws up

cells inca-

Inclusion of milk as the nitrogen source and lactose

pable of producing bacteriocins that inhibit spoilage

as the carbon and energy source in the propagation

(spore-forming bacteria) and pathogenic bacteria

medium exerts a "selective pressure" to obtain an ac-

(clostridia and Listeria monocytogenes).

tive cell crop. The choice of the neutralizing agent

In certain LAB strains used in dairy starters (Lac-

during starter propagation is another factor in obtain-

tococcus subsp. and Streptococcus thermophilus),

ing the best cell crop. The optimum neutralizer varies

mechanisms that provide resistance to destruction by

with different strains. Because of the *convenience and*

phages are encoded on plasmids and on a transposon.

amenability to electronically controlled addition, am-

The loss of those transient genetic elements makes

monia gas is generally preferred as the neutralizer of

those cells vulnerable to phages.

choice by commercial culture manufacturers.

Other intrinsic factors that affect starter perfor-

At the end of propagation, the cells are harvested.

mance may be categorized under the heading physio-

Harvesting could be achieved either by centrifu-

logical condition or state of the starter bacteria. The

gal separation or by filtration using ultrafiltration

physiological state or condition of

starter bacteria

equipment (ceramic filters that could be efficiently

sterilized are preferred). Harvested cell concentrates

When bulk starters are made in the plant, proper

may then be frozen in cups or in bead-like, pel-

temperature control, close monitoring of acidity, and

letilized form. Suitable cryoprotectants are added

prompt and efficient cooling of the starter at the end-

before freezing. An alternative to freezing is freeze-

point are critical in avoiding cell injury and assuring

drying or lyophilization. Proper selection of cryopro-

high performance in the product vat.

All the above

tectants is important to prevent cell injury, damage,

factors that are encountered in the dairy plant, the

or loss of viability. The method of freezing also af-

actual site of application, relate to the physiological

fects cell viability and damage. Rapid rate of freez-

condition of the starter bacteria (the innate proper-

ing is preferable. Use of liquid nitrogen or dry ice or

ties of starter cells) at the time they are added to the

dry ice-alcohol bath as cryogenic agents gives better

product vat. In the strict sense of the term, they are

cell integrity than freezing at –20◦C (in a mechanical

not true extrinsic factors.

freezer). Proper freeze-drying conditions have to be

The extrinsic factors in the real sense of the term re-

worked out for different starter organisms, and "pro-

late to external influences, as opposed to innate prop-

grammed" into commercial freeze dryers. Generally,

erties of starter cells. The external factors include

the rod-shaped LAB (Lactobacillus spp.) are more

presence of antibiotics in milk or dairy *mix, pres-*

sensitive to the production processes than the spheri-

ence of fairly high sanitizer residues, presence of high

cal LAB (Lactococcus and Streptococcus spp.) used

proportions of agglutinins (colostrum or early lacta-

as starters. All the factors discussed in the forego-

tion milk), and infection with phage. Antibiotics are *ing paragraphs have significant influence on starter*

used in treating udder infections like mastitis. Some-

performance.

times because of improper adherence to regulatory

mandates, antibiotic-tainted milk finds its way into

pooled milk. S. thermophilus is extremely sensitive

Extrinsic Factors

to antibiotics. Although not as sensitive as S. ther-

Extrinsic factors come into play during application

mophilus, the dairy lactococci and starter lactobacilli

of starter cultures or in the preparation of starter cul-

are functionally impaired in the presence of antibi-

tures in the dairy plant. The same principles govern-

otics used for mastitis therapy.

Excessive or improper

ing the "physiological condition" of the starter cells

use of sanitizers affects starter performance. Certain

discussed for commercial production apply for the

sanitizers like quaternary ammonium compounds are

preparation of the starter in the dairy plant. Further,

not dissipated easily, and could remain in active form *commercial cultures could be damaged by improper*

in the vat milk. These residues would inhibit starters.

handling in the dairy plant. At receipt, frozen cultures

Agglutinins are antibodies produced by the de-

should be carefully examined whether during transit

fense mechanisms of cells in response to infections.

any thawing had taken place. If partial *or complete*

Mastitic milk contains high titer of agglutinins. To

thawing had occurred, the cultures should be dis-

protect young suckling calves against infection, the

carded. Till use frozen cultures need to be stored at

early mammary secretion called colostrum contains

–40◦C. An ice cream hardening room would also suf-

high titers of antibodies including agglutinins. Many

fice. If the frozen cultures go through freeze-thaw cy-

starter lactococcal strains are susceptible to clumping

cles, the starter bacteria will be severely damaged. It

(reduction of surface area) by agglutinins, and their

is beneficial to store freeze-dried cultures in a freezer

acid-generating function is severely

affected by the

to keep the cells active.

presence of these antibodies in the vat milk.

Fast thawing of frozen cultures just before use

Phages constitute the most insidious agent affect-

in lightly chlorinated warm water at 35◦C is advis-

ing starter function. The consequences of phage in-

able. Thawing frozen cultures in a refrigerator causes

fection of starter bacteria in dairy fermentations were

cell damage. Proper conditions for rehydration of

discussed earlier. Phages in terms of host relation-

lyophilized (temperature and rehydration menstrum)

ships are of two types, namely, virulent or lytic, which

cultures assure maximum cell viability, *and recov-*

destroy host cells, and temperate or prophage or lyso-

ery of injured cells. The rehydration processes for

genic, which normally exist in benign relationship

different strains vary, and should be determined for

within the host cell. Sometimes, the prophage could

each culture combination in consultation with the cul-

be "induced" (either spontaneously or by external

ture supplier. For optimal performance of starters, the

agents like ultraviolet radiation or chemical agents)

sooner the culture is used after thawing or rehydration

into the virulent form. Prophages may exist as an in-

the better the results.

dependent DNA element in the cytoplasm of the host *cell or attached to the host chromosome. Lysogenic*

environment. Lysin is a nonspecific enzyme that

phages could sometimes act as vectors for genetic ex-

cleaves cell walls of closely related bacteria. High

change between closely related bacteria by a mech-

levels of lysin could destroy phage-unrelated com-

anism called "transduction." Such lysogenic phages

ponent strains in starter mixtures by cell lysis. This

are called "transducing phages." All these types of

phenomenon is often referred to as "lysis from

phages are found in starter LAB.

without."

Phages are tadpole-shaped particles. They have a

In dairy fermentations, a phage titer of 1.0 ×

definite head, which in some cases are symmetrical

105 per milliliter is considered detrimental to the

(isometric) and in others elongated (prolate) isoco-

process. Considerable research has been devoted to

hederal structures, attached to a tail.

The DNA of the

phages infecting dairy lactococci. The information

phage is enclosed within the head. The tail differs

on phages infecting yogurt starter bacteria has also

in length and is a hollow structure. The tail may be

been accumulating rapidly over the past decade. With

striated, and may be rigid or contractile. The tail may *the advent of modern molecular techniques, phages*

possess a tail plate, and spikes at its extremity. Lacto-

are classified on the basis of DNA homology. Cur-

coccal phages have rigid tails. The nuclear material

rently, phages are divided into 10 species under fam-

of the phages infecting starter LAB is composed of

ilies Siphoviridae and Podoviridae.

Phages affecting

DNA. The head and the tail of phages are made up of

lactococci used in cultured buttermilk and sour cream

protein. Generally, phages have host specificity, but

plants in the United States have been extensively sur-

phages crossing species boundaries are known.

veyed. A large majority of phages isolated from prod-

During the infective cycle, the phages attach to

uct samples were grouped into 936 species. Other

specific receptor sites of the host cells, and in the

groups found in these samples belonged to c2 and

presence of Ca++ form an irreversible bond with the

P355 species. The prevalence of P355 species was

host cell creating a channel to the

interior of the cell.

sparse. Phage species P355 is a relatively new phage

The phage DNA is expelled by the contraction of

that has emerged in cultured dairy product plants,

the head, and the DNA travels through the channel

and is considered as a serious threat to dairy fer-

in the tail and is delivered to the interior of the host *mentations, because of its ability to rapidly evolve*

cell. The host receptor sites in most cases are com-

into new, resistant types by genetic exchange. Phages

posed of carbohydrate entities, rhamnose being the

lacking lytic ability but possessing mechanisms to de-

most prevalent, and in one case the attachment (also

polymerize EPS produced by lactococci

have been

called adsorption) is dependent upon a chromoso-

isolated from cultured buttermilk and sour cream

mally encoded protein embedded in the cell mem-

samples in the United States. A phage with similar ac-

brane. Soon after the entry of the phage DNA, the

tivity, KSY 1, has been isolated from Viili in Finland.

host cell chromosome is degraded, and the host syn-

Phage KSY 1 falls under the family Podoviridae.

thetic mechanisms are used in phage DNA replica-

Phages affecting S. thermophilus possess isometric

tion followed by components making up the phage

heads and long noncontractile tails. All those phages

protein-coat. The assembly of the

phage occurs in

are grouped under the family Siphoviridae. The vir-

stages till the entire (mature) phage particle is com-

ulent phages fall into one DNA homology group.

pleted. When a genetically determined number of

Lysogenic relationships among S. thermophilus are

phage particles are assembled, through the concerted *quite complex. Phages affecting Lb. bulgaricus and*

action of two enzymes, holin and lysin, the host cell

dairy leuconostocs have been isolated. The leuconos-

wall is breached, and the phage particles spill out

toc phages have isometric heads and noncontractile

to the surrounding environment. The genetically de-

tails with distinct tail plates.

termined number of particles released from the host

Phage control in dairy plants involves separation

cell is called the burst size. The time lag between the

of the starter room from other manufacturing areas,

entry of the phage DNA into the host cell and the

having a separate crew for starter room duties, pro-

release of mature phage particles from *the host cells*

vision of air locks between the starter room and the

is called the eclipse period. Among dairy lactococci,

rest of the plant, provision for separate locker rooms

the burst size is around 200 particles. As the cycle

and uniforms for starter room workers, provision of

continues unabated, the phage numbers (or titer) in-

footbaths containing sanitizers at the entrance to the

crease exponentially with concomitant destruction of

starter room, restricting the movement of plant per-

host cells. When the phage titer reaches to high levels,

sonnel from and to the starter room, maintenance of

the level of lysin also increases considerably in the

positive air pressure in the starter

room, the use of

laminated air flow through microfilters (HEPA filters)

insensitive mutant is introduced to make up the orig-

in the starter room, preventing the dispersal of phage

inal mixture. The cycle is repeated as required. The *particles via air-circulating systems, and other means*

success of the scheme depends on using only lim-

of physical containment necessary. Fogging the plant

ited number of carefully selected strains in produc-

environs with 100 ppm chlorine at the end of opera-

tion, and daily monitoring for phages. The scheme

tions is also recommended.

has been successfully used in cultured dairy product

Another practical means of controlling phages is

plants in the United States and in Ireland. The insen-

using phage inhibitory media (PIM) for propagating

sitive strains thus selected are generally composed

starter bacteria. PIM are carefully formulated nutri-

of cells with phage adsorption site

mutations. The

ent media containing phosphates or other chelating

scheme has been successfully used with lactococci

agents like citrates. Phosphates and citrates chelate

and S. thermophilus.

free Ca++ in the system, and thus prevent irreversible

There are several innate phage-resistance mecha-

phage adsorption to sensitive cells. The yogurt starter

nisms encoded in the genetic material of starter LAB.

bacteria and Leuconostoc spp. do not grow well in

These mechanisms in dairy lactococci have been

PIM containing high levels of phosphates. For these

studied extensively. As mentioned earlier, many

bacteria special formulations of PIM

containing low

of these resistance mechanisms are encoded on

levels of phosphates and other chelators like citrate

plasmids. Developments in molecular biology have

and stimulants for cell growth are used. The lacto-

facilitated plasmid isolation, analysis, base sequence

cocci are relatively more tolerant of levels of phos-

determinations, transfer of functional sequences be-

phate necessary to inhibit phage proliferation.

tween lactococcal strains, and functional expression

Culture rotation is another strategy used for phage

of resistant traits in sensitive recipients. The known

control in dairy plants. In this plan, starter strains with

resistance mechanisms include

modification of

unrelated phage specificities are used in rotation dur-

adsorption sites, restriction-modification, blocking

ing production week, so that the chances of buildup

of phage DNA penetration, and abortive infection

of phage titer for any one set of strains in the dairy

mechanisms. In adsorption modification, the phage *plant are avoided. This strategy works well when used*

receptor sites are modified (by masking) such that

in combination with other measures described ear-

phage is unable to attach to the cell. In restriction-

lier. Some workers have suggested rotating strains

modification system (R/M) the incoming phage

selected on the basis of sensitivity to *differing phage*

DNA is degraded by "restriction enzymes," and made

species and elimination of starter strains that are af-

nonfunctional. To protect the host cell DNA from

fected by the rapidly evolving P335 phage species in

being chopped up by the restriction enzymes, "mod-

the rotation scheme.

ifying enzymes" are produced, which render the host

Over the past two decades, a new strategy has been

DNA invulnerable by methylation of the DNA sites.

introduced to confront phage-related problems. The

Modified methylated sites in the DNA are not recog-

scheme comprises several steps. First, the phages ap-

nized by the restriction enzymes. The

restriction and

pearing in a dairy plant are monitored over a period of

modification components in the R/M system work in

time against a bank of active starter strains, and a bat-

concert to confer phage resistance to the host. In the

tery of strains resistant to the phages appearing in the

blockage of phage DNA penetration, a modification *plant is selected. Three to six of the resistant strains*

of or a defect in a cell membrane embedded protein

are supplied as single units to be combined to make

called phage infection protein (PIP) that facilitates

up a mixed culture. A set of three such potential mix-

phage DNA penetration (PIP is encoded on a plasmid

tures are kept in reserve. One mixture *is introduced in*

in some organisms and on the chromosome in some

the plant, and the cultured products made in the plant

others) confers resistance to the host. In abortive

are monitored daily for the appearance of phages af-

infection mechanism, the phage DNA replication or

fecting any of the strains being used. If a phage is *phage assembly is disrupted and hence no release of*

detected for any strain in the mixture, that strain is

mature particles occurs. In effect, the infecting phage

removed and a reserve strain is substituted. The strain

is entrapped by the host cell. Plasmids conferring

that was pulled out is challenged against the infecting

some of the phage-resistance

mechanisms have

phage isolated from the cultured product, and spon-

been transferred to sensitive strains, making them

taneous insensitive mutants that emerge are isolated

resistant through conjugation and electrotransforma-

from a special plating medium (fast–slow differential

tion. Conjugation involves cell-to-cell contact and *agar) and purified of any residual phage particles. The*

mobilization of DNA from a donor to a recipient.

Electrotransformation involves the introduction of

Lb. bulgaricus. Symbiosis is a cooperative relation-

plasmid DNA into recipient cells by facilitating the *ship, where one organism stimulates or promotes the*

penetration of DNA via pores created in the recipient

growth and activity of another. The functional ef-

cells by short high-voltage electric pulse. Commer-

ficiency is much greater when the symbiotic com-

cially viable and successful phage-resistant starter

ponents operate together than when

acting singly.

strains have been produced by using such techniques.

There are strain differences in symbiotic compati-

Similar phage-resistant systems have been found

bility. Strain selection and pairing for yogurt starters

among other starter LAB. Plasmid conferring R/M-

is thus directly related to culture performance.

related phage resistance from a Lactococcus strain

when introduced into a S. thermophilus strain was

MICROORGANISMS USED IN

functional in conferring resistance to the heterolo-

STARTERS FOR CULTURED

gous recipient against phage lytic for that S. ther-

DAIRY PRODUCTS

mophilus strain. Recently S.

thermophilus plasmids

have revealed DNA sequences closely homologous to

Microorganisms used in starters for cultured dairy

R/M sequences found in lactococci. This observation

products are divided into two types based on the

suggests that during the evolution of these closely re-

temperature ranges at which they operate well. LAB *lated bacteria, there has been horizontal transfer of*

used in products that are incubated in the tempera-

genetic material between these bacteria.

ture range of 20–30◦C are referred to as mesophilic

starter bacteria, and those that are used in products

that are fermented above 35◦C are referred to as ther-

Miscellaneous Factors

mophilic starter bacteria. The latter term is scientifi-

There are a couple of other factors that affect culture

cally erroneous, because thermophilic bacteria grow

performance, which could be considered under this

optimally above 50◦C, and the organisms comprising

heading. These factors in reality are intrinsic to starter

thermophilic starters do not fit that

definition. These

organisms, but come into play only when the strains

organisms should be more appropriately labeled as

are combined for use in fermentations. One such fac-

thermotolerant starters.

tor is compatibility. The component strains in a mixed

In addition to the two types of starters discussed *culture should be compatible with one another to*

above, there are other groupings for starter cultures,

function in concert. Some lactococcal strains pro-

which are used in Europe. Cultures composed ex-

duce bacteriocins called lactococcins that kill other

clusively of L. lactis subspp. lactis and cremoris are

lactococci, and are thus incompatible

for use in mix-

known as “O” type cultures; those that contain in ad-

tures. Similar antagonistic activity occurs among

dition to the acid-producing lactis and cremoris sub-

other LAB too. When such strains are used in mixtures

species strain(s) of Cit+ L. lactis subsp. lactis (flavor

consisting of phage-unrelated strains with the intent *producer) are called "D" type cultures; cultures con-*

to ensure unmitigated progress of dairy fermentation

taining a combination of acid-producing lactis and

(so that if phages for one or two strains are present

cremoris subspecies and dairy Leuconostoc spp. are

in the dairy environment, the other phage-unrelated

referred to as type "L" or "B" type

cultures (referring

strains could function unimpaired), the strategy fails,

to Betococcus, a former nomenclature for Leuconos-

because if a phage infecting the dominant or only

toc bacteria); and, cultures containing lactis and cre-

surviving antagonistic strain is present in the sys-

moris subspecies plus Cit+ L. lactis subsp. lactis and *tem, there are no other surviving strains to carry out*

Leuconostoc spp. are known as "LD" or "BD" types.

the function to completion. Another bacteriocin pro-

In Holland, a different appellation is used for mixed

duced by certain strains of Lactococcus lactis subsp.

strain starters.

cremoris called diplococcin specifically kills L. lac-

Those that are propagated under aseptic conditions

tis subsp . lactis strains. Dominance among starter

in the laboratory or the dairy plant are labeled “L”

LAB because of other inherent factors (for example,

type (letter L standing for “laboratory”). And, those

metabolic efficiency, faster growth rate, etc.) is also

in contrast propagated under

nonaseptic conditions

known. So, careful selection and pairing or mixing

(i.e., without any precautions) to exclude phages in

of strains is important.

the environment in the dairy plant are called "P" type

Another factor that affects culture performance re-

(letter P standing for "practice"). The P-type starters

lates directly to yogurt starters. Yogurt starters con-

are used with good success under factory conditions,

sist of symbiotic mixture(s) of S. thermophilus and

without phage-related failures. These cultures being

constantly exposed to phages prevalent in the fac-

with other specific microflora. Yogurt by definition

tory environment serve to exert selective pressure to

is the fermented dairy product produced by culturing

naturally develop phage-resistant derivatives of the

with a starter made up of S. thermophilus and Lb.

strains present in the culture. There is a complex dy-

bulgaricus, and should contain viable

cells of both

namic operating in that system between the starter

bacteria till the end of the shelf life of the product.

strains and the "disturbing phages" and the evolution

In Table 6.1, the microorganisms used as starters

of resistant starter strains, which keeps the starter

for some of the major cultured dairy products con-

performing satisfactorily. The L-type cultures, on

sumed in the West, Eastern Europe, and the Far East

the other hand, are readily labile to phage-related

are listed under the column “Primary Microorgan-

failures.

isms.”

Another category that has come into recognition

In the production of dahi, the mesophilic lacto-

recently is artisanal or natural starters. These starters

cocci, and in some instances leuconostocs, are used

are composed of a mixture of undefined starter bac-

as starter flora. For detailed information on starter

teria, which have been carried according to the tradi-

flora for many of the fermented

products discussed

tional practice of using a small portion of the previ-

in this book, the individual chapters should be con-

ous batch of fermented products to seed a new batch.

sulted. Some of the physiological and biochemical

This is often referred to as "back slopping." Arti-

characteristics of starter bacteria are summarized in *sanal starters are still used in small-scale, cottage, or*

Tables 6.2 and 6.3.

farm operations in Europe. A similar system is found

in small-scale production of dahi in South Asian

Genus LACTOCOCCUS

countries.

Other arbitrary groupings of cultures are based

Genus Lactococcus is a relatively new

taxonomic

upon the composition of starters. Starters that are car-

grouping. Five species were hived off the larger genus

ried in mixtures made of strains that have not been

Streptococcus to make up genus Lactococcus. Only

fully characterized with respect to acid-producing

one species of genus Lactococcus (L. lactis) is used *abilities, phage susceptibility, etc. are lumped un-*

in dairy fermentations. Current taxonomic groupings

der the grouping "undefined mixed-strain starters."

rely on phenotypical, biochemical, and molecular

Starters made up of well-characterized strains (which

characteristics of the organisms. The two subspecies

could be maintained as either separate *entities or*

of L. lactis, namely lactis and cremoris, with a biova-

as a mixture) are called “defined-strain mixed cul-

riety of subspecies lactis, Cit+ or diacetylactis, for-

tures.” The latter came into prominence with the de-

merly were included in the lactic group of Sherman.

velopment of phage-insensitive replacement strategy

The distinguishing characteristics of the organisms

to overcome phage-related problems in dairy plants.

placed in various groups by Sherman are shown in

Defined-strain mixed cultures have been used very

Table 6.4.

successfully in New Zealand in large dairy plants.

Lancefield grouped the organisms included in the

Mesophilic starter bacteria consist of dairy L. lac-

former large genus Streptococcus on the basis of

tis subspecies and dairy Leuconostoc spp. Citrate-

serology of their cell-wall carbohydrates. The or-

fermenting L. lactis subsp. lactis is often referred to

ganisms within Sherman's lactic group fell under

as L. lactis subsp. lactis biovar.

diacetylactis in the

Lancefield's group N. When the dairy lactococci were

literature. The other subspecies are L. lactis subspp.

classified within the genus Streptococcus, they went

cremoris and lactis. The Leuconostoc bacteria gen-

through several changes. At one time, Lactococcus

erally used in dairy fermentations in association with *subspecies, lactis and cremoris, had full species sta-*

lactococci are Leuconostoc lactis and Leuconostoc

tus within genus Streptococcus (Streptococcus lactis

mesenteroides subsp. cremoris.

and Streptococcus cremoris). And so did the current

Thermotolerant starters used for dairy fermenta-

Cit+ biovariety (Streptococcus diacetylactis). Vari-

tions consist of S. thermophilus and Lactobacillus

ations in the spelling for the Cit+ biovariety also

spp. Among the lactobacilli two subspecies of Lac-

featured in taxonomic changes (diactilactis versus

tobacillus delbrueckii, namely, bulgaricus and lac-

diacetylactis). Later in further changes within genus

tis, are most widely used for cultured *milk products.*

Streptococcus, the full species status for lactis and

Lactobacillus acidophilus, Lactobacillus helveticus,

cremoris was modified to the subspecies level. The

and Lactobacillus casei subsp . casei are other lacto-

differentiating characteristics of the dairy lactococci

bacilli used in fermented dairy milks in association *are summarized in Table 6.5.*

Table 6.1. *Microorganisms Used in Starter Cultures for Cultured Dairy Products and Their Functions.*

Incubation

Primary

Secondary/Optional

Temperature

Major Function

Product

Microorganism(s)

Microorganism(s)

and Time

of Culture

Yogurt

Lactobacillus delbrueckii subsp.

Lactobacillus

43–45◦C/

Acidity, texture,

bulgaricus

acidophilus

2.5 hours

aroma, flavor,

Streptococcus sulvarius subsp.

Bifidobacterim longum/

probiotic

thermophilus

bifdus/infantis

Lactobacillus casei/

lactis/jugurti/

helveticus

Cultured

Lactococcus lactis subsp. lactis

Leuconostoc lactis

22◦C/

Acidity, flavor,

buttermilk

Lactococcus lactis subsp.

Leuconostoc

12–14 hours

aroma

and sour

cremoris

mesenteroides

cream

Lactococcus lactis subsp. lactis

subsp. cremoris

var. diacetylactis

Fermented

Streptococcus sulvarius subsp.

Leuconostoc lactis

23–37◦C/

Acidity, flavor,

milk

thermophilus

subsp. lactis/cremoris

8–14 hours

probiotic

Lactobacillus acidophilus

Bifidobacterim longum/bifdus

Acidophilus

Lactobacillus acidophilus

37–40∘C/

Acidity,

milk

16–18 hours

probiotic

Bulgarian

Lactobacillus delbrueckii subsp.

37–40∘C/

Acidity,

buttermilk

bulgaricus

8–12 hours

probiotic

Kefir

Lactococcus lactis subsp.

15–22◦C/

Acidity, aroma,

lactis/cremoris

24–36 hours

flavor, gas

Lactobacillus delbrueckii subsp.

(CO2),

bulgaricus

alcohol,

Lactobacillus delbrueckii subsp.

probiotic

lactis

Lactobacillus casei/

helveticus/brevis/kefir

Leuconostoc mesenteroides/

dextranicum

Yeasts:

Kluyveromyces marxianus

subsp. marxianus

Torulaspoa delbrueckii

Saccharomyces cerevisiae

Candida kefir

Acetic acid bacteria:

Acetobacter aceti

Koumiss

Lactobacillus delbrueckii subsp.

bulgaricus

Lactobacillus kefir/lactis

Yeasts:

20–25◦C/

Acidity, alcohol,

Saccharomyces lactis

12–24 hours

flavor, gas

Saccharomyces cartilaginosus

(CO_2)

Mycoderma spp.

Acetic acid bacteria:

Acetobacter aceti

Yakult

Lactobacillus casei

30–37◦C/

Acidity,

16–18 hours

probiotic

Source: Reproduced with permission from Chandan RC, Shahani KM. 1995. Other fermented dairy products. In: H-J Rhem, G

Reed (Eds), Biotechnology, Vol. 9. Wiley-VCH, Hoboken, NJ, pp. 390–391.

100

anicum

chains

iley-VCH,

oides

xtr

W

de

pairs,

sucrose

)

9,

(−

xtran

from

ol.V

Leuconostoc

mesenter

subsp.

Cocci,

–

20–25

4–10

37

22

–

0.1–0.3

0.2–0.4

∀ ∀ ∀ + +++ *De*

∀ ∀ *6.5*

,

chains

Biotechnology

oides

emoriscr

pairs,

sucrose

)D

xtran

(Eds),

de

short/long

(−

from

trait.

Leuconostoc

mesenter

subsp.

Cocci,

–

20–25

4–10

37

22

–

0.1–0.3

0.2–0.4

∀ ∀ ∀ + +++ *No*

∀ ∀ *6.5*

Reed

the

G

for

ar.v

Rhem,

lactis

bio

short

ariableV H-J

∀ = *In:*

lactis

pairs,

Products

)D

trait;

y

chains

(+

the

products.

Lactococcus

subsp.

diacetylactis

Cocci,

–

28

8–10

40

22–28

∀

0.8–1.0

− + + ∀ + +++ ∀

+ ∀ *4–6.5*

Dair

forev dairy

gati

Ne

emoris

Cultured

chains

r

cr

−= fermented

fo

Other

subsp.

pairs,

)L

Used

short/long

(+

1995.

ia

Lactococcus

lactis

Cocci,

22

8–10

37–39

22–30

0.8–1.0

+

4.0

expression);

of

KM.

gree

Bacter

de

ter

lactis

Shahani

Star

chains

RC,

subsp.

pairs,

represent

)L

short

(+

Lactococcus

lactis

Cocci,

− −

28–31

8–10

40

21–30

∀ ∀ *L 0.8–1.0* −− −− ++ ∀ ∀ −− +
∀ ∀

++ ∀ ∀ *4–6.5*

symbols

Chandan

of

Mesophilic

from

of

(%)

(number

istics

◦ C)(minutes)

milk

(%)

trait

permission

$\circ$ *C)(*

in

production

production

the

acter

$\circ$ *C/30*

max)

with

for

configuration

(60

vity

e

compound

(%

v

396.

Char

vity

p.

and

temperature

isomers

produced

production

production

acti

peroxide

reaction

)

acti

Positi

2

production

eproduced

NJ,

6.2.

temperature

acid

acid

acid

fermentation

R: en,

le

shape

tolerance

(CO

or/aroma

tolerance

$+=$

b

wth

v

:

ce

a

Optimum

Minimum

Maximum

T

Characteristic

Cell

Catalase

Gro

Incubation

Heat

Lactic

Lactic

Acetic

Gas

Proteolytic

Lipolytic

Citrate

Fla

Mucopolysaccharide

Hydrogen

Alcohol

Salt

Note

Sour

Hobok

101

casei

square

iley-VCH,

short/long

W

subsp.

with

)

9.

ends,

chains

(+

race

ol.

Lactobacillus

casei

Rods

–

37

15–20

40–45

37

L

1.2–1.5

– ∀ ∀ – ∀ ∀ + *T 2.0*

V,

ends,

chains,

Biotechnology

round

short

(Eds),

with

metachromatic

pairs,

no

granules

trait.

L

race

Reed

Lactobacillus

acidophilus

Rods

–

37

20–22

45–48

37

$--$

0.3–2.0

$++ - \forall \; \forall - + - + T\, 6.5$

the

G

for

Rhem,

ends,

ariableV H-J

Products

∀ = *In:*

y

round

kii

lactis

trait;

Dair

with

)D

the

products.

metachromatic

granules

(−

race

race

Lactobacillus

delbruec

subsp.

Rods

–

40–45

22

52

40–45

1.5–3.0

T

$- + \forall - + - + T\ 2.0$

forev dairy

Cultured

gati

r

Ne

fo

ends,

chains,

$-=$ *fermented*

subsp.

Used

round

kii

short

Other

ia

with

)D

single,

metachromatic

granules

1995.

(−

expression);

race

+

race

Bacter

ulgaricus

Lactobacillus

delbruec

b

Rods

40–45

22

52

42

++

1.5–4.0

T

++

T

2.0

of

KM.

ter

gree

de

Star

to

Shahani

ant

to

pairs

RC,

chains

represent

oid,

)D

eptococcus

vo long

motoler

+ (+

race

Str

thermophilus

Spherical

– –

40–45

20

50

40–45

$+ L\ 0.7–0.8\ T -- \forall + \forall \forall -- ++$
$\forall + \forall + - 2.0$

symbols

Chandan

of

Ther

from

of

(%)

(number

istics

◦ C)(minutes)

milk

(%)

trait

permission

◦ C)(

in

production

production

the

acter

◦ C/30

max)

with

for

configuration

(60

vity

e

compound

(%

v

397.

Char

vity

p.

and

temperature

isomers

produced

production

production

acti

peroxide

reaction

)

acti

Positi

2

production

eproduced

NJ,

6.3.

temperature

acid

acid

acid

fermentation

R: en,

le

shape

tolerance

(CO

or/aroma

tolerance

+=

b

wth

v

:

ce

a

Optimum

Minimum

Maximum

T

Characteristic

Cell

Catalase

Gro

Incubation

Heat

Lactic

Lactic

Acetic

Gas

Proteolytic

Lipolytic

Citrate

Fla

Mucopolysaccharide

Hydrogen

Alcohol

Salt

Note

Sour

Table 6.4. *Sherman's Grouping of Bacteria Comprising the Former Genus Streptococcus Growth At*

Groups

10◦C

45◦C

Hemolysis

Bacteria

Pyogenic

–

–

Beta

Pathogenic Streptococci

Varidans

–

+

Alpha

S. bovis, S. equi, S. thermophilus

Lactic

+

–

Gamma

Dairy Streptococci

Enterococcus

+

+

Alpha, Beta

Enteric Streptococci

Note: + = Positive for the trait (number of symbols represent degree of expression); − = Negative for the trait.

Recently, a new differentiating physiological char-

the NL*-galactoside permease. The lactose that is con-*

acteristic between lactis and cremoris subspecies has

veyed into the cell is split into glucose and galactose *been reported. Organisms belonging to lactis sub-*

by the enzyme β-galactosidase (β-gal). Galactose

species are capable of decarboxylating glutamate,

is modified through the Leloir pathway for feeding

while cremoris subspecies lack that property.

into major pathway(s) of carbohydrate metabolism.

Lactococci are morphologically

spherical cells.

Homofermentative lactococci metabolize carbohy-

The cells, however, are not round but oblong. The

drates through the hexose monophosphate pathway

cells occur in short chains, but most commonly as

(HMP or EMP). Figure 6.1 depicts the homofer-

pairs. Single cells also could be found. Some strains, *mentative pathway for lactose metabolism among*

especially those susceptible to agglutinins found in

lactococci.

milk, exhibit long chains. Lactococci are Gram-

Under normal fermentative conditions, homolactic

positive. They are microaerophilic, lack catalase, and

fermentation is dominant in lactococci. Low levels of *are fermentative. L. lactis subspp. lactis and cremoris*

enzymes operative in heterolactic fermentation, how-

are homofermentative.

ever, have been detected in lactococci. Under certain

conditions, for example aeration, the eclipsed het-

erolactic pathway enzymes in lactococci are also ex-

Lactose Fermentation in Lactococci

pressed, giving rise to mixed end products.

The lactococci possess a unique, multicomponent

transport system to ferry lactose into the cells,

Citrate Metabolism in Lactococci

called the phosphoenolpyruvate–phosphotransferase

system (PEP-PTS). In this system, phosphoenol

Citrate metabolism by Cit+ lactococci plays a sig-

pyruvate plays a crucial role in phosphorylating lac-

nificant part in flavor generation in cultured dairy

tose at the sixth carbon of galactose moiety of the

products. Some of the features of citrate utiliza-

disaccharide. The lactose phosphate is cleaved into

tion by starter bacteria were discussed earlier. Cit-

glucose and galactose-6-phosphate by

the enzyme

rate is translocated into the cells by citrate permease,

phosphogalactoside galactohydrolase (P-NL-gal). The

which is optimally active at slightly acidic conditions

phosphorylated galactose is suitably modified via

(< pH 6.0). Citrate metabolic pathway in mesophilic

the tagatose pathway to feed into the major path-

starter bacteria is shown in Figure 6.2.

way(s) of carbohydrate metabolism. There are a few

Pyruvate plays a central role in carbon metabolism.

unique lactococcal strains that transport lactose via

As seen in Figures 6.1 and 6.2, metabolism of lactose

***Table 6.5.** Differentiating Characteristics for the Dairy Lactococci*

Growth At

Subspecies

41∘C

4% salt

Arginine Hydrolysis

Citrate Utilization

lactis

+

+

+

−

lactis biovar. diacetylactis

+

+

+ /−

+

cremoris

−

−

−

−

Note: + = Positive for the trait (number of symbols represent degree of expression); − = Negative for the trait.

Lactose

Lactose

1

Lactose-P

2

Galactose

Glucose

ATP

7

8

Leloir

ATP

6

ADP

Pathway

HPr-P

Galactose-1-P

ADP

HPr

9

10

Galactose-6-P

Glucose-6-P

Glucose-1-P

3

11

Tagatose

Tagatose-6-P

Fructose-6-P

Pathway

ATP

ATP

4

12

ADP

ADP

Tagatose-1,6-diP

Fructose-1,6-diP

5

13

Dihydroxyacetone-P

Glyceraldehyde-3-P

Pi

NAD+

NADH

14

1,3-Diphosphoglycerate

ADP

15

ATP

3-Phosphoglycerate

16

2-Phosphoglycerate

17

Phosphoenolpyruvate

ADP

HPr

ATP

HPr-P

18

19

Pyruvate

NADH

20

NAD+

L-Lactate

Figure 6.1. *Embden-Meyerhoff -parnas pathway for lactose metabolism among homofermentative lactic acid bacteria.*

1 = NL-galactosidase, 2 = P-NL-galactosidase, 3 = galactose 6-phosphate isomerase, 4 = tagatose-6-phosphate kinase, 5 = tagatose-1,6-diphosphate aldolase, 6 = glucokinase, 7 = enzyme II, 8 = galactokinase, 9 = glucose:galactose-1-phosphate uridyl transferase uridine diphosphate-glucose epimerase, 10 = phosphoglucomutase, 11 = phosphogucose isomerase, 12 = phosphofructokinase,

13 = fructose-1,6-diphosphate aldolase, 14 = triose phosphate dehydrogenase, 15 = phosphoglycerokinase, 16 = phosphoglyceromutase, 17 = enolase, *18 = pyruvate kinase, 19 = enzyme I, 20 = lactate dehydrogenase.*

Adapted from Zourari et al., 1992; Cogan and Accolas, 1996; Hutkins, 2001; and Ray, 2004.

Citrate

Acetate

Citrate lyase

Oxaloacetate

Oxaloacetate decarboxylase

CO2

CO2

TPP

Acetaldehyde TPP

Pyruvate

Acetolactate

Diacetyl

AcetylCoA

synthase

synthase

TPP

Acetolactate

CoA

Acetolactate

decarboxylase

CO2

Diacetyl reductase

Acetoin

Diacetyl

Acetoin

reductase

NAD(P) NAD(P)H

NAD(P)H

NAD(P)

Figure 6.2. *Pathway for citrate metabolism among*

starter lactic acid bacteria. Adapted from Hutkins,

2,3-Butane diol

2001, and Ray, 2004.

and citrate leads to the formation of pyruvate. Pyru-

titratable acidity of the product reaches 0.75–0.8%.

vate derived from lactose is converted into lactic

At that level of acidity, the diacetyl concentration is

acid to keep the cycle sustained by regeneration of

at its peak. Rapid cooling will retard the reduction of *nicotinamide adenine diphosphate (NAD+). When*

diacetyl by the enzyme diacetyl reductase and con-

the intracellular level of pyruvate increases with ad-

serve the flavor. If a greater acidity (> 0.8%) is desired

ditional accretion from citrate, the cell has to find

in the product, the rapid reduction of diacetyl could

a way to detoxify excess pyruvate.

Detoxification is

be arrested by initial fortification of the milk or dairy

achieved by converting pyruvate to neutral C-4 com-

mix with citrate (regulations allow addition of 0.15%

pounds such as diacetyl and its reduced forms. Citrate

citrate in cultured buttermilk and sour cream). Suffi-

metabolism does not yield bond energy, but serves *cient availability of citrate not only provides higher*

in keeping the cellular oxidative–reductive power in

concentration of precursor for diacetyl, but also acts

balance.

as a damper against diacetyl reductase activity. An-

Diacetyl derived from citrate does not accumulate

other way to prevent the loss of diacetyl is to in-

indefinitely. When the concentration of citrate falls

corporate air into the product, accompanied by rapid

below a critical threshold, diacetyl is rapidly reduced

cooling once the acidity reaches 0.8%. This could

to acetoin and further to 2,3-butanediol. The reduc-

be done by agitation. Cit+ lactococci possess a class

tion of diacetyl results in the loss of the

characteristic

of NAD—oxidases that facilitate the transfer of hy-

nutmeat flavor of cultured dairy products. It is cru-

drogens from NADH + H+ (reduced nicotinamide

cial that the desirable nutmeat flavor is conserved in

adenine dinucleotide) directly to oxygen (or air) with

the cultured product. The reduction of diacetyl plays *the formation of nontoxic water and molecular oxy-*

a physiological role in the regeneration of NAD+ to

gen as by-products. The reaction thus provides an

keep the cycle operative. There are a few practical

alternate route for the regeneration NAD+. The al-

steps that could be taken to conserve diacetyl. Under

ternate regeneration mechanism thus

spares diacetyl

normal incubation temperatures used for production

from functioning as the hydrogen acceptor. The en-

of cultured buttermilk and sour cream (21–24◦C),

tire operation could be accomplished by simultane-

the product should be cooled rapidly soon after the

ous cooling of the product with gentle agitation to *incorporate air. Agitation also helps in rapid heat*

possess the enzymes necessary to ferment citrate to

transfer.

diacetyl, but the associated acid-producing lactococci

With the rapid strides in biochemical analyses, en-

(subspecies cremoris and Cit− lactis)

lack these en-

zyme assays, and molecular biology, strategies have

zymes. Thus, diacetyl generation by mesophilic lactic

been worked out for metabolic engineering of high

starters represents coordinate or cooperative activity

diacetyl-producing lactococci. A few successful ge-

of lactococci and leuconostocs.

netic constructs with high potential have already been

In selecting Leuconostoc strains for inclusion in

made. For information on these subjects, the reader

mixed starters, functional compatibility with lac-

is encouraged to consult references listed at the end

tococci should be first determined. Otherwise, the

of this chapter.

cultures will fail to generate flavor in the cultured

More is now known about the nature of EPS pro-

product. Leuconostocs lack the metabolic vigor of

duced by lactococci, the pathways involved in the

lactococci in milk, and to get good flavor generation,

synthesis of EPS, and the genetic sequences that code

lower incubation temperature is

necessary so that a

for EPS production. Some of these aspects are cov-

balanced growth of both leuconostocs and lactococci

ered under specific cultured products discussed else-

is obtained.

where in this book. References provided at the end of

The natural habitat of leuconostocs, like the lac-

this chapter should be consulted for greater details.

tococci, is vegetable matter containing fermentable

sugars. They are introduced in dairy environs from

Comments on Cit + L. lactis subsp. lactis

the green pasture and via fodder fed to the cows.

Morphologically, leuconostocs are spherical cells oc-

Generally, citrate-metabolizing

lactococci are slow

curring in long chains. They are Gram-positive bac-

acid producers. Most strains take longer than

teria, and display unusual resistance to fairly high

20–24 hours to form a firm coagulum in milk. Most

concentration (about 500 □g/ml) vancomycin, an

strains produce a lot of gas (CO_2) in milk. They pro-

antibiotic. Leuconostocs are heterofermentative and

duce a fairly high concentration of diacetyl in milk,

produce D-lactic acid. They are like other LAB,

but they also rapidly reduce diacetyl (have an active

catalase-negative. The citrate metabolic pathway in

diacetyl reductase). They are capable of competing

leuconostocs is the same as that for

Cit+ lactococci

well in the presence of rapid acid-generating

(Fig. 6.2). The heterofermentative dissimilation of

(non-citrate-fermenting) lactococci. They, however,

sugar by leuconostocs through the phosphoketolase

produce relatively high concentrations of acetalde-

pathway (PK) is shown in Figure 6.3. Lactose is trans-

hyde, which skews the ratio of diacetyl and acetalde-

ported in leuconostocs by NL*-galactoside permease,*

hyde in favor of the aldehyde. This imparts an un-

and the disaccharide is cleaved into its hexose units

desirable “green apple flavor” to cultured buttermilk

by NL*-galactosidase.*

and sour cream. For this reason, they are not gener-

ally preferred in starters for cultured buttermilk and

sour cream.

Genus STREPTOCOCCUS

Streptococcus thermophilus is the only species in the

Genus LEUCONOSTOC

genus that is used in dairy starter cultures. The or-

Dairy leuconostocs constitute the secondary or as-

ganism is thermotolerant, and is used

in dairy fer-

sociated bacteria in mesophilic lactic acid starters.

mentations that require a little higher temperature for

The function of leuconostocs in these starters is fla-

incubation and processing (incubation at 35–43◦C;

vor generation. Leuconostocs in pure cultures in milk

processing or cooking of certain cheese in the tem-

do not bring about much change, and are generally

perature range of 48–53°C). Young cells of S. ther-

considered inert. In association with lactococci, how-

mophilus are spherical in shape and occur in chains.

ever, leuconostoc metabolize citrate present in milk

Older cultures or colonial growth on solid media of-

to produce diacetyl. Dairy

leuconostocs ferment lac-

ten display altered morphology, almost resembling

tose, but very slowly. Lactococci and leuconostocs

short rod-shaped bacteria. S. thermophilus is included

act synergistically in generating diacetyl from citrate

in Sherman's varidans group, but does not fall under

found in milk. For optimal activity of citrate perme-

any of Lansfield's serological groupings. Transporta-

ase, acid environment is necessary. The lactococci,

tion of lactose into S. thermophilus cells is medi-

which rapidly ferment lactose in milk, facilitate

ated by NL-galactoside permease, and NL-galactosidase

the uptake of citrate by leuconostocs. Leuconostocs

cleaves the disaccharide. The organism *metabolizes*

Lactose

1

Galactose

Glucose

ATP

Leloir

ATP

2

ADP

4

Pathway

ADP

Galactose-1-P

3

5

Glucose-1-P

Glucose-6-P

NAD+

6

NADH

6-Phosphogluconate

7

Ribulose-5-P

CO2

8

Xylulose-5-P

9

Pi

10

Glyceraldehyde-3-P

Acetyl-P

ADP

P

NAD+

i

CoASH

ATP

P

17

i

11

NADH

Acetate

1,3-Diphosphoglycerate

Acetyl-CoA

ADP

NADH

18

12

ATP

NAD+

CoASH

3-Phosphoglycerate

13

Acetaldehyde

2-Phosphoglycerate

NADH

14

19

NAD+

Phosphoenolpyruvate

ADP

Ethanol

15

ATP

Pyruvate

NADH

16

NAD+

D-Lactate

Figure 6.3. *Heterofermentative pathway for lactose metabolism among starter lactic acid bacteria.*

1 = NL-galactosidase, 2 = galactokinase, 3 = glucose:galactose-1-phosphate uridyl transferase uridine diphosphate-glucose epimerase, 4 = glucokinase, 5 = phosphoglucomutase, 6 = glucose-6-phosphate dehydrogenase, 7 = 6-phosphogluconate dehydrogenase, 8 = epimerase, 9 = phosphoketolase, 10 = acetate kinase, 11 = triose phosphate dehydrogenase, 12 = phosphoglycerokinase, 13 =

phosphoglyceromutase, 14 = enolase, 15 = pyruvate kinase, 16 = lactate dehydrogenase, 17 = phosphoacetyl transferase, 18 = acetaldehyde dehydrogenase, 19 = ethanol dehydrogenase. Adapted from Hutkins, 2001, and Ray, 2004.

only the glucose portion of lactose via HMP, and *galactose is expelled from the cell into the environ-*

ment. In the dairy industry, the organism is often re-

ferred to as "coccus."

S. thermophilus cultures generally produce a weak

coagulum in milk because of low acid production.

Some strains, however, are rapid acid producers and

generate acidity comparable to lactococci. The acid-

producing ability of S. thermophilus strains was re-

cently shown to be inversely related to its urease ac-

tivity. Urea normally occurs in milk, and the enzyme

urease splits urea into ammonia and carbon dioxide.

S. thermophilus strains are normally used in asso-

ciation with Lb. delbrueckii subsp. bulgaricus. The

Lactobacillus subspecies is commonly

referred to as

"rod" in the dairy industry, and the combination of the

two bacteria is called "rod-coccus." The rod-coccus

combinations display synergistic growth response in

milk. To maximize the synergistic effect, strains of

the bacteria need to be paired with care after exper-

imenting with various combinations.

The synergism between the coccus and the rod is

rooted in their individual physiological characteris-

tics. S. thermophilus is more aerotolerant than Lb.

bulgaricus. The coccus lacks good proteolytic abil-

ity relative to the rod, but possesses greater peptidase

activity than the rod. When growing together in milk,

S. thermophilus grows vigorously at

first, because of

Figure 6.4. *Stained cells of Streptococcus*

thermophilus under light microscope.

greater aerotolerance. The rod at this stage grows

slowly but because of its greater proteolytic activity

provides sufficient peptides to stimulate the growth

of the coccus. Fermentation by S. thermophilus de-

presses the oxidation–reduction O/R potential of the

viscous body and smooth texture. The genetics and

system, and releases formate as a metabolic by-

physiology of EPS production by coccus are now

product. Lowered oxygen tension and formate in

well understood. More information on the genetics

turn stimulate Lb. bulgaricus growth,

which is fur-

of S. thermophilus is now available in the literature.

ther aided by the amino acids released by the active

peptidases secreted by the coccus. The coordinated

Genus LACTOBACILLUS

tandem activities of the coccus and the rod accelerate

the entire fermentation, which neither the coccus nor

Lactobacilli are rod-shaped, Gram-positive bacteria.

the rod would be able to achieve individually. The

Morphologically, they are variable. Some occur as

dominance of S. thermophilus in the milk fermenta-

long slender straight rods; others are curved. Some

tion wanes when the pH approaches 5.0. Beyond that,

others are short, almost coccoid rods.

A few exhibit

Lb. bulgaricus gradually supplants the coccus in the

pleomorphic cells. On the basis of sugar metabolism,

overall fermentation.

lactobacilli are divided into three groups. The lacto-

The cell morphology of S. thermophilus as it ap-

bacilli generally used as starters for cultured milks *pears under a light microscope is shown in Figure*

are Lb. delbrueckii subsp. bulgaricus and Lb. aci-

6.4. In Figure 6.5, the cell morphology of Lb. bul-

dophilus. Occasionally, Lb. delbrueckii subsp. lactis

garicus is shown. Cells of yogurt starter bacteria in a

may be used. All the aforementioned lactobacilli be-

microscopic smear are shown in Figure

6.6.

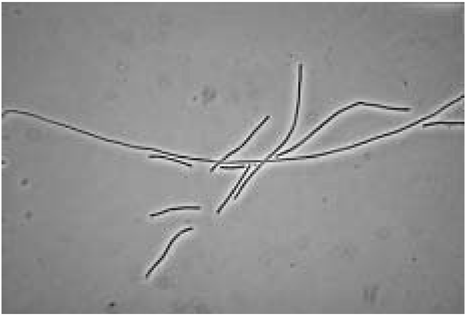
long to group 1. Group 1 lactobacilli ferment hexoses

S. thermophilus strains also produce EPS. Such

via HMP to lactic acid, and do not ferment pentoses.

strains are used in yogurt fermentations to obtain

The morphological and physiological characteristics



6 Starter Cultures for Yogurt and Fermented Milks

Figure 6.5. *Stained cells of Lactobacillus*

delbrueckii ssp. bulgaricus under light

microscope.

of lactobacilli used in dairy starter cultures are given

Lactobacillus subsp. lactis, on the other hand, is

in Tables 6.2–6.4.

comparatively a rugged organism and is easier to

Lb. bulgaricus is used in combination with S. ther-

grow and concentrate. Because regulations call for

mophilus for the production of yogurt and the in-

the use of subspecies bulgaricus in yogurt, the use of

dustrial production of dahi. Lb. bulgaricus is an ex-

subspecies lactis in yogurt starters is no more prac-

tremely fastidious organism. Lack of

certain essen-

ticed.

tial nutrients and minerals in propagation medium

Lb. acidophilus is a unique organism that is found

affects the cellular integrity of these bacteria, and

in the gut of humans, animals, and birds. The organ-

the cells exhibit abnormal morphology under nutri-

ism possesses the characteristics necessary to sur-

tional stress. Additionally, commercial preparation

vive the harsh environmental conditions in the gut, *of "rod" cultures is an extremely challenging task,*

namely, high acid tolerance and tolerance of surface-

because of their nutritional and environmental (tem-

reducing effect of bile salts. Lb. acidophilus grows

perature and pH control, exclusion of air) fastidious-

slowly in milk, but produces high amounts of lactic

ness, compounded by the need for close *control of*

acid. It is used for the production of acidophilus milk,

harvesting and preservation operations.

which is a highly acidic, acrid product. Acidophilus

Figure 6.6. *Stained microscopic smear of*

yogurt bacteria.

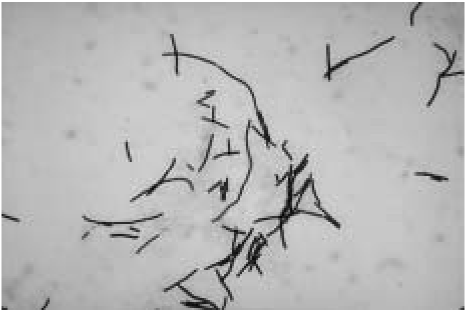


Figure 6.7. Stained cells of Lactobacillus

acidophilus under light microscope.

milk, however, has long been known to be therapeu-

Table 6.6. *Microorganisms Used as*

tic, and helpful in maintaining intestinal health. It is

Probiotics

the forerunner of the present-day sweet acidophilus

Lactobacillus spp.

Bifidobacterium spp.

milk and probiotic milks. For a more extensive dis-

cussion of the use of Lb. acidophilus in cultured dairy

L. acidophilus

products, the chapters in this book dealing with yo-

L. casei

gurt and probiotic milk(s) should be consulted. Cells

L. reuteri

of Lb. acidophilus are shown in Figure 6.7.

L. gasseri ADH

Lactobacilli are also used as probiotic cultures.

L. johnsoni LAI

B. bifidum

Probiotics are microbial cell preparations that have

L. plantarum

B. longum

a beneficial effect on health and well-being of the

L. casei subsp. rhamnosus

B. infantis

host. Probiotic cultures may be

incorporated into fer-

L. brevis

B. breve

mented and nonfermented milk products to provide

L. delbrueckii subsp.

B. adolescentis

beneficial health effects to the consumer. Probiotic

bulgaricus

L. fermentum

B. animalis

cultures, however, cannot be classified as starter cul-

L. helveticus

tures, because probiotic cultures do not play a part

in the fermentation or the preparation of the dairy

Other organisms

product. The cultured or the noncultured milk serves

Streptococcust thermophilus

as the carrier or the vehicle for the delivery of the

Enterococcus faecium

health-promoting probiotic cells. Table 6.6 lists var-

Pediococcus acidilactici

ious probiotic microorganisms in commercial prod-

Saccharomyces boulardii

ucts. Several Lactobacillus spp. are included in the

Source: Reproduced with permission

from Chandan RC.

list.

1999. Enhancing market value of milk. J. Dairy Sci. 62:2248,

American Dairy Science Association.

Genus BIFIDOBACTERIUM

Genus Bifidobacterium consists of cleft, rod-shaped

Nutritionally bifidobacteria are fastidious. They are

bacteria in the shape of the letter "Y." Not all cells *from a portion of the normal intestinal flora of hu-*

in a culture exhibit the split, Y-shaped morphology;

mans. Bifidobacteria could be isolated from the fe-

most of the cells occur as short straight rods. Bifi-

ces of newborn infants. The bifidobacterial species

dobacteria are obligate anaerobes and are catalase-

found in newborn infants differ from

that found in

negative. Some strains may tolerate limited amount

adults. Bifidobacteria are considered to play a role

of air slightly better than others. They are classified

in regulating the ecology and microbial flora of the

under Actinomyces, a subdivision under eubacteria.

gut. This role is considered to have a beneficial, Lactose

1

Galactose

Glucose

ATP

ATP

Leloir

2

Pathway

ADP

ADP

Galactose-1-P

Glucose-6-P

3

6

Glucose-6-P

Fructose-6-P

4

7

Pi

Fructose-6-P

Erythrose-4-P

Acetyl-PADP

8

5

ATP

Acetate

Glyceraldehyde-3-P

Sedoheptulose-7-P

9

Xylulose-5-P

Ribose-5-P

11

Ribulose-5-P

Pi

12

10

Xylulose-5-P

Figure 6.8. *Pathway used by Bifidobacteria*

13

for lactose metabolism.

1 = NL-galactosidase, 2 = glucokinase,

Acetyl-P

2-Glyceraldehyde-3-P

ADP

3 = phosphoglucose mutase,

14

4 = phosphoglucose isomerase,

P

ATP

i

15

5 = transaldolase, 6 = phosphoglucose

2 NADH

Acetate

isomerase, 7 = fructose-6-phosphate

2 NAD+

phosphoketolase, 8 = acetate kinase,

4 ADP

9 = transketolase, 10 = xylulose-

4 ATP

5-phosphate phosphoketolase,

Embden-Meyerhoff Pathway Enzymes

11 = ribose-5-phosphate isomerase,

2-Pyruvate

12 = ribulose-5-phosphate-3

epimerase,

Acetate

13 = xylulose-5-phosphate

2NADH

16

phosphoketolase, 14 = acetate kinase,

Formate

15 = Embden-Meyerhoff pathway enzymes,

2NAD+

16 = lactate dehydrogenase. Adapted from

2-L-Lactate

Cogan and Accolas, 1996, and Ray, 2004.

probiotic effect on intestinal health. Bifidobacteria

Because of the anaerobic nature of bifidobacteria,

use a unique pathway for carbohydrate metabolism.

they are somewhat difficult to grow, harvest, and pre-

The by-products consist of a mixture of acetic and

serve. Their viability is of critical importance in their

lactic acids. The pathway includes a unique enzyme,

use as probiotics. Their interaction with yogurt starter

fructose-6-phosphate phosphoketolase, and is used as

bacteria and other probiotic lactobacilli greatly influ-

a key diagnostic test to identify

bifidobacteria. The

ences their viability in these systems. Hydrogen per-

pathway for lactose metabolism by bifidobacteria is

oxide generated by the associated flora also affects

depicted in Figure 6.8.

bifidobacterial viability in mixed culture systems.

Further details are given in the chapter dealing with

amount of powder and mixing to get the solids

probiotic milks in this book.

completely dissolved. Care should be exercised to

wash down any milk solids adhering to the sides

STARTER CULTURE

of the vat above the liquid level.

PRODUCTION

2. Heating the milk to 85–90◦C, and holding at that

temperature for 30–45 minutes to destroy contam-

This section may be discussed under two subhead-

inants in the milk including spore-forming bacte-

ings, namely, bulk starter production in the dairy plant

ria and phages if any.

and commercial starter culture production. With the

3. Cooling to the required incubation temperature by

exception of yogurt production, where bulk starters

turning on the chill water with the agitator turned

are still widely used, for most other cultured dairy

on.

products, commercial, concentrated direct-to-vat-set

4. Inoculation with the culture using aseptic precau-

(DVS) cultures are used to inoculate product vats. For

tions with agitation to uniformly mix in the inocu-

probiotic supplementation of cultured dairy products

lum.

and nonfermented milk, DVS cultures of probiotics

5. Incubating at thermostatically preset temperature

are used. Currently DVS cultures to inoculate up to *quiescently. If the temperature and pH recording*

4,000 liters are commercially available.

equipment are connected to the vat, they need to

be turned on.

6. When the desired pH is reached, cooling with

Bulk Starter Production

agitation should be promptly initiated. Agitation

Unlike starters for cheese production, starter cultures

should be slow and gentle. The starter is ready

for cultured milks are made with milk. Reconstituted

for use once the cooling to the desired tempera-

skim milk powder (nonfat dry milk powder) is pre-

ture (preferably 5–7◦C if needed to be held longer

ferred for making up starter cultures, *because consis-*

before use) is reached.

tency in composition, microbial quality, and absence

The incubation temperature would vary with the

of inhibitors and antibiotics are necessary. Pretested

starter flora. For cultured buttermilk and sour cream

nonfat milk powder (tested for absence of inhibitors, *production, the starter is incubated at 20–22◦C. For*

good solubility, and for supporting good growth and

yogurt, the starter is incubated at 35–37◦C if it con-

"activity" of cultures) procured in bulk from specific

tains EPS producers; for regular yogurt starters, most

lots are reserved for starter production. The powder

dairy plants incubate them at around

40–43°C. Care-

is reconstituted to give 10–11% solids.

ful calibration of temperature and pH probes at least

Stainless steel double-jacketed vats equipped with

twice a week is recommended. It is advisable to use

suitable agitators, connected to appropriate plumbing

the starter as soon as it is ready. Other precautions *for circulating hot and cold water (for heating and*

were discussed earlier in this chapter.

cooling cycles), and provided with thermostat equip-

Very few dairy plants nowadays carry their own

ment for temperature control are used. The vats also

strains or maintain a frozen or lyophilized stock.

need sufficient number of sanitary ports for venting, *From the stock culture a mother culture is prepared.*

sampling, and temperature and pH probes. The vents

The mother culture is made up in volumes no greater

need filter setup to exclude microflora and phage dur-

than 1 liter. The milk used in mother culture is heat-

ing cooling, when pressure equilibration takes place.

treated in a steam chamber for 45

minutes. The

Additional ports for adding the inoculum or other ma-

mother culture is used to inoculate an intermediate

terials are also provided. Another requirement is to

culture, which is used to inoculate the starter vat. In-

have a manhole for inspecting and manual cleaning of

oculation rate for cultured buttermilk and sour cream *the vat periodically. Additionally, provisions should*

production is normally 1.0%. Current yogurt produc-

be made for cleaning-in-place (spray-ball) connec-

tion demanding 4-hour turnovers require inoculation

tion to the vats.

rates ranging from 2.5% to 5.0%. To attain shorter

The preparation of starter consists of the following *incubation time in product vats, higher incubation*

steps:

temperature (40–42°C) is necessary. For more de-

1. Reconstitution of skim milk powder to the re-

tailed information on starter preparation for the var-

quired solids level by metering in the required vol-

ious products discussed in this book, the relevant *ume of water, followed by the addition of weighed*

chapters should be consulted.

Commercial Starter Culture

to protect cell membranes, trace quantities of polysor-

Production

bates (Tweens) are added. To control foaming, food-

grade antifoam ingredients may be incorporated.

Commercial starter culture production is a highly

The medium is then either sterilized by heating at

demanding operation. It requires specialized knowl-

121◦C for a minimum of 15 minutes or heat-treated

edge of microbiology, microbial physiology, process

at 85–95◦C for 45 minutes or subjected *to ultra-*

engineering, and cryobiology. In addition to produc-

high temperature treatment (UHT) for a few seconds.

tion knowledge, a full-fledged quality control pro-

After heat treatment, the medium is cooled to the in-

gram is necessary to test incoming raw materials,

cubation temperature. After the addition of the in-

design and maintain plant sanitation, test sterility of

oculum, the medium is incubated until the predeter-

production contact surfaces, monitor plant environ-

mined endpoint is reached. During incubation, the pH

ment quality, and test every product lot for the pre-

is maintained at a predetermined level (constant neu-

scribed quality standards. The quality *control section*

tralization to maintain pH). Generally, the endpoint

is also required to train and update plant personnel

coincides with the exhaustion of sugar reflected by

on the importance of sanitation and strict adherence

the trace of the neutralization curve. The frequency

to process control protocols. The maintenance of the *of neutralization reflects the activity of the culture*

starter culture strain bank, and the entire stepwise

in the fermentor, and when the frequency decreases,

process of preparing the final inoculum for the large-

it indicates the near depletion of the sugar. Samples

scale fermentor (from the stock or "seed" culture

are usually taken to microscopically

examine the fer-

stage), falls under the purview of the quality control

mentate for cell morphology, for any gross contam-

section.

ination, for a rough estimation of cell numbers, and

Commercial starter cultures currently available for

for quantitative measurement of sugar content. After *direct addition to production vats contain billions of*

ascertaining these, the fermentor is cooled.

viable bacteria per gram, preserved in a form that

The cells are harvested either by centrifugation or

could be readily and rapidly activated in the product

by ultrafiltration. The cell concentrate is obtained

mix to perform the functions necessary *to transform*

in the form of a thick liquid of the consistency

the product mix to the desired cultured product. To

of cream and is weighed and rapidly cooled. Ster-

attain that, the selected starter bacteria need to be

ile preparations of cryoprotectants (glycerol, nonfat

grown in a suitable menstruum to high numbers and *milk, monosodium glutamate, sugars, etc.) are added,*

to concentrate the cells. The composition of the me-

and uniformly mixed with the cell concentrate. The

dia used to grow various bacteria differs. Usually, the

concentrate may be filled as such into cans and frozen

materials used in the growth media consist of food-

or frozen in droplet form in liquid

nitrogen (pellets),

grade, agricultural by-products and their derivatives.

retrieved, and packaged. The concentrate as such or

The trade has special requirements for the raw mate-

in pellet form may also be lyophilized in industrial-

rials that go into media formulations and for the way

scale freeze dryers.

they are mixed and processed. Examples of such re-

Quality control tests for commercial cultures in-

quirements include Kosher standards, absence of in-

clude the following:

gredients derived from genetically modified crops,

r

absence of allergenic materials, etc.

Viable cell numbers.

r

The generally used ingredients in media formu-

Absence of contaminants, pathogens, and

lations include nonfat milk, whey, hydrolysates of

extraneous matter.

r

milk and whey proteins, soy isolates, soy protein hy-

Acid-producing and other functional

activities.

r

drolysates, meat hydrolysates and extracts, egg pro-

Package integrity, accuracy of label information

teins, corn steep liquor, malt extracts, potato infu-

on the package.

r

sions, yeast extracts/yeast autolysates, sugars such

Shelf life of the product according to

as lactose, glucose, high-fructose corn syrup, corn

specification.

sugar, sucrose, and minerals such as magnesium,

manganese, calcium, iron, phosphates, salt, etc. For

Miscellaneous Starters

some fastidious bacteria, amino acids and vitamins

may be included. The phosphates are

added to pro-

In traditional production of Kefir, the starter consists

vide mineral requirements as well as for buffering.

of Kefir grains. Kefir grains are made up of polysac-

For some bacteria, which need unsaturated fatty acids

charide matrix with a convoluted structure. Within *the folds of the grain yeasts, an assortment of LAB*

The recommended reviews listed below cover spe-

is found. This flora is responsible for Kefir fermenta-

cific starter bacteria, bacteriophages affecting starter

tion. The grains could be reused. After the completion

bacteria, genetics and physiology of EPS production *of one batch, the grains are strained out, washed in*

by starter bacteria, and other relevant topics on starter

water, dried, and reused. More details on the Kefir

bacteria.

grains and other starters used in Koumiss produc-

tion are discussed in the chapter dealing with those

products.

Books

Cogan TM, Accolas J-P (Eds). 1996. Dairy Starter

BIBLIOGRAPHY

Cultures. VCH Publishers, New York, p. 277.

Literature on starter cultures is extensive and volu-

Foster EM, Nelson FE, Speck ML, Doetsch RN, Olson

minous. It is difficult to cover the vast amount of

JC Jr. 1957. Dairy Microbiology. Prentice-Hall,

information on starter culture bacteria in a chapter.

Englewood Cliffs, NJ, p. 492.

Literature citations were deliberately avoided in this

Gilliland SE (Ed). 1985. Bacterial Starter Cultures for

Foods. CRC Press, Boca Raton, FL, p. 205.

chapter to provide continuity, and to avoid an exten-

Kosikowski FV, Mistry VV. 1997. Cheese and

sive bibliography. Instead references for the follow-

Fermented Milk Foods, Vols. I and II, 3rd ed. F.V.

ing books, book chapters, monographs, reviews and

Kosikowski, L.L.C., Westport, CT.

research articles are provided for the reader to gain

Ray B. 2004. Fundamental Food Microbiology. CRC *a greater understanding of starter flora, their phys-*

Press, Boca Raton, FL, pp. 142–146.

iology, their genetics, their functions in fermented

Salminen S, von Wright A (Eds). 1998. Lactic Acid

dairy products, and their various applications in dairy

Bacteria—Microbiology and Functional Aspects.

foods.

Marcel Dekker, New York, p. 617.

For a comprehensive treatment of starter cultures,

Sandine WE. 1979. Lactic Starter Culture Technology,

the reader should consult Dairy Starter Cultures

Pfizer Cheese Monographs. Pfizer Inc., New York,

(1996), Bacterial Starter Cultures for Foods (1985),

p. 55.

and Lactic Acid Bacteria—Microbiology and Func-

Sellars RL, Babel FJ. 1985. Cultures for the

tional Aspects (1998). For the technology and prac-

Manufacture of Dairy Products, 2nd ed. Chr.

tical aspects of dairy starter cultures, the monograph

Hansen's Laboratory Inc., Milwaukee, WI, p. 62.

Lactic Starter Culture Technology is

recommended.

Other practical information on starter cultures may

be gleaned from Cheese and Fermented Milk Foods,

Chapters in Books

Volumes I and II (1997), and the trade publica-

tion Cultures for the Manufacture of Dairy Products

Arihara K, Luchansky JB. 1995. Dairy Lactobacilli. In:

(1985). For historical and basic information on lactic

YH Hui, GG Khachataurians (Eds), Food

starter cultures, the book Dairy Microbiology (1957)

Biotechnology: Microorganisms. VCH Publishers,

is excellent.

New York, pp. 609–643.

There are chapters from several books that deal

Chandan RC, Shahani KM. 1995. Other fermented

dairy products. In: H-J Rehm, G Reed (Eds),

with starter cultures. They contain valuable infor-

Biotechnology, Vol. 9: Enzymes, Biomass, Food and

mation. In Dairy Microbiology Handbook (2002),

Feed. VCH Publishers, New York, pp. 386–418.

Tamime has covered several aspects of

the organisms

Dessart SR, Steenson LR. 1995. Biotechnology of

used in dairy starter cultures, and their production.

dairy Leuconostoc. In: YH Hui, GG Khachataurians

In Food Biotechnology (1995), dairy lactococci are

(Eds), Food Biotechnology: Microorganisms. VCH

discussed by Sanders, dairy lactobacilli by Arihara

Publishers, New York, pp. 665–702.

and Luchansky, and dairy leuconostocs by Dessart

Frank JF, Hassan AN. 2001. Starter cultures and their

and Steenson. The book Applied Dairy Microbiol-

use. In: EH Marth, JL Steele (Eds), Applied Dairy

ogy (1998) contains a chapter on starter cultures by

Microbiology, 2nd ed. Marcel Dekker, New York, *Frank and Hassan, and the genetics and metabolism*

pp. 151–206.

of starter cultures are covered by Steele. Vedamuthu

Hutkins RW. 2001. Metabolism of starter cultures. In:

has discussed the role of starter cultures in flavor gen-

EH Marth, JL Steele (Eds), Applied Dairy

eration in fermented foods in a chapter in Handbook

Microbiology, 2nd ed. Marcel Dekker, New York,

on Anaerobic Fermentations (1988).

pp. 207–241.

6 Starter Cultures for Yogurt and Fermented Milks

115

Porubcan RS, Sellars RL. 1979. Lactic starter culture

Everson TC. 1991. Control of phage in the dairy plant.

concentrates. In: HJ Peppler, D

Perlman (Eds),

Bull. Int. Dairy Fed. 263.

Microbial Technology, Vol. 1, 2nd ed. Academic

Hemme D, Foucaud-Scheunmann C. 2004.

Press, New York, pp. 59–92.

Leuconostoc, characteristics, use in dairy

Sanders ME. 1995. Lactococci. In: YH Hui, GG

technology and prospects in functional *foods. Int.*

Khachataurians (Eds), Food Biotechnology:

Dairy J. 14:467–494.

Microorganisms. VCH Publishers, New York, pp.

Hugenholtz JM. 1993. Citrate metabolism in lactic

645–664.

acid bacteria. FEMS Microbiol. Rev. 12:165–178.

Steele JL. 1998. Genetics and

metabolism of starter

Hugenholtz JM, Starrenburg JC, Veerkamp AH. 1994.

cultures. In: EH Marth, JL Steele (Eds), Applied

Diacetyl production by Lactococcus lactis:

Dairy Microbiology, 1st ed. Marcel Dekker, New

Optimisation and metabolic engineering. In:

York, pp. 173–194.

Proceedings of the 6th European Congress on

Tamime AY. 2002. Microbiology of starter cultures. In:

Biotechnology, pp. 225–228.

RK Robinson (Ed), Dairy Microbiology Handbook:

Mercenier A. 1990. Molecular genetics of

Microbiology of Milk and Milk Products, 3rd ed.

Streptococcus thermophilus. FEMS Microbiol. Rev.

John Wiley & Sons, New York, pp. 261–366.

87:61–74.

Vedamuthu ER. 1998. Engineering flavor into

Moineau S, Tremblay D, Labrie S. 2002. Phages of

fermented foods. In: LE Erickson, DCY Fung (Eds),

lactic acid bacteria: From genomics to industrial

Handbook on Anaerobic Fermentations. Marcel *applications. ASM News 68:388–393.*

Dekker, New York, pp. 641–694.

Neve H, Teuber M. 1991. Basic microbiology and

molecular biology of bacteriophages of lactic acid

Review Articles and

bacteria in dairies. Bull. Int. Dairy Fed. 263.

Research Papers

Nomura M, Kobayashi M, Ohmomo S, Okamoto T.

2000. Inactivation of the glutamate dehydrogenase

Allison GE, Klaenhammer TR. 1998. Phage resistance

gene in Lactococcus lactis subsp. cremoris. Appl.

mechanisms in lactic acid bacteria. Int. Dairy J.

Environ. Microbiol. 66:2235–2237.

8:207–226.

Oberg CJ, Broadbent JR. 1993. Thermophilic starter

Boucher I, Moineau S. 2001. Phages of Lactococcus

cultures: Another set of problems. J. Dairy Sci.

lactis: An ecological and economical equilibrium.

76:2392–2406.

Recent Res. Dev. Virol. 3:243–256.

Orban JL, Patterson JA. 2000. Modification of the

Broadbent JR, McMahon DJ, Walker DL, Oberg CJ, *phosphoketolase assay for rapid identification of*

Moineau S. 2003. Biochemistry, genetics and

bifidobacteria. J. Microbiol. Methods 40:221–224.

applications of exopolysaccharide production in

Van Kranenberg R. 1999. Exopolysaccharide

Streptococcus thermophilus: A review. J. Dairy Sci.

biosynthesis in Lactococcus lactis: A

molecular

86:407–423.

characterization. Doctoral Dissertation, Wageningen

Chandan RC. 1999. Enhancing market value of milk

University, Holland, Ponsen Looijen BV,

by adding cultures. J. Dairy Sci. 82:2245–2256.

Wageningen, Holland.

Cogan TM, Peitersen N, Sellars RL.

1991. Starter

Vedamuthu ER. 1994. The dairy Leuconostoc: Use in

system. Bull. Int. Dairy Fed. 263.

dairy products. J. Dairy Sci. 77:2725–2737.

Deveau H, Moineau S. 2003. Use of RFLP to

Zourari A, Accolas JP, Desmazeaud MJ. 1992.

characterize Lactococcus lactis strains producing

Metabolism and biochemical characteristics of

exoploysaccharides. J. Dairy Sci. 86:1472–1475.

yogurt bacteria. A review. Lait 72:1–34.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

7

Laboratory Analysis of

Fermented Milks

Robert T. Marshall

Compositional Tests

Tests of the fermented product, done prior to the ad-

Tests for Fat Content

dition of fruits, flavorings, and other additives, reveal

Tests for Moisture and Total Solids

whether the formulated and processed

product meets

Tests for Nonfat Milk Solids

the specifications. Together these pre- and postpro-

Tests for Protein

cessing tests reveal whether the product contains the

Tests for Lactose

correct amount of valuable characterizing ingredients

Titratable Acidity

and has been fermented correctly. When flavorings

Measurement of pH

or other additives are added, further testing may be

Chemical Tests

Tests for Flavorful Substances

needed to determine whether specifications for color,

Tests for Free Fatty Acids

viscosity, flavor, distribution of particulates, and fill-

Physical Properties Tests

ing of containers have been satisfied. The finished

Density and Specific Gravity

product then needs to be tested for microorganisms

Rheological Tests

that are indicators of postprocessing contamination.

Water-Holding Capacity

Usually this is done with a test for coliform bacteria

Microbiological Properties

or for enterobacteria. Some manufacturers test for

Tests for Coliform Bacteria

yeasts and molds. Microbiological tests of ingredi-

Tests for Enterobacteriaceae

ents are needed when significant risks to safety and/or

Yeast and Mold Counts

quality are encountered.

Tests for Culture Bacteria

Antimicrobial Substances

This chapter has been designed to present a com-

Sensory Tests

prehensive discussion of tests that may be used with

Preference Testing

fermented dairy products and their ingredients. The

Acceptance Testing

categories are compositional, chemical, physical, mi-

Descriptive Analysis

crobiological, antimicrobial substance, and sensory

Sensory Tests for Quality Control

tests. The approach used is to discuss the general

References

principles and applications of the tests, to provide

references of sources of most of them, *and to com-*

Routine analyses of fermented milk products are lim-

ment on the utility of the tests.

ited normally to those that are pertaining to the gross

composition of the product and to its quality and

COMPOSITIONAL TESTS

safety. The progress of fermentation is monitored

with tests of the acidity or pH value.

Composition

The main purpose of compositional testing is to deter-

is controlled primarily by tests done on the ingredi-

mine whether the amounts of valuable characterizing

ents at the time of preparation of the basic mix. These

ingredients are within formulated tolerances. Most

tests are usually limited to the analyses of the con-

important among these are the milk fat and nonfat

tent of fat and total solids of the dairy ingredients.

milk solids components. When concentrated or dried

sources of ingredients are used, moisture content or

milk, and cream, diameters of the necks *of test bottles*

total solids must be known. Knowing these parame-

vary directly with the expected fat content.

ters, the process of standardization can proceed. For

example, in preparing sour cream, nonfat milk may

be combined with heavy cream to adjust the fat con-

Gerber Test

tent to 18%. The formula then depends on how much

Similar to the Babcock test, a volume of sample is

fat is present in each ingredient and on how much the

measured into a test bottle containing concentrated

fat will be diluted with other additives such as nonfat

sulfuric acid. After the milk or cream is mixed with

dry milk and stabilizer.

the acid, isoamyl alcohol is added and further mixing

is done to fully digest the nonfat components. Cen-

Tests for Fat Content

trifugation separates the fat from the aqueous phase,

and tempering in a water bath permits reading of the

The volumetric Babcock and Gerber methods, the

volume of extracted fat in the calibrated neck of the *gravimetric ether extraction method, and instrumen-*

specially designed Gerber test bottle.

tal tests are available. These methods are described

in Standard Methods for the Examination of Dairy

Products (Hooi et al., 2004). The International Dairy

Ether Extraction Test

Federation has set tolerances for testing the percent-

age of fat in dairy foods as follows: milk, 0.02%; skim

Precise determination of fat content is provided by

milk, 0.01%; and 20% cream, 0.1%. Application of

the ether extraction method, which is also known as

a satisfactory method should result in no more than

the Roese–Gottlieb test or the Mojonnier modifica-

5% of the tests falling outside these

limits. Although

tion of that test. This is the official reference method

the varying viscosities of cream make it necessary

for milk fat. Weighing of the sample and of the ex-

to weigh the sample in performing the Babcock and

tracted fat reduces the probability of error that may be

Gerber tests, the amount of fat extracted is deter-

introduced by the volumetric measurements used in

mined by measurement of the height of fat column in

the Babcock and Gerber tests. Furthermore, this test

the graduated cylinder of the test bottle. Applications

is easily adapted to testing all types of fermented milk

of these "volumetric-type" tests are limited to liquid

products regardless of their viscosity *and composi-*

products, and added sugars may produce charred par-

tion. Ammonium hydroxide and ethanol are added to

ticles that occlude the fat column.

condition the sample prior to the extraction of fat with

ethyl ether and petroleum ether. The lighter weight

solvent layer that contains the fat is separated from

Babcock Test

the aqueous layer by centrifugation before it is poured

The method calls for measuring a specific volume

into a clean, dried, and preweighed dish. Traces of fat

of milk, nonfat milk, or cream into a bottle that has

are removed from the residue in the extraction flask

a calibrated neck, digesting the nonfat organic sub-

by twice-repeated extractions with ether. The ether

stances of the sample with concentrated sulfuric acid,

is then evaporated from the dish leaving the fat in

centrifuging to separate the light-weight fat from the

the dish. After cooling in a desiccator, the dish plus

heavier serum. Then water is added to the sample to

fat is weighed and the net weight of the *fat is de-*

cause the fat to rise into a calibrated neck of the test

termined. The percentage of fat is then calculated as

bottle, and the sample is centrifuged again to cleanly

weight of fat divided by weight of sample × 100.

separate the fat into the neck where its volume is mea-

Sample weight varies inversely with the percentage *sured. Close control of the temperature of the test is*

of fat expected in the sample. In transferring the sam-

required, especially at the time of reading the volume

ple to the extraction flask it is important to assure that

of fat in the neck of the bottle. Heat produced by the

the sample is homogenous. Warming of raw milk de-

chemical degradation of the milk's

protein and car-

creases the tendency for fat to stick to the surfaces of

bohydrate components, as well as the high density

pipets.

of the sulfuric acid provides a large difference in the

densities of the serum and fat. In addition, the acid

Instrumental Tests

breaks the emulsion of the fat by

digesting the fat

globule membrane. Because of the large difference

The absorption of infrared energy at different wave-

in the amount of fat contained in skim (nonfat) milk,

lengths by certain bonds of fats, proteins, and *carbohydrates coupled with the abilities to measure*

concentrated dairy products, including yogurt, calls

that absorption has made possible the development

for adding about 25 g of clean sand and a small stir-

of instruments that can quantify the amount of these

ring rod to the weighing dish then drying this in a

components in milk and certain milk

products. Op-

vacuum oven at 102◦C for at least 1 hour. After the

timal absorption is observed for carbonyl groups in

sample is weighed into the center of the cooled pan,

ester linkages of fat molecules at 5.723 nm, for car-

the sample is mixed into the sand with the stirring

bon to hydrogen bonds in fatty acids at 3.47 nm, for *rod and is covered with a dried fiberglass cover. The*

peptide linkages of proteins at 6.465 nm, and for hy-

entire unit is then placed in the vacuum oven to dry

droxyl groups in lactose molecules at 9.610 nm. Al-

for 2 hours at 102◦C and at a minimum vacuum of

though absorption is not solely by these bonds, cor-

−86 kPa. After cooling the dish in a

desiccator at

rections can be made for absorption by other species

room temperature for 45 minutes, the dish is weighed

of bonds. Although the instruments are expensive the

on an analytical balance. The percent moisture is cal-

rate of testing can be quite high. Samples of milk

culated by dividing the loss in weight by the weight *must be homogenized uniformly to minimize the er-*

of the sample and then multiplying the result by 100.

ror caused by light scattering. The instrument must

The percent solids is 100 minus the percent mois-

be calibrated with samples of the same type of milk

ture. A small amount of dried air is permitted to pass

that are being tested by the reference *method.*

through the oven during drying. The reference meth-

Another instrumental method of determining fat

ods of the International Dairy Federation for milk,

content of samples employs nuclear magnetic res-

cream, and evaporated milk (Anonymous, 1987) and

onance (NMR) technology developed by the CEM *for yogurt (Anonymous, 1991) call for drying the*

Corporation. The sample must first be dried to re-

samples at 102◦C.

move hydrogen bound in water of the sample. The

The forced-draft oven may be used for most of the

instrument then sends a pulse of radio-frequency en-

milk products and their ingredients. After weighing *ergy through the sample causing the remaining hy-*

into the dried dish, liquid samples are evaporated to

drogen to generate a signal known as free induction

a semidry state on a steam bath. Oven temperature

decay (FID). The intensity of the FID is then ana-

for milk products is 100◦C and the time of heating

lyzed to determine the amount of

protons of the fat

is 3 hours. Following drying the procedure continues

present in the sample. In the application by the CEM

as with the vacuum oven method.

firm the sample is dried in their moisture/solids an-

alyzer, rolled into a film, and inserted into the NMR

Microwave Oven Test

chamber for analysis. The test is

reported to have a

precision of ±0.01%, is applicable to a wide variety

Moisture of solid and semisolid samples can be de-

of samples, and requires a few minutes for comple-

termined by a microwave oven method. Since mi-

tion (www.cem.com).

crowave units vary in power and uniformity of dis-

tribution of that power, power setting, position in the

unit, and time of drying must be determined for each

Tests for Moisture and Total Solids

unit and the expected moisture content of the sam-

ple. These results should be compared to the results

Hot Air Oven Tests

obtained by a reference method. The sample, located

The rather simple test for moisture and total solids

between the dried fiberglass pads, is placed on the an-

in most milk products involves evaporation of wa-

alytical balance inside the oven where it is weighed,

ter from a weighed sample followed by weigh-back

dried, and weighed back. Some instruments provide

of the cooled dish containing the dry

sample. Ei-

direct reading of the moisture or solids.

ther a vacuum oven or a forced-draft oven may be

used in the official method for fermented dairy foods

Infrared Instrument Test

(see AOAC Official Methods of Analysis or Stan-

dard Methods for the Examination of Dairy Prod-

Total solids in milk can be estimated using infrared

ucts) (Horowitz, 2003; Wehr and Frank, 2004). The

milk analysis instruments that are capable of deter-

procedure calls for accurate and quick weighing of

mining the content of fat, protein, and lactose. An ex-

3 ± 0.5 g of sample into a dry “moisture dish” on an

perimentally determined factor is

added to the sum of

analytical balance. Conditions of drying vary with the

the content of these major fractions of milk to provide

type of sample and oven. The sand pan method for

the amount of total solids.

Tests for Nonfat Milk Solids

an excess of dye is added to a specified quantity of

acidified sample, the dye-protein complex that forms

When the sample is composed only of the con-

can be removed and the amount of unbound dye

stituents of milk, the percentage of nonfat milk solids

can be quantified colorimetrically. This value is then

is the product of subtraction of the

percent fat from

compared to values in a calibration curve to ascer-

the percent total solids. Direct determination of non-

tain the protein content. Acid orange 12 is the dye

fat solids content of products containing constituents

that has been selected for the official dye-binding test

other than milk requires detailed analyses and is not *published in Standard Methods for the Examination*

practical under industrial conditions. Knowledge of

of Dairy Products (Hooi et al., 2004). Since the dye-

the amount of each ingredient used plus the composi-

binding constant between normal milk protein and

tion of the ingredients containing milk solids permits

acid orange 12 is known, the amount of *dye bound*

accurate calculation of the nonfat solids content of the

in a test can be used to calculate the amount of milk

product. For example, when 20% flavoring is added

protein in a tested sample. Treatments that change the

to plain nonfat yogurt that contains 14% total nonfat

nature of the protein affect the dye-binding constant *milk solids, the nonfat solids content of the finished*

and, therefore, produce error in the test. Since con-

product is [(100–20)/100] 14 = 11.2%.

centrations of the various protein fractions of milk

vary among animals, the test is more variable among

Tests for Protein

cows than among lots of mixed herd milk.

Although the content of protein is not determined rou-

tinely for most dairy products, protein in raw milk is

Infrared Analyzer Test

measured in markets in which producers receive pay-

As presented in the preceding discussion of instru-

ment on a component basis. Furthermore, the aver-

mental methods of determining fat content, the ap-

age protein content must be known for the purpose of

plication of infrared light to compositional analysis

creating nutrition facts labels. Therefore, processors

includes quantification of protein. Because of their

may need to know the protein content of ingredients

unique absorption of infrared energy, the number of

or products.

peptide bonds of proteins can be quantified and the

data used in comparison to a standard curve. This

Kjeldahl Test

curve is constructed using samples that have been

tested by the Kjeldahl reference method. These “cal-

This is the reference method for protein. The major

ibration samples” are tested on the infrared analyzer, *steps in the procedure follow. A known quantity of*

and the standard curve is developed by the software

sample is digested by boiling in concentrated sulfuric

of the instrument.

acid plus a catalyst. The nitrogen that is freed from

the protein and the nonprotein nitrogen of the sam-

ple are converted to ammonia, and then distilled into

Tests for Lactose

an acid that is partially neutralized by the ammonia.

The concentration of lactose in fermented milk prod-

The excess acid in the receiving flask is then deter-

ucts decreases as fermentation progresses, lactic acid

mined by titration, and the concentration of protein is

being the end product of a series of enzymatic reac-

calculated by multiplying the percent nitrogen in the

tions produced by culture bacteria under anaerobic

distillate by the accepted factor of 6.38 that applies to

conditions. The concentration of lactose in a product

milk proteins. Although this method provides accu-

can be important to persons who are lactose malab-

rate results, it is time-consuming and *fails to provide*

sorbers and need to limit their intake of this natural

a precise value. However, it is the method on which

sugar of milk. Whereas milk normally contains 4.6–

the instrumental tests are calibrated.

5.0% lactose, development of 1% titratable acidity

in that milk reduces the lactose content to about 4%.

However, the addition of nonfat milk solids to milk

Dye-Binding Test

or nonfat milk, as is often done in making cultured

Certain dyes in acidic conditions are bound to amino

buttermilk and yogurt, raises the lactose content by

groups of lysine, arginine and histidine, amino acids

about one-half of the amount of nonfat milk solids *of milk proteins, in a constant manner such that when*

added. For these reasons it is necessary to quantify

the amount of lactose in products to provide infor-

as yogurt increases the apparent acidity, and, conse-

mation for writing the nutrition facts label.

quently, the titratable acidity. Milk tastes sour to most

people when the developed acidity is between 0.05%

and 0.10%. When the titratable acidity of yogurt con-

Polarimetric Method

taining 14% nonfat milk solids is 1%, the apparent

This is the reference method for lactose measure-

acidity would be expected to be about 0.20% and the *ment in liquid milks. The procedure calls for precip-*

developed acidity about 0.80%.

itating the protein from milk with mercuric iodide

The test involves measurement of 9 or 18 g of sam-

and phosphotungstic acid and removing the coagu-

ple into a beaker, addition of two volumes of water

lum, including the fat, by filtration. The rotation of *plus 0.5 ml of the pH indicator phenolphthalein, and*

plane-polarized light in a polarimeter is then read and

titration to the first permanent shade of pink produced

converted to concentration of lactose.

by the indicator. This color appears at a pH of approx-

imately 8.3, a pH at which the buffering capacity of

milk is quite low. The titrant, 0.1000N sodium hy-

HPLC Method

droxide, is added from a calibrated buret. When the

This method provides for weighing 10 ± 0.003 g

sample weight is 9 g and normality of the alkali is

of sample into a 100 ml volumetric flask, and then

0.1000, the titer is easily read as the ml of NaOH used

adding 1 ml of 0.9N sulfuric acid to precipitate the *in the titration divided by 10. This is true because 1 ml*

protein. The sample is diluted to volume before be-

of 0.1N NaOH neutralizes 0.009 g of lactic acid that

ing vigorously shaken. After the curds have settled,

has a molecular weight of 90.

filtrate is collected for injection through a membrane

Error in the test occurs with variations in the appar-

filter (0.45-□m pore size) and into the high-pressure

ent acidity, speed of titration, amount of indicator, and

liquid chromatograph. Samples are carried through

temperature of the sample. When the rate of titration

the chromatographic column with a mixture of ace-

is slow, the calcium phosphate of milk precipitates

tonitrile and water. Standards, made

with ⎵-lactose

freeing hydrogen ions thus neutralizing some alkali.

and NL-lactose, are used as quantitative references. Ar-

Therefore, consistent speed of titration is important.

eas under the peaks of the samples are compared with

Addition of water to the sample lowers the rate of pre-

areas under the peaks of the standards to determine *cipitation of these phosphates and limits the effect of*

concentrations of lactose in the samples.

them on the titer.

In a similar manner concentrations of glucose and

When the color of the sample can interfere with the

galactose, the products of lactose hydrolysis, can be

color of phenolphthalein, it is necessary to detect the *quantified in fermented milk products.*

end point of the titration at pH 8.3 with a pH meter.

Titratable Acidity

Measurement of pH

The most important characterizing component com-

The quick and dependable method of measuring the

mon to fermented dairy foods is lactic acid. The most

acid produced during fermentation is

with a pH me-

common method of estimating the content of lactic

ter. The instrument is standardized with solutions of

acid in dairy products is the test for titratable acidity.

buffers that have pH values above and below the ex-

Although lactic acid is not the only acidic substance

pected pH of the samples to be tested. For fermented *in these fermented products, it is the dominant one*

dairy foods this normally means that buffers of pH

so that the result of this test is expressed in percent-

4 and 7 are used to calibrate the instrument. When

age lactic acid. The titratable acidity of fresh milk

measuring or standardizing, the electrode must be

in which no fermentation has occurred

ranges from

immersed sufficiently to cover both the pH-sensitive

0.12% to 0.16% and varies directly with the amount

bulb and the wick of the reference electrode. Often a

of phosphates, citrates, protein, and carbon dioxide in

“combination electrode” is used so that a single bulb

the sample. This “titer” is called the apparent acidity, *is visible. To assure that potassium chloride moves*

and the additional titer that results from fermentation

through the wick, the vent hole on the side of the

of the sugars of milk is called the “developed acidity.”

electrode must be open. The electrode must be kept

Together they constitute the total or titratable acid-

clean. Coatings of fat on the surface

can be removed

ity. Addition of nonfat milk solids to products such

by swabbing the bulb with hexane, isopropanol, or

dilute detergent. The most accurate results are ob-

value is defined as the milliliters of 1N base required

tained when the buffers and samples

are at the same

to neutralize the acids in 100 g of fat. Raw milk nor-

ambient temperature.

mally tests between 0.25 and 0.40. Values exceeding

1.0 are suspect, and most people can detect the rancid

flavor when values reach 1.5.

CHEMICAL TESTS

Abnormal fermentations can produce significant *quantities of acetic and propionic acids. Quantifica-*

Tests for Flavorful Substances

tion of these acids can be done by gas chromatogra-

Certain components of fermented milk products

phy.

characterize typical flavors. The most important of

these flavors are diacetyl of cultured buttermilk, sour *cream, and cottage cheese; acetaldehyde of yogurt;*

PHYSICAL PROPERTIES TESTS

and ethanol of the yeast-fermented products that in-

Producers of fermented milk products generally tar-

clude kefir and koumiss. Because of the high volatil-

get their product's physical characteristics toward

ity of these flavorful substances, their concentrations *a selected market. These characteristics are primar-*

can be determined by gas chromatography (GC).

ily color, texture, body, and, in products containing

Richelieu et al. (1997) developed a method that es-

fruits or other inclusions, the size, color, and dis-

sentially prevents the oxidative decarboxylation of

tribution of particulates. Several of the *physical at-*

␣-acetolactic acid to diacetyl and its subsequent re-

tributes can be measured instrumentally while sen-

duction to acetoin during analysis. This is a potential

sory tests are required to match the results with the

problem in the quantification of diacetyl because of

likes and needs of consumers. In general the desir-

the chemical instability of ⎵-acetolactic acid. The

able attributes of fermented milk products include

method involves adjustment of pH to 7 followed by

color typical of the flavor, body that has significant

headspace analysis by GC. The procedure (Riche-

viscosity or is a soft gel, texture that is smooth, and

lieu et al., 1997) permits the

quantification of other

an abundance of particulates that are typical in color

volatiles in samples including acetone, ethylacetate,

and are distributed uniformly throughout the prod-

2-butanone, ethanol, and acetoin.

uct. The weight per unit volume is of importance in

formulation and preparation of the mix as well as in *some aspects of packaging. Determination of the ef-*

Tests for Free Fatty Acids

fects on viscosity of using "ropy cultures" may be of

particular interest for yogurt producers who seek to

Chemical substances that are detrimental to flavors

enhance the body of yogurts with capsule-producing

of fermented milk products include free fatty acids *lactic cultures. Furthermore, tests of the effects of*

that can be enzymatically released from the acylglyc-

variations in solids content and of added stabilizers

erides of milk lipids. Milk that contains an excess

and emulsifiers include measurements of the physical

amount of free fatty acids is said to be rancid or

properties.

lipolyzed. Concentrations of free fatty acids are most

often determined by the acid degree value test. The

procedure calls for combining 18 g of liquid milk

Density and Specific Gravity

product with surface-active BDI reagent (Bureau of

Dairy Industry reagent) that consists of Triton X-100

Weight per unit volume is rather easily determined, *and sodium tetraphosphate. This mixture, in a*

but density varies inversely with temperature, espe-

Babcock test bottle, is agitated and placed in a boil-

cially with water and fat. Therefore, change in density

ing water bath. After agitating the hot mixture and

with change in temperature may demand considera-

exposing it to heat for 15–20 minutes, *the bottles are*

tion especially when the ingredients are not at the

centrifuged and then filled with aqueous methanol so

same temperature as is the final product. The density

the separated fat rises into the slim neck of the bottle.

of the final product can be predicted when densities

After centrifuging again, the sample is tempered to *and quantities of the ingredients are known. For ex-*

57◦C in a water bath before 1 ml of fat is removed,

ample, assume that sour cream contains 18% fat (F),

dissolved in a 4:1 mixture of petroleum ether and

8% nonfat milk solids (NMS), and 74% water (W)

n-propanol, and titrated to the phenolphthalein end

for which the densities (at 15◦C) are

0.93, 1.58, and

point with 0.02N potassium hydroxide. Acid degree

1, respectively. The following formula is used in the

calculation:

structure as determined by a compression-type test.

As the gel is compressed, an

instrument, such as an

Density =

100

(%F / 0 . 93) + (%NMS / 1 . 58) + (%W / 1)

Instron texture-measuring device, records the stress

(force divided by area of application) in kPa. The

=

100

point at which there is a break in the stress/strain

$(18 / 0.93) + (8 / 1.58) + (74 / 1)$

curve is the yield point, and this point coincides

$= 1.016 g / ml$

with the rearrangement of the internal structure. At a

Specific gravity of a substance is the density of the

somewhat higher stress, called the rupture stress, the *substance divided by the density of water at the same*

structure collapses completely and the product has

temperature. Although the density of milk decreases

properties of a viscous fluid, i.e., it will flow. Stirred

considerably with increases in temperature, for ex-

yogurts may be induced to flow so that the apparent

ample from about 1.032 at 10◦C to

about 1.027 at

viscosity can be measured as with a thin paste. This

40◦C, specific gravity of milk changes little over the

viscosity is shear-sensitive and the yogurt may be

same temperature range. This is true because water

described as partially thixotropic. (With thixotrophic

is the major component of milk.

fluids, as shear rate increases apparent viscosity de-

creases.) Apparent viscosity tends to decrease with

time during application of continuous shearing in the

same way as with cream.

Rheological Tests

The low stresses that must be applied in measuring

The structure of yogurts is basically a protein network *the rheological properties of yogurt require the use of*

that forms during successful lactic fermentation when

delicate instruments. The structure of the yogurt must

the pH is lowered to the isoelectric point of casein,

be undisturbed as measurement commences. There-

about pH 4.7. The strength of this network is affected

fore, preparing of set-type yogurt in the *test appara-*

by several factors. Most processes for yogurt produc-

tus is preferred. With stirred yogurts, recovery of the

tion involve high heat treatment of the milk that re-

structure may take place within a few minutes after

sults in denaturation of the NL*-lactoglobulin and the*

it is disturbed. In comparisons among treatments it

␣-lactalbumin causing them to form complexes with

is necessary to avoid differences in time and tem-

the casein micelles. These complexes increase the

perature among samples within the experiment. The

viscosity of the system. As fat globules are broken

presence of particulates within yogurt leads to vari-

down during homogenization, proteins

are adsorbed

ance in measurements of rheological parameters.

to the newly formed surfaces and the surface area

The fluid nature of cultured buttermilk and other

increases markedly. For example, a globule 5 □m in

such fermented milks permits their viscosities to be

diameter will produce 125 globules 1□m in diameter *measured with instruments such as the cone and*

(d 3) and these will have five times the surface area of

plate viscometer or the double cylinder Couette-type

the original globule. Associations among the restruc-

viscometer. However, the capillary-type viscometer

tured fat globules, resulting from depositions of de-

does not work well for such viscous

materials. It is

natured whey proteins and caseins on their surfaces,

important to observe that with most fermented milk

add strength to the structure. Formulation is an im-

products the measured viscosity decreases progres-

portant determinant of consistency of fermented milk

sively as shear rate is increased. Since the viscosity *products. As solids are added, with the consequent*

that is measured over the span of stresses is not a

reduction in water content, viscosity and firmness

constant value, as would be true of Newtonian fluids,

increase. This is especially true when proteins are

this response is said to be non-Newtonian, and the

added, because they bind water and

their increased

value derived at a single designated stress is referred

concentration enhances the protein structure. Pren-

to as the apparent viscosity.

tice (1992) reported that increasing the dry matter of

yogurt from 12% to 15% resulted in an increase in

Water-Holding Capacity

the firmness of a set yogurt by a factor *of nearly 2*

and of stirred yogurt by slightly more.

One of the defects in appearance of fermented dairy

Although it is possible to measure an apparent

foods is free whey. Although free whey is not in it-

viscosity of broken down yogurt gel, a more use-

self detrimental to the food, presence of it may sug-

ful measure of the firmness of the set-type yogurt is

gest there were problems in production or distribu-

its resistance to rupture, i.e., the yield point of the

tion of the product. Factors that favor the release of

whey from the product include insufficient proteins or *postpasteurization contamination. The test has some*

stabilizing ingredients, improper processing, excess

limitations in application to fermented dairy prod-

acidity, high storage temperature, and/or vibrations

ucts because viability of coliforms is decreased in

of the containers sufficient to destroy a gel network.

the acid environment of these products.

It is recom-

Although visual inspection of the finished product is

mended that tests be completed on freshly processed

the usual method of determining the presence and ex-

samples. Furthermore, the presence of fermentable

tent of the defect, it is possible to quantify the water-

sweeteners in flavored yogurts or other products may *holding capacity of these products by centrifuging*

lead to false positive results.

them at the normal storage temperature in a trans-

Several methods are described in Standard Meth-

parent graduated centrifuge tube. Set-type yogurts

ods for the Examination of Dairy Products (Davidson

should be set in the tube. Stirred-type yogurts and *et al., 2004)**.** The most applicable to fermented prod-*

cultured cream products should be permitted to rest

ucts are the plate method with violet red bile (VRB)

and be refrigerated after filling the tubes to allow de-

agar or the dry rehydratable film (Petrifilm) method.

velopment of the normal structure. This type of test

The plate method can be modified to

improve the

is useful when comparisons are being made among

chances of recovering cells that may have been in-

formulas, especially in tests of stabilizers, protein

jured. The modification calls for plating the sample

types or concentrations, and among heat treatments.

in a layer of tryptic soy agar, allowing it to solidify, *Laboratories should develop their own standards of*

then overlaying that layer with an equal amount of

acceptability based on their unique formulas and op-

double-strength VRB agar. Pectin may be substituted

erations. The objective is to minimize the occurrence

for agar as the gelling agent in the plate test when

and magnitude of the defect under

acceptable condi-

the probability exists that injured cells will be killed

tions of operation.

by the heat of the VRB agar. Incubation is at 32◦C

for 24 ± hours. Typical colonies are dark red and at

least 0.5 mm in diameter on uncrowded plates. Con-

MICROBIOLOGICAL

firmation of the identities of

representative colonies

PROPERTIES

should be done when products contain sugars other

than lactose.

Fermented products of milk were first naturally pro-

The Petrifilm method requires that 1 ml of sam-

duced and became accepted by humans who came

ple be deposited onto a 20 cm2 area of *an absorbent*

to realize that natural souring not only prolonged the

pad that contains nutrients, inhibitor, lactose, gelling

useful life of milk but also decreased the incidence of

agent, and an indicator dye. A transparent film is low-

transmission of disease through it. The production of

ered onto the surface of the prepared plate. After in-

lactic acid in milk decreases the pH to a point below

cubation under the conditions cited above, counts are

which many spoilage bacteria and some pathogens

made of red colonies that are associated with a gas

grow. Furthermore, fermentation reduces the amount

bubble.

of lactose in the product making it more suitable for *consumption to lactose malabsorbing persons than*

the unfermented form of the product. Still there is

Tests for ENTEROBACTERIACEAE

some risk that pathogenic microorganisms may sur-

This group of Gram-negative bacteria containing the

vive in fermented dairy foods. Therefore, tests have

coliform group plus similar microorganisms can fer-

been developed to detect and/or enumerate undesir-

ment glucose when plated in MacConkey glucose

able bacteria in fermented milk products.

agar and incubated at 35◦C for 24 ± 2 hours. The test

is otherwise completed as is the plate-type coliform

test, and it is a more sensitive indicator of postpas-

Tests for Coliform Bacteria

teurization contamination than is the coliform test.

This method selects for aerobic or facultatively

anaerobic, Gram-negative, nonspore-forming, rod-

Yeast and Mold Counts

shaped bacteria that are able to ferment lactose with

the production of acid and gas within 48 hours

Yeast and molds grow well in acidic environments.

when incubated at 32◦C or 35◦C. These bacteria

However, their rates of growth at cold temperatures

are destroyed by pasteurization; therefore, their pres-

are slow. They can be selected from among bac-

ence in finished dairy products is an evidence of

teria in samples by using media acidified to pH

7 Laboratory Analysis of Fermented

3.5 or media containing broad-spectrum antibiotics,

ANTIMICROBIAL SUBSTANCES

i.e., equal portions of chlortetracycline hydrochlo-

ride and chloramphenicol (Frank and Yousef, 2004).

Although the two major reasons for excluding an-

The latter favors recovery of acid-

sensitive fungal

tibiotics from human foods are to protect the con-

cells. Greater recovery of these aerobic fungi is ex-

sumer from untoward reactions to the antibiotic and

pected when samples are surface-plated rather than

to avoid development of resistance by microorgan-

pour-plated. Because these organisms typically grow *isms to antibiotics, the manufacturer of fermented*

slowly at the incubation temperature of 25◦C, in-

dairy foods has the additional and vital concern that

cubation time is 5 days. To limit the spreading of

there be no inhibition of growth of the culture bac-

certain fungi on the plate surfaces, it is recom-

teria by antimicrobial substances.

Therefore, antimi-

mended that rose bengal and dicloran be added to the

crobial tests should be done routinely on the milk to

medium.

be fermented. In the United States it is required that

all bulk truckloads of milk be screened for antibiotics.

This affords a minimal level of protection to the man-

Tests for Culture Bacteria

ufacturer of fermented products. However, screening

tests do not detect all antibiotics nor are they suffi-

Developments in microbiology have made it possible

ciently sensitive to assure that there will be no inhi-

to select, reproduce, and store bacteria that consis-

bition of any specific culture. Standard Methods for *tently produce the desired flavor, aroma, texture, and*

the Examination of Dairy Products (Bulthaus, 2004)

appearance in several types of fermented dairy foods.

provides 18 methods for antimicrobial testing. The

It is sometimes necessary to selectively quantify their

major indicator bacterium used in the tests is Bacillus

numbers in these foods.

stearothermophilus var. calidolactis. In the reference

Counts of lactic acid bacteria are done using

method, spores suspended in an agar medium germi-

Elliker's lactic agar in plates that are either over-

nate and grow rapidly making the medium cloudy if

laid with a layer of the medium or are incubated in

the antibiotic is not present at an

inhibitory concen-

an oxygen-reduced environment. Incubation is for

tration. The milk to be tested is placed on a paper disc

48 hours at 32◦C for mesophilic or 37◦C for ther-

resting on the medium, and the diameter of the zone

moduric bacteria. Because the method has a low de-

of inhibition around the paper disc indicates the con-

gree of selectivity, confirmation of the identities of

centration of the inhibitor present. The test bacterium

representative colonies should reveal Gram-positive,

is sensitive to varying concentrations of several an-

catalase-negative rods, or cocci as expected in the

tibiotics. The same bacterium is used in the Delvotest.

sample. Acid production by well-

separated colonies

In this method a pH indicator dye, nutrients, and milk

can be detected when bromcresol purple indicator is

are added to a small glass vial containing the bacte-

added to the medium.

rial spores and agar. After incubation for 2.5 hours,

Counts of yogurt bacteria are facilitated by the

the analyst checks the color of the medium to see

use of yogurt lactic agar that differentiates rods from

whether the bacterium has grown and produced acid

cocci (Frank and Yousef, 2004). The medium is com-

sufficient to change the color of the medium from

posed of Elliker's lactic agar supplemented with non-

purple to yellow. The Brilliant Black

Reduction Test

fat milk solids. Yogurt is diluted 1:100 in 0.1% pep-

(BR Test AS) is similar to the Delvotest, the main

tone water and blended at high speed for 2 minutes to

difference being the indicator. In the BR Test AS,

break up the chains and clumps of cells. Then 0.1 ml

growth of the B. stearothermophilus var. calidolactis *portions of serial dilutions are surface-plated on dried*

strain C953 cells is indicated when the black dye is

surfaces of the plates. Incubation in an atmosphere

reduced to the colorless state.

low in oxygen and high in CO_2 is at 37◦C for 48 hours.

Immunoassays have been developed for specific

Colonies of Streptococcus thermophilus are small, *antibiotics. In general these assays can be described*

white, and without a cloudy zone; whereas, those of

as follows. A sample of milk is introduced to a solid

Lactobacillus bulgaricus are large, white, and sur-

phase, such as polystyrene, to which are adsorbed

rounded by a cloudy zone.

antibodies for specific antibiotics. Any such antibi-

Diacetyl is produced primarily from citrate by

otics are adsorbed from the milk onto the specific

Leuconostoc cremoris and Lactococcus lactis var.

antibodies. This solid phase is then washed to re-

diacetylactis. These citrate-fermenting bacteria can

move the unadsorbed material, and a tracer with an

be enumerated according to the

International Dairy

attached enzyme is then added. The tracer is adsorbed

Federation Standard 180:1997 (Anonymous, 1997).

to sites on the antibody that contain no antibiotic. A

among a group of samples, they do not reveal the

chromagenic substrate for the specific *enzyme is then*

magnitude of differences within the ranking. How-

added. The amount of color that develops during an

ever, if one sample is consistently ranked at the top

incubation period indicates the amount of the spe-

or bottom of the group, while others are inconsis-

cific inhibitor present. The more antibiotic present *tently ranked, that sample can be considered to differ*

the less color develops, because the adsorbed antibi-

markedly from the others. Analysis of the results of

otic limits the adsorption of the tracer and, thus, the

ranking tests can be analyzed by reference to Basker's

concentration of the enzyme.

tables (Basker, 1988).

It is also possible to do a preference test in which

the panelists scale their degree of preference. For ex-

ample, they may indicate whether the difference is

Manufacturers must have the likes and dislikes of

large or moderate in the like or dislike direction or

consumers in mind as they formulate and produce fer-

whether there is no preference.

mented milk products. Regardless of how positively

the consumer thinks about the nutritional and health

Acceptance Testing

benefits of consumption of these foods, repeated pur-

chases depend heavily on flavor, body, texture, and

The common method of acceptance testing involves *appearance. Therefore, it is vital that the producers*

the use of a hedonic scale that may have 9 or 11 points.

have in place an effective process of evaluating these

A 9-point scale contains the following points: like ex-

characteristics using members of the target popula-

tremely, like very much, like moderately, like slightly,

tion. Obtaining representative

respondents is essen-

neither like nor dislike, dislike slightly, dislike mod-

tial. Frequency of use or purchase of the product is a

erately, dislike very much, and dislike extremely.

good criterion for making selections.

Consumer preferences are considered to exist on a

continuum. Samples are served in randomized suc-

cession and panelists respond by marking on the he-

Preference Testing

donic scale. Truncating the scale to 5 or 7 points is

Consumers are often asked to indicate a preference

not advised since there is a tendency for panelists to

for one product versus another or to rank a group

avoid extremes in ranking. Such a practice will tend *of products in order of preference. Results of such*

to force the results toward the center—neither like

tests are useful in product development. Of course,

nor dislike.

the analyst wants results of preference testing to be

"Just right" scaling is useful in testing whether a

valid. When the question is "Which product do you *selected characteristic is at the desirable level of in-*

like better?" consumers respond to the characteris-

tensity. For example, a "just right" scale of sourness

tics of the product as a whole. To ask them why

would be anchored on the left with "highly lacking

they like it better is likely to lead to confusion on

sourness" and at the other end with

"much too sour."

their part and to difficulty in the analysis on the

It would have "just right" in the center. The distribu-

part of the analyst. Numbers of respondents must be

tion of a desirable set of responses should be peaked

large, and samples must be presented in random order

in the center and symmetrical. The center of the plot-

and coded. The results may be tested with the two-

ted distribution may not, of course, occur over the

tailed z value. Tables showing minimum numbers

"just right" segment of the scale. Furthermore, the

of agreeing judgments for numbers of participants

mean may not reflect the true result if, for example,

up to 100 are published in most

statistics or sensory

the panel contains two groups of consumers, one that

analysis books. Analysts must realize that showing

prefers a high and another low level of the charac-

no significant preference of one sample over another

teristic being tested. The latter may yield a bimodal

does not mean the samples do not differ. For exam-

distribution.

ple, there may be no difference in preference between

peppermint and spearmint, but the two flavors are

Descriptive Analysis

different.

In preference ranking there must be a forced-

Sometimes a detailed description of the sensory at-

choice for each participant so that no *ties in rank are*

tributes of a product is needed to enable comparison

permitted. Although rankings provide preferences

of one product to another or to characterize a single

product. Such a test is called descriptive analysis.

Sensory Tests for Quality Control

The method requires that a specific defined language

In the dairy industry it is a common practice to use

be used in the description of product attributes—a

highly trained analysts to evaluate finished products

language that is fully understood by the sensory pan-

using as a reference the scoring guide generated by *elists. Therefore, sensory judges must be trained to*

the Committee on the Sensory Evaluation of Dairy

use exact product descriptors, ones that will reflect

Products of the American Dairy Science Association.

true differences among the tested products. Further-

In this practice the judge must have a mental standard

more, terms should not be redundant of *or correlated*

of the high quality desired in the product. Defects that

to other descriptors. For example, it is not advisable to

are observed in a product are then given a numerical

use both the terms smooth and coarse in describing

value that determines the acceptability of a product.

texture. Panelists should be able to readily agree on

Often multiple trained judges meet around a set of

the meaning of a specific term. Reference standards

representative samples and, using the scoring guide,

for each descriptor are highly recommended.

come to an agreement as to the acceptability of these

Descriptive analysis is often used in developing a

products. By describing the defects of *the product*

flavor profile of a product. Four to six highly trained

they can develop recommendations for improving

judges are required. Panelists precisely define the fla-

products produced in the future.

vors of the product category over a period of several

It is vital that sensory analysts be screened for re-

days before they are employed in describing the fla-

liability and consistency in judgment. A procedure

vorful components of the target product. Both the

should be in place to ensure that multiple judges agree

intensity of the flavor and the order of occurrence

both on types and intensities of defects, as well as

among all of the flavor notes are

recorded. The panel

their relative importance to the acceptability of the

leader, through discussion and consensus, derives a

fermented dairy food. Use of reference and control

consensus profile from the responses of the panelists.

samples is highly recommended. Reference samples

The method described above has been expanded *are those that have been described by experts as rep-*

to provide quantitative results, i.e., quantitative de-

resenting the ideal product profile of the firm. Control

scriptive analysis (QDA). Data are generated on an

samples are unidentified samples taken from one or

unstructured line scale by a panel of 10 to 12 judges

more of those being evaluated and

placed within the

who individually generate a set of terms to describe

series of samples being evaluated. Consistency can

the product. The panel then develops a standard vo-

be determined by randomly presenting to the analysts

cabulary by consensus. They choose reference sam-

a set of coded samples in which there are multiple *ples and define the descriptors. Evaluations of coded,*

samples of the same product. Abilities to reproduce

randomly served samples are performed individually

the equivalent quality ratings on replicated products

by the panelists. Panelists mark on 6-inch graphic

should be required.

lines anchored with single chosen descriptors (exam-

Since analysts vary in the flavor thresholds for

ple: sourness—from weak on the left end to strong on

significant off-flavors, especially bitter and rancid

the right end of the scale). Numerical values are then

(lipolyzed), it is important that these deficiencies be

found for each descriptor by measurement from the

recognized and controlled.

left end of the line. The resulting data can be analyzed

Implementation of a sensory QC program has four

statistically.

requirements. First, representative products must be

Another method of describing the sensory at-

used to establish quality specifications. Second, qual-

tributes of a food product is called "free-choice pro-

ified sensory analysts must be employed. Third, pro-

filing." Each individual panelist describes the sensory

tocols that will minimize error must be developed

attributes and develops a personal rating scale. This

for testing. These include instructions for collecting,

set of attributes and rating scale are then used by the

storing, and handling samples;

methods of serving,

panelist to describe the product in question. Results

blind coding, and provision of reference samples.

are then subjected to an elaborate statistical proce-

Fourth, procedures must be developed for reporting

dure called the generalized Procrustes analysis. This

and using the data generated, including criteria for *method allows for minimal training of panelists, but*

action.

interpretation of the meaning of the chosen descrip-

Readers are directed to the textbook by Lawless

tors is difficult. Furthermore, the number of descrip-

and Heymann (1999) for further descriptions of these

tors may vary widely among panelists.

methods of sensory analysis.

REFERENCES

Frank JF, Yousef AE. 2004. Tests for groups of

microorganisms. In: H Wehr, JF Frank (Eds),

Anonymous. 1987. Determination of Total Solids in

Standard Methods for the Examination of Dairy

Milk, Cream and Evaporated Milk. Standard

Products, 17th ed. American Public Health

21B:1987. Brussels: IDF/ISO/AOAC.

Association, Washington, pp. 227–247.

Anonymous. 1991. Determination of Total Solids

Hooi R, Barbano DM, Bradley Jr RL, Budde D,

Content in Yogurt. Standard 151:1991. Brussels:

Bulthaus M, Chettiar M, Lynch J, Reddy R. 2004.

IDF/ISO/AOAC.

Chemical and physical methods. In: H Wehr, JF

Anonymous. 1997. Enumeration of Citrate

Frank (Eds), Standard Methods for the Examination

Fermenting Lactic Acid Bacteria in Mesophilic

of Dairy Products, 17th ed. American Public Health

Starter Cultures. Standard 180:1997. Brussels: IDF/

Association, Washington, pp. 363–536.

ISO/AOAC.

Horowitz W. 2003. Official Methods of Analysis, 17th

Basker KD. 1988. Critical values of differences among

ed., 2nd rev. AOAC International, Gaithersberg.

rank sums for multiple comparisons. Food Technol.

Lawless HT, Heymann H. 1999. Sensory Evaluation of

42(2):79–84, 42(7):88–89.

Food: Principles and Practices. Kluwer Academic

Bulthaus M. 2004. Detection of antibiotic/drug

Publishers, Hingham.

residues in milk and dairy products. In: H Wehr, JF

Prentice JH. 1992. Dairy Rheology: A Concise Guide.

Frank (Eds), Standard Methods for the Examination

VCH Publishers, New York.

of Dairy Products, 17th ed. American Public Health

Richelieu M, Houlberg U, Nielsen JC. 1997.

Association, Washington, pp. 293–323.

Determination of á-acetolactic acid and volatile

Davidson PM, Roth LA, Gambrel-Lenarz SA. 2004.

compounds by headspace gas chromatography.

Coliform and other indicator bacteria. In: H Wehr, JF

J. Dairy Sci. 80:1918–1925.

Frank (Eds), Standard Methods for the Examination

Wehr H, Frank JF. 2004. Standard Methods for the

of Dairy Products, 17th ed. American Public Health

Examination of Dairy Products. 17th ed. American

Association, Washington, pp. 187–226.

Public Health Association, Washington.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

8

Fermented Dairy Packaging Materials

Aaron L. Brody

Introduction

the environment whose elements are always working

Fundamentals of Packaging

to revert contents back to their original molecular

Definition

components.

Packaging Technology

This chapter addresses the totality of containment

Graphics

and protection of yogurt and fermented dairy prod-

Structural Design

ucts from process through consumer use but, of

Packaging Materials

course, represents only a brief overview. Readers who

Paper and Paperboard

require greater depth are referred to various textbooks

Metal

Glass

and articles on the subject cited in the bibliography.

Plastic

Much of the secondary literature on this topic is not

Packaging Levels

in the peer-review journals, but will be found in trade

Interactions of Product and Packaging

journals and analogous publications. The informa-

The Package in Product Distribution

tion to be derived from such a probe is generally

Graphic Design and Assessment

contemporary and relevant, and should be valuable

Economics of Packaging

to readers.

Regulation

This chapter begins with fundamentals, includ-

Packaging and the Environment

ing the requirements, the major package materials

Source Reduction

employed, and their principal applications in dairy

Recycling

Incineration

foods. Dairy packaging operations, including those

Biodegradability

for fermented dairy products such as yogurt and cot-

Packaging for Yogurt and Fermented Dairy Products

tage cheese are also described. Since suppliers play

Pasteurized Fluid Milk

a major role in providing packaging integers, they

Shelf Stable Fluid Dairy Products

are classified and in some instances,

identified, with

Solid Dairy Product Packaging

no implication of endorsement as a result of inclu-

Future trends

sion or criticism as a result of omission. The more

Bibliography

traditional (from a dairy technologist's standpoint)

"packaging" or product/packaging interactions are

reviewed. The more traditional (from a packaging

INTRODUCTION

technologist's standpoint) distribution packaging is

also discussed briefly. Graphic design, regulations

Perhaps as much as any component of the dairy prod-

affecting packaging, and the role of packaging solid

uct processing and distribution system, packaging *waste in the environment are discussed. This chap-*

contributes to the safe delivery of the contained prod-

ter concludes with an enumeration of fermented dairy

ucts to end consumers. Without packaging the con-

product packaging, both current and projected for the

tained dairy products would not be protected against

future.

enables the consumer to carry more than one primary

package of a product at a time, i.e., the multipacker.

It is also the external label, carton, tag, etc., that com-

Packaging is the most effective means to protect

plements the primary package.

contained fresh, stable, and fermented dairy prod-

ucts from their point of manufacture through to their

Distribution Packaging

consumption. It is also arguably the most effective

means of communication between the dairy prod-

Distribution packaging is a means of unitizing many

ucts marketer and the end user of the fermented

primary and/or secondary packages to facilitate the

dairy products, since the form and graphics of pack-

movement of a large multiple of packages as a sin-

ages are visible at the instant of purchase decision

gle entity. In this manner the packages *are protected*

and subsequently in the home and/or point of actual

and may be economically moved rather than having

consumption.

to move one package at a time. Typical distribution

packages include corrugated fiberboard cases, shrink

Definition

film bundles, and pallets.

Packaging is the totality of all elements required to

contain the product within an envelope that functions

Packaging Technology

as a barrier between the product and the environ-

Packaging technology is the application of scien-

ment that is invariably hostile to the product unless

tific and technical principles to employ packaging for *the protection afforded by packaging is present. En-*

functional purposes, including protection and com-

vironmental insults include temperature, moisture,

munication.

oxygen, microorganisms, animals, insects, vibration,

impact shock, and human intrusion. By totality is

Graphics

meant the package material and its visual and tactile

appearance, the machinery for linking the product to

Graphics represent the external appearance of the

the package materials, the external distribution pack-

package and usually includes copy, form, shape,

aging and its associated equipment, the distribution

color, typography, pictorials, etc., to *communicate*

itself, opening and removing the contents when and

some essential or desired information to the con-

where desired, disposal of the spent package, etc.

sumer or intermediary.

The package is the material in its structural form

such as a bottle, jar, can, pouch, bag, carton, case, etc.

Structural Design

The most important definitional element is that

packaging is a means of protection for the product

Structural design is the three-dimensional shape

while it is in distribution.

of the package, cylinder, rectangular solid, tapered

cylinder, flat, etc. Structure is also the word used to *connote the components and order of a multilayer*

Primary Packaging

package material such as a flexible lamination.

Primary packaging is that which is in intimate and di-

rect contact with the contents. As such it represents

PACKAGING MATERIALS

the principal barrier between the product and the en-

vironment. Most if not all of the protection against

In an ideal world a single package material and struc-

oxygen, microorganisms, light, moisture gain, or

ture would suffice to protect all yogurts and fer-

loss, etc., is built into the primary packaging. Among

mented dairy products. In this case, a steel can could

the more common primary packages

are metal cans

function in this role, but the size, heavy weight, and

and bottles; glass jars and bottles; flexible pouches,

adverse economics of a steel can in many contexts

paperboard folding cartons; and plastic cups, bowls,

dictate that it may not necessarily be employed when

tubs, and trays.

a less expensive and lighter weight material is avail-

able. Because of the nature of package materials it is

usually necessary to combine different materials to

Secondary Packaging

achieve a desired objective, but even the combination

Secondary packaging is external to the primary pack-

of materials is usually less expensive than employ-

aging and often an outer carton or a multipacker. It

ing all metal or glass plus a metal closure for many

applications. Even metal requires coating for protec-

tion. The corrugated structure consists of three layers

tion to be useful in most food applications, and so *of two outer flat sheets called liners of paperboard,*

even the “single-ply” package materials are really

usually virgin, plus an inner fluted sheet or medium

multiples.

that can be either virgin or recycled. The corrugated

structure offers vertical and horizontal compression

and impact strength to protect the contents, usually

Paper and Paperboard

primary packages.

Paper and paperboard represent by far the most

Increasingly, the printing on corrugated fiberboard

widely used package material both in the United

liners is being improved to permit the cases to be used

States and around the world. Because of its derivation *as retail displays or even as consumer packages and*

from cellulose fibers, paper per se is not a barrier to

multipacks.

moisture or oxygen and so it is generally combined

with other materials such as plastic or even aluminum

Metal

foil to render it effective in packaging applications.

Most of this category is comprised of paperboard

Metal is most often used for cylindrical cans, which

rather than paper, with the dividing boundary being

are either thermally processed for microbiological

0.010 inch caliber or gauge, paper being below the

stability, e.g., evaporated milk, or internally pressur-

line and paperboard being above 0.010

inch.

ized with carbon dioxide as for beer, and carbonated

The two basic types of paperboard are virgin or

beverages. Aluminum is by far the most important

that originating directly and primarily from trees and

metal used for can fabrication, being the primary

their wood, and recycled, or that whose raw material *metal for beer and carbonated beverage cans, and*

is used paper and paperboard. Generally virgin pa-

increasingly used for still beverage cans such as for

perboard, i.e., from tree wood, is cleaner and more

juices and aseptically canned milk, but only sparsely

uniform, and has the greatest strength per caliper (unit

for food cans except for shallow pet

food and fish

gauge). Furthermore, it accepts the barrier material

cans. In the past aluminum cans with easy open tops

for coating more easily than does recycled paper-

were used to contain milk-based puddings and yo-

board. On the other hand recycled paperboard may,

gurts that were filled aseptically. This application *if desired, have a superior surface for printing. Recy-*

has been replaced by barrier plastic cups with pee-

cled paperboard has been used as a secondary (non-

lable flexible lidding materials. Almost all aluminum

food contact) package material for many decades,

cans are two-piece. More recently, impact/extrusion-

with the origins of the material being *largely trim-*

formed aluminum bottles are being applied for dairy

mings and scrap from paper, paperboard, and corru-

products. Bottles are narrow neck structures, usually

gated fiberboard converting plants.

closed with metal screw closures, but sometimes with

Because paperboard is moisture sensitive, for dairy *polypropylene closures.*

products packaging it is generally necessary to pro-

Steel represents the major metal used for food cans,

tect the paperboard, which then functions primarily

usually being coated with chromium oxide and later

as a structural material. Among the coatings used are

coated with a thermoset plastic to protect the metal *low-density polyethylene applied by hot melt extru-*

from corrosion.

sion over the entire surface. Polyethylene is an ex-

Aluminum is also used in very thin or foil gauges

cellent moisture and water barrier to protect the base

−ca 0.00035 inch or below, as a flexible or semirigid

paperboard.

packaging laminant to impart oxygen and water vapor

Paperboard is used in dairy product packaging

barrier to the lamination. In this form, because it is

as the substrate for both gable top and aseptic

fragile, the aluminum must be protected from damage

brick/block-shaped cartons to contain fluids. In the

by plastic or paper.

latter application it is extrusion laminated with plas-

tic and aluminum foil to foster a long time shelf life.

Glass

Coated paperboard is also used to fabricate cups and

trays to contain semisolid dairy products such as yo-

Glass is historically the oldest packaging material

gurt and cottage cheese.

still in use. Glass is the best barrier known and by far

Probably the major dairy products packaging ap-

the most inert to product contents. Furthermore, in

plication for paperboard, however, is in three-layer

appropriate structures, glass has the greatest vertical

form in corrugated fiberboard cases used for distribu-

compressive strength. On the other

hand, glass is very

heavy per unit of contents contained, is energy inten-

excellent moisture and water resistance but is a very

sive to manufacture, and, as is well known, is prone to

poor gas barrier. HDPE is used to form bottles for

breakage with impact. Glass may be

fabricated into

milk and many other liquids, as well as a wide variety

bottles and jars, almost all of which require plastic

of other products with modest barrier requirements.

or metal devices to close. Although glass was the

HDPE may also be formed into cups, tubs, or trays

most widely used material for packaging fluid milk *to contain yogurt and cottage cheese.*

and its fermented analogues during the first half of

the twentieth century, its dairy products applications

Polyester

during the past two decades have dwindled to virtu-

ally zero. Occasionally, a few dairies offer yogurt in

Polyethylene terephthalate polyester (PET) has been *glass to convey a high quality image, but most dairies*

available as a specialty film packaging material for

shun glass as a hazardous material in production and

many years, but only since the late 1970s did it enter

packaging operations.

as a significant package material. A modest oxygen

and water vapor barrier, in package form after ori-

entation, PET is tough and transparent. PET's ma-

Plastic

jor packaging applications today are for carbonated

Plastic is the newest package material having been

beverage bottles, with other bottles and jars as for

developed during the last century and having come

drinkable yogurt, salad dressing, peanut butter, etc., *into prominence only since the 1950s. In actuality,*

thermoformed cups and tubs, etc., in the semirigid

the term "plastic" describes a family of materials re-

category are secondary applications at present. PET

lated by their common derivation from petrochemical

may also be formed into films that are tough and di-

sources. Each is quite different in

properties relative

mensionally stable and, therefore, are quite good as

to packaging requirements, and so no single plastic

laminants to protect aluminum foil or for lidding-type

material is capable of being universally employed.

flexible closures. In partially crystallized form PET

All plastic package materials are characterized by *may be fabricated into trays for dual oven (microwave*

their lightweight, relative ease of fabrication, low

and conventional conduction–convection) reheating.

cost, and ability to be tailored for specific end ap-

plications. Together, by weight, all plastics comprise

Polypropylene

about 20% of package materials, but because of their *low densities, protect far larger volumes of contents*

In oriented film form, polypropylene is an excellent,

than any other package materials, perhaps 60–70%

economic, tough, transparent, high-moisture barrier,

of all foods and dairy products.

low-gas barrier package material, which has captured

almost the entire quality flexible packaging mar-

ket. Among the packages being made with oriented

Polyethylene

polypropylene (OPP) are potato chip pouches, bak-

The most commonly used packaging plastic is

ery goods overwraps, and candy bar wraps. Because

polyethylene, which may be obtained in high,

of its relatively high temperature resistance (up to *medium, and low densities with variations now avail-*

250°F), polypropylene resin is combined with other

able on each of these. Low-density polyethylene

higher barrier packaging materials to produce multi-

(LDPE) is tough, flexible, easily formed after heat-

layer plastic bottles and cans such as for ketchup or

ing, lightweight, and forgiving as a

heat sealant. It

for "bucket-type" cans for microwave reheating. For

is an excellent water and water vapor barrier, but a

economic reasons (i.e., when the commodity price is

poor oxygen and flavor barrier. LDPE's most com-

favorable), polypropylene may be injection molded

mon uses are as flexible pouches and bags, and as *into tubs and cups to contain fermented dairy prod-*

the heat sealable extrusion coatings on paper, paper-

ucts such as yogurt and cottage cheese.

board, and aluminum foil. Thus LDPE is the coating

on gable top fluid cartons, the laminant on aseptic

Polystyrene

bricks and blocks, and the heat seal coating on many *flexible lidding materials.*

Polystyrene is a plastic with a relatively poor oxygen

High-density polyethylene (HDPE) is a semirigid,

and water vapor barrier but good structural proper-

somewhat stiff translucent easily thermoformable

ties. Being inexpensive and easy to form by sheet

plastic. With fairly good heat resistance, HDPE has *extrusion and thermoforming or injection molding*

methods, polystyrene has been one plastic of choice

suppliers of raw materials, those who convert these

for cup/tub containment of yogurt, cottage cheese,

raw materials into useful packages, suppliers of ma-

etc., since the demise of wax-coated paperboard dur-

chinery, designers, publishers, schools, etc.

ing the late twentieth century.

Raw Material Suppliers

Oxygen-Barrier Materials

Raw material suppliers include organizations, which

Most of the above plastics are not good oxygen bar-

obtain basic materials from the

planetary resources

riers. To obtain the oxygen barrier, two plastic resins,

such as the ground, air, or oceans and transform them

polyvinylidene chloride (PVDC), and ethylene vinyl

in very large quantities into bulk materials that may

alcohol (EVOH) are employed commercially. PVDC

then be converted into packaging. Among such orga-

is the older of the two and has excellent water vapor

nizations that generally do not supply dairies are alu-

and fat resistance but is relatively difficult to fab-

minum miners and refiners, steel mills, paper and pa-

ricate, as well as being questioned on environmen-

perboard mills, and petrochemical companies. Such

tal grounds for its hydrogen chloride

content. Much

companies deliver materials such as coils of metal

PVDC is used in emulsion-coating form on films to

sheet, rolls of paperboard, carloads of plastic resin,

achieve oxygen barrier in films used for processed

etc., to converters. The principal exception to this is

meats and cured cheese.

the glass industry whose nature fosters the direct in-

EVOH is a better oxygen-barrier material and is

tegration of raw material and converting into bottles

easier to fabricate but is very sensitive to moisture.

and jars without intermediate companies.

The economics of both high-oxygen barrier mate-

Among the packaging material,

suppliers of inter-

rials dictate that they be combined with other less

est to dairy product packagers currently are in the

expensive structural plastic resins. Thus EVOH is

area of paperboard: International Paper; Blue Ridge;

usually coextruded (i.e., forced with another plastic

Smurfit Stone; and Weyerhaueser, which are exam-

through a common die) with polypropylene to pro-

ples of companies that manufacture virgin paper-

duce films, sheets, or coatings. The EVOH is pro-

board used downstream in gable top cartons and/or

tected from environmental or product moisture in

corrugated fiberboard cases. Basic aluminum suppli-

these applications. In addition to its *involvement in*

ers include Alcan and Alcoa. Steel suppliers include

“bucket-style” cans, EVOH is also an increasingly

USX and Weirton. Plastic resin suppliers include

important material to protect food and beverage con-

DuPont, Dow, and Exxon Mobil for polyethylene;

tents from flavor interaction with packaging mate-

Voridian for polyester; Dow for polystyrene; and BP

rials. With many food and beverage contents now

Chemical for polypropylenes.

being held for prolonged periods up to a year at am-

bient temperature, the probability of adverse prod-

Converters

uct plastic interactions, largely flavor changes, is *relatively high. Consequently, an intermediate high-*

Converters are organizations, which supply useful

barrier material such as EVOH serves to minimize

packaging to dairies and other food packagers. Such

such interactions in packages such as those for chilled

organizations acquire commodity-type raw materials

juices.

from their own suppliers and process and combine

them to produce flexible films, sheets, cups, cans,

tubs, trays, bottles, jars, cartons, cases, etc. Among

Packaging Levels

the operations provided by converters are printing,

No such entity as comprehensive packaging exists in

extruding, cutting, molding, lamination, adhesion, *a single supplier or user organization, even though*

cup formation, nesting, slitting, and coating. Quanti-

comprehensiveness should be indispensable to ef-

ties involved are generally much smaller than those

fective and functional packaging. All packaging is

offered by their new material suppliers, and sufficient

divided into a large number of

individual entities se-

for their dairy and food users.

lected from a broad array of offerings to permit the

Converters tending to focus on the dairy industry

dairy products packager to select according to the

include International Paper, Blue Ridge, and Tetra

product, protection, distribution, marketing, need, or

Pak for gable top paperboard cartons; and Sweetheart

desire. These operations may be defined in tier or

and Sealright for paperboard rounds. Corrugated

horizontal form. Examples of the levels include the

fiberboard case manufacturers include International

Paper, Smurfit-Stone, and several hundred other

Packaging Equipment

smaller companies. Ice cream and frozen yogurt car-

Not the least important of providers are the packaging

ton manufacturers are headed by Graphic Packag-

equipment manufacturers, agents, and importers. Of

ing, with Sealright (Huhtamaki) as the major sup-

some importance to dairy packagers are Evergreen

plier for bulk ice cream containers.

Steel metal

and Nimco for gable top paperboard cartoning. Tetra

can makers include Rexam and Crown Cork and

Pak now supplies not only its traditional aseptic pack-

Seal. Aluminum can makers include Ball and Crown

aging equipment but also gable top cartoning ma-

Cork and Seal. Glass bottle manufacturers include *chinery. Among the aseptic plastic cup equipment*

Owens Illinois, St. Gobain, and Consumers. Flex-

suppliers are Bosch, Hassia, Hamba, Autoprod, and

ible packaging converters include Curwood, Print-

Holmatic. Plastic bottle-filling equipment is supplied

pack, Alcan, Winpak, and Cryovac, as well as several

by U. S. Bottlers, Krones, etc. Cup

fillers may be

hundred smaller firms. Plastic bottle blow molders

obtained from Autoprod, Holmatic, and Sealright.

and injection blow molders include Owens–Illinois,

Suppliers for flexible packaging equipment for prod-

Consolidated, Amcor and Alcan, as well as many

ucts such as cheese include Hayssen, Multivac, and *smaller companies and self-manufacturers. Cup and*

Tiromat. Secondary packaging equipment suppli-

tub molders include Fabri-Kal, Berry, Sweetheart,

ers include MeadWestvaco and Graphic Packaging.

and Solo (particularly for polyester cups). These are

Suppliers of machinery for distribution packaging in-

intended only to indicate a few of the *wide array*

clude ABC, Salwasser, Douglas, and Pearson.

of suppliers which are available to fermented dairy

product packagers to provide their package material

needs. In almost every instance there are many sup-

Packaging Development

pliers. In no instance can a single supplier provide *a complete range of all package materials that a fer-*

The development of packaging is a sequence that in-

mented dairy packager might require.

volves a broad range of disciplines and professionals

who interact in overlapping to finally deliver pack-

ages to the consumer. The most indispensable con-

Packagers

sideration in developing packaging is the product,

Packagers are the yogurt and fermented dairy prod-

and hence, consumer safety, with the interaction of

uct processors which marry the package materials to

packaging and contained food or dairy product being

the food and dairy products. Packagers employ ma-

one element, and the interaction of

processing and

chinery designed, engineered, and built by specialist

package another. Interactions are not permitted that

firms.

might in distribution extract contaminants from the

contained food or dairy contents.

No processing operation such as heating can com-

Distributors

promise the safety as, for example, hot filling or

Distributors include the means to deliver the pack-

retort processing, which could conceivably disrupt

aged dairy and food products to the consumers.

heat seals and permit recontamination by microor-

Distribution channels include warehouses, trans-

ganisms.

portation, wholesalers, brokers, jobbers, retailers,

The above are axiomatic in the selection of package

etc. Retailers include grocery and food service out-

materials and structures.

lets.

The next requirement in the development of pack-

In addition to these tiers a range of suppliers *aging is the technical function. If the package can*

provide goods and services to comprehend the re-

contain and protect the product in normal distribu-

quirements of comprehensive packaging. Graphic

tion, it has fulfilled its basic objective. Thus, an ini-

designers, for example, offer the services, which are

tial step in packaging development is

the engineering

converted by printing plate makers into the hardware

to ensure technical functionality. Variables such as

required to deliver ready-to-display packages. The

moisture protection, seal integrity, protection against

output of graphic designers is intended to comply

the entry of oxygen or microorganisms, resistance to *with regulatory requirements, as well as to meet the*

heat or cold or both in sequence, product/package

desires of marketing managers for retail communi-

flavor interaction, etc., are specified and measured

cation.

versus the ability of the package to meet the other

8 Fermented Dairy Packaging Materials

necessary and desired criteria. Subsequently, the abil-

tamper-evident/tamper-resistant devices, etc. When-

ity of the package to withstand the distribution en-

ever a structural change is made, the resulting pack-

vironment using such measures as impact, vibra-

age should be reevaluated, but this step is not always *tion, and compression resistance are predicted and*

performed in the haste of meeting the marketing, pro-

measured.

duction, distribution, financial, etc. schedules.

In some instances, the variables may be predicted

Today graphic design is usually performed with

by mathematical models knowing the end objective *computer assistance and so rapid action is quite fea-*

in terms, first, of desired shelf life under specific tem-

sible. In a large project, it is highly recommended that

peratures; and second, the effect of that variable on

the package design including all its structural features

the shelf life. A typical example might be a cottage

undergo both consumer and retail

display testing.

cheese product in refrigerated distribution that would

Too much investment has been made in the package

have a target shelf life of 40 days. The model would

to avoid this key step, although many dairy product

begin with microbiological growth as probably inde-

companies may overlook it. A host of consumer and *pendent of packaging. From a packaging perspective*

marketing research firms conduct such tests ranging

a variable such as no more than 1% moisture loss

from focus groups to actual in-store displays or in-

through the package structure in those 40 days at

home testing. None is perfect and comprehensive,

40◦F would be inputted to predict the

gauge of the

although each purveyor of a test procedure believes

package material options required in the particular

that it is the ideal measuring tool. The most important

structure being considered. Of course the mathemat-

design test must be the simulation of in-store display,

ical models in shelf-life prediction are only screening *i.e., perception of the package by consumers in the*

the guidelines today, and so actual laboratory testing

normal shopping environment as in a mass display

will be required to verify the tests.

among other similar and competitive products. Yet

Similarly distribution resistance may be mathe-

another necessary test is how consumers actually use *matically predicted with fairly good accuracy, but*

the package to deliver the product to themselves to

actual laboratory testing is needed in almost every in-

ascertain any consumer perceived flaws or areas, in

stance. In many instances, the use of real distribution

which the package design may be improved.

is employed although, of course, the

test variables of

During the development of the package, it is nec-

a single truck ride are such that the results can be

essary to select the equipment on which the pack-

misleading. Nevertheless, many packaging develop-

age is to be made to ensure that the product, pack-

ers use actual truck shipments as a testing protocol *age material, and machine are compatible. Machine*

in lieu of vibration and drop testers.

retrofitting and reengineering is not only feasible, it

Most of the time the sequence is to extrapolate

is to be encouraged prior to completion of develop-

from known packages of similar products such as,

ment. Package and equipment development should *for example, if the product is a flavor variation of an*

be a totally integrated effort and should be continu-

existing commercial product, relatively little shelf-

ous from the inception of any packaging development

life testing is necessary. Some testing should be per-

project. As much as possible, off-the-shelf equipment

formed to ascertain the effects of the *differences such*

should be used since custom equipment development

as flavor interactions.

requires high investment. Standard equipment can be

Although laboratory samples are satisfactory for

modified to accommodate special requirements of the

initial evaluations, it is necessary to conduct tests *product and package.*

on actual production samples, since these invari-

Not the final step in the initial development is sec-

ably differ significantly from the pristine prototypes.

ondary and tertiary or distribution packaging. Here

When actual production line sample packages are

both the package and the equipment must be devel-

not immediately available, the closer the samples are

oped and selected or modified for the unitization and

to machine-made, the better for real-life prediction.

containment of primary packages.

While functionality testing and its associated reengi-

Throughout the process, it is desirable to develop

neering of the package structure are underway, the

the economics of the package including the cost of

marketing inputs are incorporated into the package.

the package materials, equipment, labor, utilities, etc.

These include the graphic requirements, both legal

Each should be developed in a total systems context

and those desired for marketing and communication,

to ensure that the economics are not

dictated solely

structural features such as pour spouts, reclosure tabs,

by the purchase price of the package materials—a

variable that can be highly misleading in the context

that can represent an education for novices, and a

of the total distribution and marketing *objectives.*

stimulus for those who function in packaging on an

All packaging development must include contin-

every day basis. For in-depth information there is no

uous monitoring, feedback, and refining to ensure

outstanding periodical today. Nevertheless, the roles

that some environmental variable has not changed, *of Packaging Digest with its large sprawling person-*

or that there has not been a change in the product,

alized articles and Food and Drug Packaging with

or that some improvement in package materials has

its not infrequent features and editorials, Packaging

not introduced the possibility of effecting a change

World, and BrandPackaging, targeted

at marketers,

to better the performance or the economics, or both.

cannot in any way be minimized: All offer good and

timely information and are a must-reading for dairy

products packaging professionals.

Resources Available for Packaging

Nonpackaging trade periodicals such as Dairy

Development and Implementation

Field cover packaging with rewritten press releases,

In addition to the suppliers indicated above for pro-

reporting or, occasionally, professionally prepared

viding the hardware and software, there are many

pieces. Unfortunately, such journals do not provide

other resources that are not always immediately vis-

regular information on packaging and

cannot be de-

ible. As indicated above, graphic designers are val-

pended upon as a source. On the other hand, when

ued suppliers since, unlike mainstream advertising

there is coverage, the information on the specific ap-

agency or free lance artists, they are experienced in

plication is usually quite good. Food Technology of-

packaging design including the peculiar nature of

fers in-depth pieces, contemporary, and future pack-

shelf display and the vagaries of package material

aging technologies.

converter printing.

A number of books on packaging have been pub-

Consulting firms (such as, for example, Packag-

lished, including some by this author, for example,

ing/Brody, Inc.) deliver a variety of accurate insights

Encyclopedia of Packaging Technology, second edi-

into the technologies of packaging, and also can, if

tion, 1997, John Wiley and Sons, NY. The books are

desired, actually engineer and test the package struc-

usually general texts and contain only *brief or passing*

tures and broker the supply. Most consulting organi-

references to dairy packaging per se. To date, to our

zations, if they are indeed organizations and not sin-

knowledge no definitive text on dairy products pack-

gle persons, offer advice based on information not

aging has been written and published. Dairy products *gleaned from experience but rather education. Pack-*

texts often contain single chapters on packaging like

agers seeking insights from consultants are urged to

this one, which is necessarily sketchy since such a

study their dossiers carefully to determine that their

broad field must be covered in such a short space.

counsel is really that and not merely

superficial bits

Professional and trade associations both publish

of little or no real value. It is also important to ascer-

information on packaging and sponsor meetings and

tain that the counsel is coming from the professional

conferences on the subject. Those by the US profes-

with whom the communication is made. Many larger *sional packaging society, Institute of Packaging Pro-*

consultancies often delegate the actual consulting to

fessionals (IOPP), generally emphasize more general

persons who are either juniors or who are not busy so

packaging topics rather than focusing on specifics of a

the inputs contain little relevant substance. The as-

particular group such as dairy.

Recently, however, in-

signed person(s) have been learning about the topic

creased emphasis has been placed on food and bever-

during the consultancy assignment.

age, including dairy products packaging. The reverse

Many packaging journals are published in both the

is true for dairy associations, which tend to focus on

United States and the other parts of the world. Each

the mainstream of dairy products rather than on pack-

is distinctive in its coverage of packaging subject

aging for dairy products. On the other hand when a

material, but all share one characteristic: They are

professional group covers a dairy packaging subject,

assembled and edited by journalists for *maximum*

the treatment tends to be quite good.

reader interest. Despite the reporting and investiga-

Both professional and trade associations, as well

tive research behind the published pieces, they often

as for-profit companies organize and produce exhi-

lack the critical insights that a packaging professional *bitions and conferences on packaging and on dairy*

would impact. Furthermore, there is little follow-

products. There has not yet been an American dairy

up to ascertain the progress on developments. Thus

products packaging exhibition, although in Europe,

packaging journals provide a highlighting service

excellent dairy packaging expositions

have been

presented from time to time. The major world pack-

that perceptibly alters the quality of the contained

aging exposition is Interpack held every three years in

product is highly undesirable.

Germany, but generally absent of much

direct dairy

Although the notion of extraction is relatively easy

packaging. In the United States, the major packag-

to understand, it is also necessary to grasp the idea

ing exhibition is Pack Expo held every other year,

that extraction can occur not only in what might be

but also suffering, in this context, from a paucity of *regarded as normal contact but also under unusual*

dairy products packaging. Regardless packaging pro-

conditions. For example migration of package ma-

fessionals involved in dairy packaging have much to

terial constituents can occur in distribution, which

gain from alert attendance at major packaging exhibi-

may take place at ambient, chilled, or *frozen con-*

tions, which usually present much that is innovative

ditions. Migration rates vary considerably under the

and applicable to dairy product packaging interests.

three different temperature conditions with the ambi-

Thirteen American universities offer degree pro-

ent generally more rapid in accordance with Arrhe-

grams in packaging with one, Clemson University,

nius laws that dictate exponentially increasing rates

offering a program in food packaging. The largest

as a function of temperature. But if the product is

packaging program is the Michigan State University

placed in contact with the interior package material

School of Packaging. Behind them is

Rochester Insti-

at an elevated temperature during some processing or

tute of Technology. Among the other universities of-

consumer preparation time, migration can be greatly

fering packaging are: University of Missouri (Rolla);

accelerated, thus leading to brief but nevertheless sig-

Rutgers, the State University of New Jersey; Univer-

nificant component migration. This situation became

sity of Wisconsin (Stout); Indiana State University;

evident in the case of microwave susceptors whose

and San Jose State University. Generally universi-

normal component migration patterns in original pro-

ties offering curricula in food science and technology

cessing, packaging, and distribution

demonstrated

have a single course in food packaging. Dairy curric-

benign activity. When the susceptors perform their

ula may sometimes offer a course in packaging from

normal function of surface heating, however brief,

a nonpackaging faculty member. A few universities

very high temperature periods occur during which *have research programs dealing with dairy packag-*

new chemical entities are formed, which may mi-

ing, the most prominent of which is North Carolina

grate during the interval from the package material

State University with an aseptic packaging center.

into the food. Although this specific situation proved

A very limited number of federal and

state govern-

to not present any public health problems, it alerted

ment agencies conduct research in packaging with

both officials and food packagers to the possibility

the FDA being the most prominent among these, fo-

and the potential consequences when actual use con-

cusing, as might be expected, on safety aspects. Off-

ditions are not considered.

shore, however, government and quasi-government

The microwave susceptor case also highlighted an-

agencies perform both basic and applied research

other effect that was initially demonstrated with re-

on packaging. Among these are Campden Chorley-

tort pouches many years ago: indirect migration. The *wood Food & Drink Research Association and SIK in*

term "indirect" is used in regulatory contexts to indi-

Sweden.

cate a component that is not intentionally introduced

All of these groups represent resources that should

into a food or dairy product, but enters from a sec-

be employed in comprehending the totality of pack-

ondary source such as from the surrounding package

aging as it applies to dairy products packaging issues.

material. In this context, however, indirect means that

the component comes not from the package mate-

INTERACTIONS OF PRODUCT

rial in direct and intimate contact with the product,

AND PACKAGING

but rather from a layer that is remote from contact,

e.g., an adhesive or an outer ply. In this situation

As has been previously mentioned, it is axiomatic

the migrant not only leaves its own substrate, it also

that no significant interaction takes place between

migrates across other packaging components to the

the contained product and the package

material. This

surface of the inner layer and potential contact with

is particularly important in considering the possibil-

the contained dairy product.

ity of any potentially toxic materials being extracted

Contact is not necessary since the migrant might

from the package materials into the contained prod-

evaporate or sublime into the interior package en-

uct, an event specifically prohibited by law and reg-

vironment and then be borne to the food surface

ulation. From a business perspective any interaction

for interaction. As indicated above, these actions are *accelerated at elevated temperatures, even brief ex-*

in gable top polyethylene-coated paperboard cartons,

posures.

the desirable flavor constituents are scalped suffi-

One variable that was not always considered was

ciently to be detectable by consumers. To overcome

that for most of the history of packaged dairy prod-

this serious problem, chilled juice packers often now

ucts, contact between plastic and contents was usu-

specify flavor barrier plastics on the interiors of their

ally brief and at relatively low temperatures, thus

cartons. Scalping of desirable flavor constituents of

minimizing or even hiding any adverse interaction.

dairy products by polyolefin has been

noted. Lipid-

With the development of aseptic packaging systems,

soluble volatiles might be expected to be found in

hot filling and extended shelf life using plastic pack-

the interior heat-sealant layers of dairy product pack-

aging, product-package material contact time at am-

aging and to be responsible for some of the flavor *bient temperatures extended to weeks, months, and*

deteriorations because of product over time. Dairy

even, occasionally, years. Under these circumstances,

product packagers should be alert for this possibil-

measurable interactions can take place, with some

ity in developing packaging for their products, even

caution required to ensure against

harmful migra-

those being distributed under refrigerated conditions

tion. Some of the interior package materials such as

for short periods.

polyethylene are not inert to organics, and so long-

Yet another interaction that should be of some con-

term exposure can and does result in undesirable in-

cern is the change in package material properties over

teractions. Since no known package material contains

time or the change in either product contents or the

or transmutes to components that might be harm-

environment. For example, paperboard loses most of

ful in final product consumption, and this effect is

its physical strength when exposed to

water or even

very carefully monitored by plastic resin suppliers,

water vapor. Consequently, the protection of paper-

the probability of a public health problem is almost

board is essential to the protection of the product. Wet

absent. On the other hand interactions that can al-

strength paperboard has been a standard for years, but *ter product quality can occur, and even if they are*

this is only a relatively minor temporary expedient.

not harmful to consumers, they can be detrimental to

Hiding all raw paperboard edges and seals is another

sales. Thus all packaging should be tested to ensure

more expensive, but significant step, and is almost

that under the total conditions of

processing, pack-

always employed for long-term distribution such as

aging, and distribution, no measurable interaction of

for aseptic packages. Perhaps this should also be stan-

product and package occurs.

dard practice for all paperboard packaging for liquid

The reverse of entry of undesirable materials is the *and fluid dairy products.*

removal of desirable constituents, another of the is-

The nylon gas barriers of cured cheese packaging

sues of employing plastics in proximity with the dairy

are altered by the inevitable presence of moisture and

product contents. Scalping or loss of product com-

must be accounted for in developing packaging for *ponents to the contact package materials has been*

any dairy products. The situation with the newer oxy-

a known phenomenon for many years, but largely

gen barrier, ethylene vinyl alcohol (EVOH), is even

overlooked, since only infrequently was there any

more severe, with as much as 75% of the gas bar-

prolonged contact time of plastic and

liquid or fluid

rier properties being lost at relative humidities above

product at ambient temperature. Since the advent of

70%. Even under these circumstances these two sen-

aseptic and extended shelf-life packaging, however,

sitive plastics are commercially employed for dairy

long-time intimate contact was initiated and con-

product packaging because even after the property

ditions were established for the plastic material to

decreases, they represent superior barrier to the al-

remove desirable product compounds. These have

ternatives.

been largely oil-based compounds that dissolve in

These recitations on problems with plastic packag-

polyethylene, but also include volatiles, which nor-

ing materials hint that perhaps avoidance of plastic

mally contribute to the desirable flavor attributes.

might be a desirable alternative. Given that plastic

Many juices are subject to scalping, an event that has

materials are imperfect, in total, they generally rep-

led to the replacement or modification *of the interior*

resent a better alternative than attempting, for ex-

plastic heat sealants with more inert plastics.

ample, to package in uncoated paperboard, which

Of some interest to fermented dairy product pack-

would have no liquid barrier, or in glass that would be

agers is that measurable losses may be measured in *both expensive and hazardous to consumers in these*

long-term refrigerated distribution. For example dur-

litigious times. Furthermore, the cleaning of glass,

ing the 50+ day chilled extended shelf life of juices

particularly in reusable situations, is not devoid of *problems with respect to energy, breakage, and resid-*

or a variation) shrink film capable of tightly binding

ual cleaning compounds. Metal cans would be an al-

primary packages into a single unit that is stronger

ternative, but metal must be plastic coated in the inte-

than the individual primary packages because of the

rior to protect the metal with almost all *the problems*

“cellular” construction. Shrink film is also a good

associated with plastic in contact with product.

moisture barrier and so protects interior paperboard

It is better to employ the packaging with the best

from the inevitable moisture of dairy product distri-

combination of properties knowing in advance the *bution environments. The small amount of heat re-*

problems that might be encountered, and to account

quired to shrink the film around the unitized primary

for these issues, than to use a suboptimum material or

packages is so inconsequential that even ice cream

structure. If plastics appear to present serious prob-

packages are readily unitized and held *together by*

lems in this context, consider the alternatives that,

heat shrunk plastic film.

in reality, could present even more serious major

Many dairy products are distributed in returnable

problems.

rigid plastic crates, totes, or cases. These units, usu-

ally injection molded high-density

polyethylene but

THE PACKAGE IN PRODUCT

sometimes polypropylene or other structures, are en-

DISTRIBUTION

gineered to cradle and contain numbers of primary

packages to protect them from virtually any physi-

Among the many functions of packaging are to pro-

cal abuse. Often the individual primary *packages are*

tect the contents from distributional physical abuse

in cells within the crate or tote to prevent the pri-

such as vibration, impact, compression, etc. The no-

mary packages from any contact with each other and

tion of delivering dairy products one at a time is, of

thus eliminate surface abrasion that can damage glass *course, preposterous. Therefore, primary packages*

bottles, paperboard cartons, and even plastic bottles.

should be unitized into groups that are more easily

When the dairy's distribution system permits, i.e.,

moved en masse. All packaging including the pri-

direct delivery by a person who can take back the rel-

mary packages must be protected

throughout the en-

atively bulky and expensive returnable plastic case, it

tire distribution cycle, including warehousing, trans-

makes physical and economic sense to employ such

portation, docking, inventorying, retailer handling,

distribution packaging. The initial capital investment

etc. The primary package itself must be able to with-

is high but the total system cost over time and re-

stand retail display, handling by the consumer, and

peated reuse, when the infrastructure is available and

in-home or food service handling when applicable.

in place, is well below that of purchasing individual

Since the primary package is the principal barrier,

disposable distribution packages.

it is necessary to engineer it to remain intact through-

Distribution stresses and the protection afforded

out the entire distribution cycle. It must withstand

by various alternative distribution packaging systems

physical stresses such as would be encountered on

may be computed by reliable tested methods with ex-

the production and packaging lines,

including im-

cellent predictability. These methods are more often

pact, abrading, turning corners, compression, and, in

employed by packaging engineers associated with

dairy product plants, heat and water. Subsequent to

high-price hardware items, but the test bed and com-

the packaging lines, primary packages are unitized, *puter techniques may be readily applied to distribu-*

sometimes under compression, sometimes by drop-

tion packaging for dairy products. In the system, test

ping, but in any case, to be further contained and pro-

packages are subjected to known stress inputs such as

tected by some outer unitizer. The next outer package

vibration or impact, and the point of

failure is quan-

is most often a corrugated fiberboard case, which is

tified. Knowing the properties of alternative distri-

engineered to resist modest vibration impacts, com-

bution packaging such as corrugated fiberboard of a

pression, and drops. Unfortunately, corrugated fiber-

specific edge crush test and dimension, or an internal *board cases are susceptible to moisture and water and*

egg crate-type structure, computer modeling can pre-

lose their protective properties rapidly as a result of

dict the distribution performance. In this manner the

exposure. This vulnerability must be accounted for

minimum distribution packaging required to protect

when employing corrugated fiberboard

as a distribu-

the primary packaging may be derived by computa-

tion package.

tion rather than by empirical methods. Nevertheless,

Alternatives to the corrugated fiberboard case in-

it is advisable to conduct actual test shipments to ver-

clude corrugated fiberboard trays or pads combined *ify the theoretical results. Computer methods avoid*

with plastic (usually low-density polyethylene film

the long and tedious and often very inaccurate trial

and error methods that have been the hallmark of

packaging design, computer graphics also generate *distribution packaging selection.*

multiple variations for evaluation. Computer-graphic

capabilities are so sophisticated that the camera-

GRAPHIC DESIGN AND

ready art for printing plate manufacture are generated

ASSESSMENT

by the computer and can even drive the plate-making

process.

Graphic design is the development of the external

With design being so critical for market accep-

appearance of the packaging to comply with regu-

tance, personal opinion by marketing managers or

lations and to meet marketing desires that are hope-

graphic design managers is a poor means of selecting

fully dictated by consumer and retailer *needs and*

the optimum design. Objective evaluation of design

perceived needs. Good graphic designers also incor-

is nearly as important for evaluation as is consumer

porate structural features that are not incompatible

testing of the product. If the consumer does not try the

with the protection requirements of the product but *product or cannot find the product, it is of little value*

are compatible with retail display or consumer use,

to the dairy. Many different techniques for packag-

e.g., dispensing spouts. Good graphic design is per-

ing (graphic) evaluation are offered, not one of which

formed to ensure that the package appearance in retail

is universally accepted. Each, however, *has its own*

display has visual impact in mass among an array of

advocates. The most common evaluation technique

other competitive packages. Designs may appear ex-

probably is a focus group in which a small group of

cellent in isolation, but in mass display at retail level,

representative consumers examines and discusses the *they might be lost. When media advertising is used, it*

totality under the guidance of a moderator.

is necessary to ensure that the package appearance is

Among the more intriguing evaluation methods are

attractive in photography or on television as the case

measurement of eye movement, time required to rec-

may be.

ognize the package on a darkened screen, and mea-

Graphic design is usually best managed from a

surement of brain waves responding to exposure to

marketing department since this is the group that is

the design. Perhaps the best method is placement of

most influenced by the shelf appearance of the pack-

the package in a mass display in a test *store environ-*

age. It is important, however, that the packaging de-

ment followed by measurement of sales and follow-

velopment professional be actively involved in the

up with a selected sample of purchasers to ascertain

process to ensure that the technical aspects are not

their reasons for their decision.

violated in the name of appearance. Shelf appear-

ance and other marketing oriented features are also

ECONOMICS OF PACKAGING

important.

Graphic design today should be performed by

Contrary to general belief, with infrequent excep-

packaging design professionals. The use of free-lance *tions, packaging does not cost more than the product*

or advertising agency artists with little or no experi-

contained. Generally packaging costs represent con-

ence in packaging design is not to be encouraged. It is

siderably less than 10% of the retail price of the food

even better to employ professionals with experience

or dairy product on the retail shelf.

in yogurt and fermented dairy products packaging.

Not too long ago packaging costs were generally

In the past, all graphic design was performed with

computed solely by the primary package materials

paper, pencil, colored pens, ink, etc. Such artist's ren-

purchase price. With education, however, packag-

ditions required time and relative

difficulty of chang-

ing purchasing and marketing managers now usu-

ing and evaluating changes. Today most graphic

ally measure packaging costs by adding all relevant

designers are able to design on graphic comput-

variables and allocating all fixed, including capital,

ers, permitting marketing managers to experience *expenditures for equipment. Thus, the economics of*

design variations immediately. Three-dimensional

packaging include such costs as those for the acqui-

views may be depicted on the two-dimensional video

sition of the primary packaging materials; plus the

display screen, and hard copy versions. Mass displays

secondary and distribution packaging

materials; plus

can be represented in virtual reality on video display

the labels, adhesives, coding inks, etc., i.e., the ad-

screens. Almost instant color copies may be wrapped

juncts, plus the labor, plus the utilities, etc. In addi-

around physical structures to enable marketing man-

tion, allocation of fixed plant costs such as supervi-

agers to actually see and touch three-dimensional

sion and maintenance, floor space, etc. is included.

samples immediately. While permitting instant

Just as important in determination of economics of

packaging is the machinery which invariably has a *foods offered at retail outside of food service out-*

high initial cost and must be evaluated for output,

lets have been required to carry a complete statement

output speed, efficiency, scrap losses, both for pack-

of nutritional attributes in a prescribed format. The

aging materials and product, down time, and ability to

regulations also established rules for *making limited*

link efficiently with both downstream and upstream

health claims based on nutritional value or any other

packaging equipment. Only after examining all facets

aspect of the product.

of packaging costs can the true economics of packag-

During the 1970s, FDA established a set of rules *ing be accurately evaluated. Soon the days of judging*

for Good Manufacturing Practices, many of which

packaging costs on the basis of the number of colors

are aimed at ensuring that the packaging is safe, not

on the label, such as was, and perhaps still is, being

only from a content standpoint but also from a pro-

done for the no frills levels of packaged *food and*

cessing and containment perspective. Specific rules

dairy products, will be ended. There is much more to

for handling low-acid foods, and many dairy products

packaging economics than number of colors printed,

certainly falling into this category, are in effect. These

which is usually a trivial contributor to the total eco-

rules might be regarded as the common sense rules of

nomics.

operating a fermented dairy processing or packaging

line, formalized as a regulation. For example anyone

REGULATION

operating a retort must be trained in retort operation.

Complete records must be kept for all low-acid retort

Beyond the regulatory issues relating to the safety of

operations. Closures for cans and glass jars, as well

package materials and the contained products are the

as other retort packages for retorted low acid foods

regulations governing on-package information, i.e.,

are specified. Regulations for aseptic packaging espe-

the so-called labeling declarations. As *should be well*

cially with regard to thermal processing of contents,

known to every dairy technologist, a host of federal,

sterilization of package materials, and seal integrity

state, and local agencies have some manner of label

are stipulated with provision made for application to

jurisdiction over dairy product packaging.

FDA, if the system has not been used previously in

The most important of these, of course, is Food and

commercial practice. FDA also requires that any or-

Drug Administration (FDA) whose authority usually

ganization packaging and processing low acid foods

takes precedence. Were the products meat, the United

for ambient temperature distribution

submit its pro-

States Department of Agriculture (USDA) would

cess to FDA prior to initiating operations so that FDA

have jurisdiction, taking their lead from FDA, but

can ascertain that the persons and equipment and op-

exercising a difference in that prior approval is often

erations are qualified to function.

required. Alcoholic beverages fall under the Bureau

The several highly publicized incidents of tamper-

of Alcohol, Tobacco, and Firearms of the Treasury

ing with over-the-counter drugs and a few foods that

Department, taking their lead from the FDA. A con-

occurred in the 1980s triggered a number of laws

siderable amount of authority, usually *unexercised,*

and regulations stipulating tamper evidence/tamper

rests with the Federal Trade Commission, which has

resistance for these drug products. Simultaneously

the power to regulate relationship of on-package in-

many food and dairy processors and packagers imple-

formation to advertising promotion and other com-

mented tamper evident/tamper resistant package fea-

munications.

tures both to deter criminal intent and to deter inno-

In addition to those with legal authority are the

cent in-store taste-testing and content contamination.

quasi-legal groups and trade regulations, which stip-

The rules apply only to the proprietary drugs, and so *ulate packaging information requirements. For ex-*

food and dairy processor/packagers are not required

ample the Railroad Board stipulates the mandatory

to follow the specific guidelines of the FDA regula-

labeling relating to board strength on the corrugated

tions. Nevertheless, almost all food and dairy pack-

shipping cases. Supermarkets dictate

the presence of

agers that have incorporated tamper evident/tamper

a machine-readable universal product code (UPC) on

resistant features use the regulatory guidelines. These

primary packages. FDA regulations prescribe five

guidelines specify a number of devices, which are re-

major information items on food and dairy pack-

garded as being generally effective, and the presence

ages including the generic identity of the contents,

of a printed instruction to signal to the consumer the

net weight, source of the product, a list of ingredi-

absence of the device or a tampered package.

ents in descending order or weight or volume im-

In general, government regulations

regarding pro-

portance, and nutritional attributes. Since 1994, all

cessing and packaging of food and dairy products

are quite good and make very good sense to food and

viable alternative. When recycling was demanded on

dairy packaging technologists. There is *little onerous*

the basis that no packaging was being recycled, the

about any of the regulations since they are reiterations

food and packaging industries responded with valid

of good technical and commercial practices designed

data demonstrating that large fractions of spent pack-

for delivery of safe products in packages that com-

aging materials were already being recycled.

municate accurate information.

In actual fact only 27–28% of the municipal solid

waste stream is package material, a proportion that

PACKAGING AND THE

has been declining even as the rate of growth of the

ENVIRONMENT

stream has been declining.

The argument presented is that paper is recyclable

Probably the most widely discussed and debated as-

and so newspapers and telephone books may be re-

pect of packaging today since 1970 has been the

moved from the waste stream and recycled. Although

environmental impact of the solid waste generated

true in the technical sense, paper loses *properties in*

from packaging. Regardless of the merits of the pub-

each recycle and indefinite recycling can lead to no

lic and private declarations, the issue has generated

useful raw material. Properties of recycled paper-

more laws, regulations, proposals, consumer actions,

board are quite different from those of virgin and

and media discussion than the combined total of all

the two cannot be used interchangeably in all appli-

other issues related to food and dairy product pack-

cations.

aging during that period.

Without imposed laws, the paper and paperboard

According to the environmentalists fostering this *industry functioned well using economic laws of sup-*

issue, packaging is the major component of the mu-

ply and demand. The cost of returning used glass

nicipal solid waste stream and should be eliminated

packaging to the rapidly decreasing number of glass

or made of nothing but materials that have been re-

furnaces in the United States is too

high for economic

cycled from the solid waste from consumers' homes.

justification, but nevertheless, many municipalities

If not, goes their story, the rapidly diminishing num-

are doing just that. In our lifetime there will be no

ber of landfills will overflow with this solid waste

economic driving force for spent glass return with *and contaminate the soil and ground water. As a re-*

one probable result being that the decline of glass as

sult of these claims, hundreds of laws and regulations

a packaging material will be accelerated.

have been passed restricting food and dairy packag-

Because the price of aluminum is so high and also

ing, or at the very least, dictating

household sepa-

because aluminum may be safely and economically

ration of packaging solid waste and curbside place-

recycled, aluminum can recycling has been a com-

ment for recycling pick-up. Thousands of laws and

mercial practice for more than two decades now, or

regulations have been proposed to limit packaging, *ever since the aluminum can took a commanding lead*

including stipulating minimum contents of postcon-

in the beer and carbonated beverage packaging mar-

sumer solid waste to be incorporated into the pack-

ket. An infrastructure has been in position, function-

aging materials. In extreme instances, packages have

ing well, even as the supply grows and *the demand*

been banned, as in the State of Maine where the paper-

remains static.

board/plastic/aluminum foil aseptic brick/block pack

Plastics have been the particular target of envi-

was largely banned on the grounds that it was "not

ronmental agitation and regulation on the rationale *recyclable.”*

that plastic does not degrade in sanitary landfills and

The actual facts refute almost all the claims regard-

that it is an unnecessary expenditure of our limited

ing the role of packaging in the solid waste stream,

planetary energy resources. Consumer (and politi-

and the chronology of the environmentalists move-

cian, often dairy technologist, marketer, journalist,

ment in this regard reflects abrupt turns to reflect the

etc.) perception is that plastics constitute over half of

reactions to initial misinformation that precipitated

the total packaging solid waste stream. The reality is

most of the laws and actions. For example, at the out-

that plastics constitute about 20% of

the weight of

set, most environmentalist groups cited "biodegrad-

packaging.

able" packaging as the best answer to the problem

Both the Environmental Protection Agency and re-

of solid waste, but after it was clearly and loudly

sponsible professional and trade organizations have *demonstrated that biodegradation does not occur in*

developed a hierarchy of means of "coping" with

reasonable time within properly constituted sanitary

packaging solid waste, with EPA also indicating that

landfills, biodegradability was virtually erased as a

their recommendations deal with all of solid waste *and not just the minority that is packaging. Their or-*

the property values, dirt, and air pollution; the high

der is source reduction, recycling, incineration, san-

amount of truck traffic necessary to feed the input

itary landfill, and degradability.

scrap; and the disposal of the ash,

which is perceived

to be high in undesirable heavy metal elements. The

"not in my backyard," "not in my term of office" syn-

Source Reduction

dromes dominate the development of effective waste

The reduction in the quantity of packaging materi-

to energy incinerators.

als used to contain food, dairy, and

other products.

Source reduction is and has always been one of the

Biodegradability

primary activities of food and dairy packagers. Since

these business entities produce volume and profit by

Self-degradation was viewed by many in the envi-

lowering the delivering of the best products at the *ronmentalist movement as the ideal answer to pack-*

lowest cost, reducing the cost of packaging by render-

aging solid waste. The so-called "biodegradability"

ing it more efficient is a normal operating procedure.

would remove all packaging, particularly plastic,

solid waste just as soon as the packaging had per-

formed its protection function.

Archaeological stud-

Recycling

ies of landfills indicate, however, that both plastic and

This category may be divided into reuse of packages

paper in landfills did not degrade in finite times. Fur-

directly for the same purposes such as returnable

thermore, if the landfills were intended for an even-

glass or plastic bottles, a procedure that involves

tual use for building foundation or any other use-

considerable caution relative to product safety;

ful application, a base that would degrade after time

closed-loop recycling, which means reuse of the

would be highly undesirable. Self-degradation also

packaging material for the same

application; and

interferes with recycling efforts. Yet another issue of

recycling of the spent materials into some useful but

degradable plastics is the unknown end products of

not necessarily similar application (which is often not

self-degradation, which could be toxic or even more

packaging). Much of the commercial activity centers *destructive to the environment than the perceived ad-*

on recycling into some packaging application that is

verse effects of packaging solid waste.

not the same as the original or into a nonpackaging

Nevertheless, efforts and investments are under-

application. Among the more advanced package ma-

way to develop and produce degradable packaging *terial recycling efforts are aluminum cans returned to*

materials with the term "degradable" meaning either

produce aluminum cans, high-density polyethylene

biodegradable or photodegradable.

milk and detergent bottles into motor oil and liquid

Dairy interests are working diligently to minimize

detergent bottles, polyester carbonated beverage *both the real and perceived effects of packaging on*

bottles into polyester carpet fiber and insulated

the solid waste stream. Professionals experienced in

jacket filling, glass bottles into new glass bottles,

food and dairy packaging are sensitive to the role

and paperboard into recycled paperboard cartons

of packaging in protecting the contents *on behalf of*

or corrugated fiberboard fluting medium. The high-

the consuming public, and of the resultant relatively

density polyethylene bottle recycling businesses are

minimum contribution of packaging to solid waste.

relatively new to the package-recycling scene and so

Regardless of the facts, the packaging industry is *are still relatively small.*

working toward the resolution of the real problem,

but attempting to employ only rational technical and

economic means.

Incineration

When paper and plastic are burned in appropriate

facilities, the energy generated can be used to heat *or to produce electricity, a useful and cost effective*

outlet. Well-engineered incinerators can burn waste

To this point, this chapter has addressed dairy pack-

efficiently with no air contamination and with little

aging principles and not focused on fermented dairy

residual ash. Although the initial capital cost is high, *products packaging. This section deals with the spe-*

financial returns can be very good from the sale of

cific applications and descriptions of some of the

steam or electric power. Obstacles to waste to energy

major systems in use or proposed for dairy products

plants include consumer perception, particularly of

packaging.

Pasteurized Fluid Milk

fluid milk. The particular grade of polyethylene is

required to achieve an effective heat seal to ensure

Almost by definition pasteurized fluid milk and

against leakage either during filling or distribution.

derivatives such as buttermilk, kefir, *and drinkable*

The resulting pouch resists impact from drops and

yogurt are distributed under refrigeration and so are

from internal hydraulic action by the contents. The

not expected to deliver long shelf lives. Microbiolog-

pouch is filled on a vertical form–fill–seal machine

ical control protocols today are prolonging chilled *especially engineered for liquid filling. The pouch is*

shelf lives for such products.

intended to be inserted into a rigid plastic pitcher,

manually cut open by the consumer, and dispensed

Glass Bottles

from the opened pouch in the pitcher.

The classical package for pasteurized fluid milk and

analogs is the returnable glass bottle *that is cleaned*

Tetrahedrons

after each use, refilled with the milk, and resealed

Developed as the original structure by Tetra Pak

with a reclosable but disposable closure. Returnable,

in Sweden more than 50 years ago, the tetrahedral

reusable glass bottles are used occasionally in the *shape has been used for fluid milk and dairy prod-*

United States but are generally regarded as archaic

ucts packaging because it employed less package

even as they are advocated by environmentalists' in-

material per unit volume contents than any other

terests. From time to time glass jars are employed for

commercial package. The shape

continues to be

yogurt. Such product packaging is usually applied to

used in Europe and occasionally in North America

convey premium quality. Closure is often with alu-

for liquids, despite its awkward shape for inclu-

minum foil sealed to the glass finish.

sion in distribution packaging, and difficulty of shelf *display, in-home storage, opening, and dispensing.*

Returnable Plastic Bottles

Tetrahedrons for pasteurized fluid milk, puddings,

etc., containment are fabricated from polyethylene-

Largely in response to the environmentalist move-

coated virgin paperboard, or if for ambient tempera-

ment, returnable plastic bottles were introduced into *ture, shelf stable contents of a lamination of paper-*

the fluid milk and analog distribution system. Any re-

board/polyethylene/aluminum foil. The package is

turnable/reusable distribution system requires an in-

filled and sealed on vertical form/fill/seal equipment

frastructure that can recover the used containers and

on which the two transverse seals are

at 90◦ angles to

return them efficiently. To ensure the continued use

each other. The internal polyethylene coating serves

of such a system, it must be economic to all involved.

as the heat sealant.

The thrust of the returnable plastic bottle movement

in the United States was for public school-size bottles

Plastic Bottles

involving few, if any, fermented dairy products. The

preferred plastic, polycarbonate is a tough, low bar-

Extrusion blow-molded high-density polyethylene

rier/high temperature-resistant plastic, which is used

bottles are among the most popular package forms

in packaging mainly for returnable carboys for drink-

for fluid milk and its fermented and flavored ana-

ing water. No commercial applications are known for

logues. The weight per unit volume of fluid contents

returnable polycarbonate bottle or jar packaging for

is the lowest of any packaging structure that can be

fermented dairy products.

opened, reclosed, and comfortably dispensed. High-

density polyethylene is an excellent water and water

vapor barrier, and therefore is well suited to con-

Plastic Pouches

tain fluid dairy and analogue products. It is a low

For decades flexible polyethylene pouches have been

cost and easy to fabricate plastic package material,

used to contain fluid milk and analogues in bag-in-

which produces a bottle that is tough and impact re-

box configurations. The box is corrugated fiberboard

sistant. Bottles are filled on standard in-line or ro-

for structural rigidity. Both filling and dispensing is

tary turret liquid gravity filling equipment and closed

through a plastic fitment, i.e., device, heat-welded

with friction fit injection molded

polypropylene clo-

into the plastic film at the bottom.

sures usually with tamper resistant features. In re-

In Europe and Canada, consumer-size pouches

cent years both unit-portion and liter-size plastic bot-

fabricated from medium-density or linear low-

tles have been labeled with printed full body shrink *density polyethylene films are commonly used for*

film that are highly decorated. Coupled with extended

shelf-life processing and packaging, these advances

temperature shelf stability.) The term "shelf stable"

have sparked major exponential increases in sales of *means that the contents will not spoil microbiologi-*

fluid milk products.

cally but does not necessarily mean that the product

Injection blow-molded polyester bottles are also

will not deteriorate biochemically and thus retain its

being applied for fluid dairy product containment.

initial quality.

Polyester bottles are usually more expensive than

high-density polyethylene but may be useful because

Post-Fill Retorting

of their clarity.

Traditional shelf stability is achieved by sealing the

package and applying heat sufficient for sterilization,

Gable Top Paperboard Cartons

taking account of the rate of thermal

death of the

Below gallon size and especially in quart and

microorganisms and the rate of heat penetration. For

half-pint sizes popular in the United States for fluid

fluid dairy products, which are low acid or at a pH

milk products packaging are gable top paperboard

above 4.6, temperatures required are usually above *cartons. These cartons are made from liquid resistant,*

250◦F, which implies retorting and control of external

virgin paperboard extrusion-coated with low-density

and internal pressures of the packages. Canning is the

polyethylene to impart liquid and water vapor

traditional postfilling heat process to achieve ambient

resistance, as well as broad range heat *sealability.*

temperature shelf stability.

The cartons are delivered to dairies in knocked-down

Canning is largely in cylindrical steel or now alu-

sleeve form that permits rapid erection into open top

minum cans, which are hermetically sealed mechan-

cartons on appropriate packaging equipment. On this *ically by double-seaming a metal end to the body*

equipment the sleeves are opened and forced over a

flange after filling. After closure, the cans are cooked

mandrel on which a flat bottom heat seal is made by

under pressure and cooled to generate a partial vac-

after overlapping the bottom flaps of the carton. The

uum within the container and reduce

the rate of bio-

erected open top carton is stripped from the mandrel,

chemical oxidative deterioration. Glass bottles and

set upright and filled using gravity-type filler. The

jars may also be considered as a segment of the can-

top is heat-sealed by folding in a portion of the edges

ning spectrum.

and face-to-face sealing the gable top using pressure

After filling glass containers are hermetically

and conduction heat. The cartons are sufficiently

closed with rubber compound-lined steel or lined

robust to contain fluid milk and analogues for

polypropylene closures. The glass packages are care-

the distribution times required with

longer term

fully aligned and placed in retorts for pressure-

shelf-life impractical because of the edge wicking

cooking during which the pressure is carefully con-

of the paperboard (for longer distribution times,

trolled with an external overpressure to ensure against

the internal construction is changed). Among the *internal steam pressure blowing off the closures. Fur-*

advantages of paperboard cartons are that they may

thermore, because of the usual sensitivity of glass

be preprinted almost always with basic flexographic

to thermal stresses, careful increase and decrease of

decoration, and now, increasingly with rotogravure

temperature is practiced. Very little

fluid dairy prod-

or web-offset high-resolution graphics for consumer

uct today is packaged in glass in the United States,

display impact. Gable top cartons are not easy to

although the practice was not uncommon two gener-

open, but are reasonable to dispense from, and are

ations ago or now in Europe.

impossible to reclose improperly. They are relatively

In Europe also, retorting in plastic bottles is

inexpensive in almost all small sizes.

not uncommon with high-density polyethylene and

polypropylene being the packaging materials of

choice. Both are resistant to retort temperatures, but

Shelf Stable Fluid Dairy Products

are poor oxygen barriers, and so the contents are

Shelf stability implies heat treatment, either before

subject to significant biochemical deterioration at

or after filling to sterilize the contents, i.e., renders

ambient temperatures. The system is used for rela-

them free of all microorganisms of public health sig-

tively short-term ambient temperature

distribution.

nificance and of microorganisms that could cause

Recently in the United States, liquid dairy meal sub-

spoilage under normal conditions of distribution,

stitutes have been packaged in multiplayer barrier

i.e., ambient temperature. (Obviously, altering the

plastic bottles that are retorted after hermetic sealing *water activity of solids could also permit ambient*

with semirigid closures.

Aseptic Packaging

mode is quite similar in principle of operation to that

of Combibloc. Products include liquid egg, long-life

Aseptic packaging is the independent sterilization of *cream and flavored milk.*

product and package and assembly of the components

Aseptic packaging of plastic cups may be accom-

under sterile conditions to achieve ambient tempera-

plished on thermoform-fill-seal or preformed cup

ture shelf stability. Because of the several operations,

deposit-fill-seal systems. In thermoform-fill-seal sys-

aseptic packaging is statistically riskier than canning,

tems, sterilization may be previous to the dairy in the

which has a final heat process to compensate for any

converting plant or may be on the aseptic packaging

errors prior to closure. One reason for using aseptic

machine. The most widely used aseptic thermoform-

procedures is to significantly reduce

the thermal in-

fill-seal system is from France's ERCA. On one

put to the product since it can be heat sterilized in

ERCA system, the heat of extrusion of plastic may

thin film in heat exchangers prior to filling. A second

sterilize the webs to be used. On the machine a pro-

reason is that almost any package material, structure, *tective web of film is stripped away from the inte-*

or size may be used. Lightweight flexible or compos-

rior surface and the remaining thermoformable web

ite materials may be sterilized by various technolo-

is heated sufficiently to soften it. Sterile air pressure

gies that render the material sterile without damaging

is applied to form the plastic into a cup *shape in a*

it. Sterilization of the container may be by thermal

mold. The open top cup is filled in-line and a flexi-

methods such as dry heat, steam, or chemicals such

ble closure material is stripped of its protective film

as hydrogen peroxide.

and heat sealed to the flange of the base cups. With

The most widely used aseptic packaging is paper-

a rate of about 20 cycles per minute 10 or more cups

board composite bricks or blocks. In the Tetra Pak

are formed, filled, and sealed simultaneously. Output

system, on a presterilized machine, a prescored web

can be as high as 300+ per minute for 4 to 8 ounce

of packaging material is unwound into

a bath of hot

capacity cups.

hydrogen peroxide and dried in a sterile environment.

Other thermoform-fill-seal machines such as an-

The web is formed into a tube in which previously

other by ERCA or Bosch immerse the two webs in

sterilized, cooled fluid is pumped. Induction energy *hydrogen peroxide and evaporate the sterilant within*

heat seals both a back longitudinal and transverse

the machine to achieve sterility.

seam. The latter takes place through the product con-

On the Hassia thermoform-fill-seal machine,

tents thus eliminating any headspace. The sealed tube

steam is used both to sterilize the materials and to *is cut from the web and the pouch is formed into a*

thermoform the base plastic web into cup shape.

brick shape on a mandrel.

Hassia equipment has not been accepted for asepti-

On Hassia equipment, flexible tubes of barrier flex-

cally packaging low-acid dairy products in the United

ible laminations are sterilized by exposure to hydro-

States. Thermoform-fill-seal systems generally use

gen peroxide followed by heat drying. The tubes are

coextrusions of polystyrene as the thermoformable

filled with presterilized yogurt or pudding and sealed

structural component and polyvinylidene chloride as

at both ends to produce either sterile, or in some cases,

the barrier component.

extended refrigerated shelf life, puddings, or yogurts

Deposit-fill-seal systems use inputs of preformed

that have gained great popularity since the late 1990s.

cups, which may or may not be sterilized on the ma-

In the Combibloc system, used more in Europe,

chine. All are closed by heat sealing with flexible

paperboard composite materials are

preformed in

materials, which are either predie cut or cut from

the converting plant into prescored knocked-down

a web on the machine. The most widely used are

sleeves. At the presterilized aseptic packaging ma-

those for liquid coffee lighteners in which the nested

chine, the blanks are erected and set upright. Hydro-

cups are presterilized by ionizing radiation and then

gen peroxide is sprayed into the open top containers

aseptically transferred to the machine for denesting,

and then heated to both raise the operating tempera-

filling with sterile product, and heat sealed. Portion

ture of the chemical and evaporate away the residual.

Packaging and Purity Packaging

systems are simi-

Filling takes place in a horizontal mode with face-

lar in operation. Both use thermoformed polystyrene

to-face heat sealing of the material using ultrasonic

cups and aluminum foil/heat seal coating closures.

methods. Because the machine is horizontal, multi-

Generally the output is maintained under refrigerated *lane operation is possible and speed can be as high*

conditions despite their sterility, thus accounting for

as 400 packages per minute.

their use of nonbarrier packaging materials.

The Pure Pak gable top paperboard carton sys-

Hamba machines are applied for aseptic packag-

tem that continues to be used occasionally in aseptic *ing of milk-based puddings using prethermoformed*

polypropylene cups. To date, Hamba machines have

overwrapped, or the cheese may be pumped hot into

not been accepted by regulatory authorities for asep-

aluminum foil lamination overwraps with the heat *tic operation in the United States, thus accounting*

used to reduce the microbiological count. In Europe

for the refrigerated or extended shelf-life distribu-

considerable quantities of soft cheeses are packaged

tion. The product's quality, however, benefits from

on thermoform-fill-seal machines using polystyrene

the chilled distribution.

as the base cup material and aluminum foil lamina-

In Europe several aseptic bottle fillers are com-

tion as the heat seal closure.

mercial with hydrogen peroxide as the sterilant of

Frozen yogurt may be packaged in bulk for food

choice. The systems may employ either glass or plas-

service scooping and dispensing. Bulk packaging is *tic with polypropylene or high-density polyethylene*

generally, but increasingly less so, cylindrical spi-

as the preferred materials for short-term ambient tem-

ral wound virgin paperboard coated with polyethy-

perature distribution, and coextrusions with ethylene

lene with heat-sealed similar paperboard base and

vinyl alcohol for longer term

distribution. Bosch sys-

friction fit top, also paperboard. Cylindrical shapes

tems have been used for infant formula; Serac, Stork,

are almost traditional from Sealright (Huhtamaki),

and Krones systems have been used for fluid milk

with filling by fluid methods on their equipment. The

products. All are more widely used today in an ul-

cylinders may be received in knocked down form to

traclean mode to produce extended (chilled) shelf-

save on package material inventory space in which

life fluid dairy products including flavored milks and

case Sealright equipment is employed to erect the

drinkable yogurts. Shelf lives of more than 2 months

containers.

are commonly commercial.

Most frozen yogurt is packaged in coated, bleached

For larger size bag-in-box, preformed pouches fab-

virgin paperboard half-gallon cartons received in

ricated from metallized polyester film and fitted with

the form of knocked down sleeves. Cartons are au-

filling and dispensing fitments are presterilized us-

tomatically erected and filled through one end af-

ing ionizing gamma radiation. On Scholle, DuPont

ter which they are mechanically closed by lock-

Canada, or similar type aseptic filling equipment,

ing the tabs on the cartons. Increasing quantities of

sterile product is introduced through the fitment,

consumer size ice cream, particularly

the premium

which is subsequently sealed. Some web vertical

types, are packaged in rectangular corner convolute

form/fill/seal machines are also operated in aseptic

wound paperboard containers which are closed by

mode.

friction fit overcaps, again either paperboard or in-

sert injection-molded paperboard/plastic. Novelties

are first overwrapped on continuous motion horizon-

Solid Dairy Product Packaging

tal form/fill/seal equipment with polyethylene coated

Often in dairy product packaging, there is little dif-

paper or cavitated core oriented polypropylene as the

ference in filling and closing between solid and fluid *material. Wrapped novelties are then unitized and*

products. The difference comes later in distribution

placed in the ends of opened paperboard folding car-

after the product has set. Thus, from an initial pack-

tons, which are closed by hot melt adhesive.

aging standpoint, packaging is the same, but from

Numerous other packaging

technologies and ma-

a package selection standpoint, it is important to

terials are used commercially and are proposed for

choose structures that will contain the final product

dairy product packaging. This dissertation cannot

and be useful to the consumer. Products such as yo-

encompass every packaging means available to the *gurt and pudding whose packaging was referred to*

dairy packager. A sampling has been offered to re-

previously are handled from a packaging operation

flect the principal technologies and basic information

standpoint as if they were fluids, but from a con-

has been presented to suggest to dairy packagers al-

sumer standpoint, their packages must

take account

ternatives should the suppliers current offerings be

of spoonability. Numerous soft cheeses, spreads, etc.,

less than desired.

fall into this category.

Soft cheeses are generally pumped into ei-

FUTURE TRENDS

ther thermoformed polystyrene or injection-molded *polypropylene cups or tubs, which are then closed*

There will be continued application of aseptic tech-

by a combination of aluminum foil heat-sealed to

niques to deliver products for refrigerated distribu-

the flange; friction fit thermoform, with or with-

tion. The quality of thermally processed dairy prod-

out tamper resistant ring around the

rim. Some soft

ucts will be better retained by chilled distribution pro-

cheeses are pumped into molds and then cut to be

cedures. The quality retention durations for chilled

dairy products will be extended by introduction of

David J, Graves R, Carlson VR. 1996.

Aseptic

clean room extended shelf-life technologies.

Processing and Packaging of Food, CRC Press,

No longer will there be specific technologies. The

Boca Raton, FL.

new dairy packager will integrate more than one

Doyle M. 1996. Packaging Strategy, CRC Press, Boca *packaging technology into systems that will deliver a*

Raton, FL .

synergy of the benefits from each of the contributing

Gray I, Harte B, Miltz J. 1987. Food Product—Package

technologies. In the more distant future, packaging

Compatability, Technomic, CRC Press, Boca Raton,

systems will become so sensitive and responsive that

FL.

they, and not the process, will be the dominant factors

Hanlon JF, Kelsey RJ, Forcino H. 1998. Handbook of

Package Engineering, 3rd ed. CRC Press, Boca

in the delivery of quality dairy products. In an era of

Raton, FL.

active packaging, the package will be called upon to

Harkham, A. 1989. Packaging Strategy, CRC Press

sense the contents and to adjust to its technical needs

(Technomic) Boca Raton, FL.

for lower temperature, or aroma enhancement, or mi-

Holdsworth SD. 1992. Aseptic Processing and

crobiological suppression; and to the marketers de-

Packaging of Food Products, Elsevier, New York.

sire for impact communications with light and sound

Hotchkiss J. 1988. Food and packaging interactions.

taking over for mere passive graphics.

American Chemical Society, Washington, DC.

The environmental issue is emotional and replete

Institute of Food Science and Technology. 1985. In:

with misinformation and misperceptions. Regardless

Proceedings of Symposium on Aseptic Processing

of the facts, numerous problems are already present.

and Packaging of Foods, Lund University, Sweden,

The issue will continue to mushroom with few pre-

SIK.

dictable paths. Dairy packagers must be cognizant

Institute of Packaging Professionals. 1991. IOPP *of the volatile situation and be prepared to respond*

Packaging Reduction Recycling and Disposal

to those having either the force of law or consumer

Guidelines, Institute of Packaging Professionals,

perceptions, however erroneous they might be. Dairy

Naperville, IL.

packager suppliers are reactive to environmentalists'

Jenkins W, Harrington J. 1991. Packaging Foods with

pressures and will usually be active in assisting their

Plastics, CRC Press (Technomic), Boca Raton, FL.

customers. The decision must be made by the dairy

Man D, Jones A. 2000. Shelf-Life Evaluation of

on response: Do they accommodate every single sug-

Foods. Apsen Publications,

Gaitherburg, MD.

gestion from the field, regardless of how it disturbs

Osborn KR, Jenkins W. 1992. Plastic Films,

or how much it costs, or do they assume a proac-

Technology and Packaging Applications, CRC Press

tive position and attempt to bring a reasoned ap-

(Technomic), Boca Raton, FL.

Package Machinery Manufacturers Institute. 2004.

proach to the total picture of packaging in the solid

Packaging Machinery Directory. Alexandria, VA.

waste environment? No matter what stance they take,

Packaging Strategies. 1990. Aseptic Packaging, USA.

environmentalism will be the top priority for many

Packaging Strategies, West Chester,

PA.

years.

Paine F, Paine H. 1983. A Handbook of Food

As dairy packaging is being advanced, its progress

Packaging, United Kingdom, Leonard Hill, London,

toward a new dimension is already visible on the

UK.

technological horizon that will be

recognized by a

Reuter H. 1989. Aseptic Packaging of Food, CRC

perceptive consumer.

Press (Technomic), Boca Raton, FL. Robertson G.

1993. Food Packaging, Marcel Dekker, New York.

BIBLIOGRAPHY

Selke S. 1990. Packaging and the Environment, CRC

Press (Technomic), Boca Raton, FL.

Brody A, Marsh KS. 1997. Encyclopedia of Packaging

Selke S. 1997. Understanding Plastics Packaging

Technology,. 2nd ed. John Wiley & Sons, New York.

Technology, Gardner Publications,

Brody AL, Lord J. 2000. Developing New Food

Cincinnati/Hanser.

Products for a Changing Marketplace, CRC Press, *Soroka W. 2002. Fundamentals of Packaging*

Boca Raton, FL.

Technology, Institute of Packaging Professionals, St.

Brody AL, Strupinsky E, Kline L. 2001. Active

Charles, IL.

Packaging for Food Applications, CRC Press Boca

Stern W. 1981. Handbook of Package Design

Raton, FL.

Research, John Wiley & Sons, New York.

Part II

Manufacture of Yogurt

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

9

Yogurt: Fruit Preparations

and Flavoring Materials

Kevin R. O'Rell and Ramesh C. Chandan

Introduction

vanilla, peach, raspberry, strawberry-banana, plain, *Fruit as Raw Material for Yogurt Preparations*

blueberry, lemon-lime, cherry, and mixed berry.

Processing of Fruit for Use in Yogurt Fruit

The fruit preparations for addition to yogurt are

Preparations

specially designed to meet the marketing require-

Formulation of Fruit Preparations

ments for different types of yogurt. The stirred

Specialty Fruit Preparations

variety that now makes up 74% of the total refrig-

Processing Yogurt Fruit Preparations

erated yogurt category involves mechanical blend-

Packaging of Fruit Preparations

ing of the fermented mass with fruit preparation.

References

Acknowledgement

Therefore, the fruit preparation is formulated to fur-

nish adequate viscosity for thorough blending into

yogurt mass without significant dilution of the fin-

INTRODUCTION

ished product. At the same time, the fruit pieces

are designed to be interdispersed throughout the

Plain yogurt, which makes up 5% of the total re-

body of yogurt without settling on the bottom of

frigerated yogurt category, is used by consumers

the cup. The sensory attributes (aroma, flavor, and

as low/nonfat dressing for salads, as a topping for

color) and pH (acid–sweetness balance) of the fin-

potatoes and vegetables, as well as for *cooking*

ished product depend on the contribution from fruit

meals. Nevertheless, the popularity of yogurt has

preparation.

been propelled by the availability of sweetened fruit-

In the case of fruit-on-the bottom (FOB) style that

flavored product (Chandan, 1982, 2004; Chandan *makes up 8% of refrigerated yogurt sales, the fruit*

and Shahani, 1993; Tamime and Robinson, 1999).

preparation is designed to stay at the bottom, while

The addition of fruit preparations, fruit flavors, fruit

either white unfermented yogurt mass (low in viscos-

purees, and flavor extracts enhances versatility of

ity) or finished yogurt previously

incubated in bulk is

taste, color, and texture for the consumer. Fruits

being deposited on the top of the cup. For FOB, ide-

are generally perceived as healthy by the consumer.

ally, the fruit preparation is thickened (but not gelled)

The soluble and insoluble fiber located in the fruit

to suppress fruit floatation, or mixing with the milk *extends protection against cardiovascular diseases*

phase during filling or transportation. In addition, the

and colon cancer, respectively. Also, some fruits,

stabilization, the calcium content, the pH, and the os-

especially blueberries, contain high levels of an-

motic pressure generated by the fruit preparation at

thocyanins, which are flavonoids that

have poten-

the interface of fruit and yogurt base is taken into

tial health benefits functioning as antioxidants. Ac-

consideration to assure compatibility of the two lay-

cordingly, fruit association with yogurt endorses the

ers during incubation of the cup. The casein from

healthy image of yogurt even further.

the yogurt can precipitate out due to exposure to low

The top 10 selling flavors that account for nearly

pH and the osmotic pressure difference between the

70% of the total volume of yogurt sold based on

yogurt and the fruit preparation resulting in a lumpy

dollar sales in descending order are: strawberry,

or gritty texture after stirring.

The yogurt fruit preparations for consumption by

color, flavor, and texture. For instance, fruit picking is

toddlers and children are designed to integrate spe-

appropriate depending on the softness of the ripened

cial requirements for the consumer.

For instance, in

fruit. Soft fruit varieties are picked at mature stage to

toddler yogurts, to avoid choking, the fruit prepara-

avoid overripeness, which other would near to unde-

tions are made from fruit purees, fruit juices, and/or

sirable transportation and processing problems.

flavors. This is also true for yogurt targeting children, *The time to pick fruit depends on the type, va-*

where market research has shown a preference for

riety, location, weather, and end-product use. Cit-

no fruit particulates. Similarly, in the manufacture of

rus fruits do not ripen after harvesting, while some

whipped yogurt, the fruit preparation generally uses

other fruits continue to ripen under

favorable con-

fruit puree that contains fruit fragments small enough

ditions. The quality of fruit is generally measured

so as to avoid interference with the foaming process.

by objective physical–chemical procedures. Texture

In case of drinks, fruit preparations are designed to

is measured by compression or by force required to *contain juices, purees, and small fragments to avoid*

penetrate the fruit. The concentration of juice solids

settling of fruit during shelf life of the product and

(mostly sugars) as a measure of maturity of fruit can

enhance the drinking experience.

be assessed by a refractometer or a hydrometer. The

Fruit preparation for use in yogurt manufacture *refractometer determines the ability of a solution to*

may be defined as a stabilized suspension of fruit

refract or bend a beam of light. The degree of refrac-

particles or puree in a sweetened, acidified matrix,

tion is directly proportional to the strength of the so-

with or without added flavors/coloring material. The

lution. The hand-held refractometers

are very conve-

preparation is heat processed to effect enhancement

nient in field conditions. A hydrometer also measures

in shelf life by destroying microorganisms and con-

the concentration of juice. It consists of a weighted

stituent enzymes. The fruit preparations are generally

spindle with graduated stem. The hydrometer floats *added to yogurt products within a range of 10–20%*

in a juice and the reading at the meniscus of juice and

level in the final product. In addition, most fruited yo-

air is a measure of the density/concentration of the

gurts contain natural or artificial flavorings to boost

juice. The acid concentration changes with fruit ma-

the fruit flavor profile of the product.

For enhancing

turity. It is measured by simple titration with standard

the eye appeal, appropriate color preparations may

alkali.

be incorporated in the fruit-for-yogurt preparations.

The flavor profile of many fruits is a function of

The most popular fruit flavored yogurts are straw-

sugar and acid ratio. Sweetness and tartness of the

berry, raspberry, cherry, blueberry, mixed berry, boy-

flavor of fruit product is assessed by this ratio. Per-

senberry, peach, banana, lemon, tropical blends, apri-

centage of soluble solids in a fruit is stated as degrees

cot, apple, and their combinations. Also, addition of

Brix, which relates specific gravity of a *solution or*

fruit and other flavors popular in the bakery and ice

juice to equivalent concentration of sucrose. In the

cream industries are incorporated to bring an inno-

fruit industry, the term Brix (sugar) to acid ratio is

vative assortment of creative flavor profiles to the

commonly used. When the Brix-acid ratio is high, the *consumer.*

fruit contains high sugar and less acid, which in turn

implies that the fruit is sweet and less tart. Seasonal

FRUIT AS RAW MATERIAL FOR

variations in Brix and Brix-acid ratio are noticeable

YOGURT PREPARATIONS

in most fruits.

After the fruit reaches certain Brix and Brix-acid

The diversity of fruits available for fruit-for-yogurt

ratio, it is ready for harvesting. Harvesting by hand

preparations necessitates selection of cultivars that

is labor-intensive but is unavoidable in certain fruits.

would be relevant to fruit integrity and flavor require-

Use of a mechanical harvester is increasing, but pre-

ments in the finished yogurt product.

Accordingly,

cautions must be taken to avoid damage to the fruit.

the fruit should be compatible with the rigors of the

The harvested fruit is washed thoroughly to get rid of

processing techniques.

contaminants like soil, microorganisms, pesticides,

The quality of fruit is determined by the variety, *leaves, and stems. It may be sorted according to the*

the stock of tree/ bush, growing practices, and soil

size and grades. Unless the fruit is grown strictly for

and weather conditions. The fruit grower picks the

processing, it is likely that the best quality will be

fruit according to its ripeness and maturity. Matu-

shipped to the fresh market where it

can command

rity of fruit pertains to the condition of fruit ready to

premium prices. Declining quality generally corre-

eat right away or after a predetermined time period of

sponds with smaller piece size. After the fresh mar-

ripening. Ripeness of fruit refers to peak condition of

ket, the best quality is typically used for individually *quick frozen (IQF) and bulk frozen as a straight*

juice concentrate. Puree is produced with and without

pack or a sweetened pack. The IQF processing

sugar and can be concentrated. For juice concentrate,

provides fruit that will most closely approach fresh.

berries are pressed, filtered and concentrated under

This is because in IQF no sugar is added and freez-

vacuum to produce product from 42 to 70◦Brix.

ing takes place relatively quickly, minimizing dam-

age to the tissue by the ice crystal formation. Freezing

Blueberries

in any form will extend the fruit shelf life for more *than a year. Generally, the poorer qualities go to the*

In North America, two distinct types of blueberries

purees and juice/juice concentrates. These selected

are grown. Wild blueberries that are small berries (1/4

fruit lots are processed further for use in the manu-

to 3/8 inches) known for their sweet intense flavor,

facture of juice, jam, fruit toppings, *bakery fillings,*

and cultivated blueberries that are larger berries (1/2

and fruit preparations for ice cream, yogurt, and cot-

to 5/8 inches or larger). The wild crop is harvested

tage cheese.

by hand and the season begins in late July and ex-

tends for up to 6 weeks. Most cultivated blueberries *are mechanically harvested and the season runs from*

Processing of Fruit for Use in

April to September. Before processing, the berries

Yogurt Fruit Preparations

are cleaned by blowing away the twigs, leaves and

Yogurt manufacturers use specially processed fruit

other debris. They are then graded for size, washed, *preparations because of convenience of use and to*

and hand inspected for green and defective fruit. Ap-

impart added value to yogurt. Since fruit suppliers

proximately three-quarters of the processed berries

specialize in general fruit processing, the economies

are frozen, either IQF or bulk pack, straight or sugar

of scale in purchasing fruit offer

economical advan-

pack (usually 4 + 1). Some blueberries are directly

tage to the yogurt processor. Also, the expertise of

canned with a starch and sugar solution added. Puree

the fruit processor extends food safety and shelf-life

and juice products are made from crushed berries,

optimization in yogurt.

thermally treated to inactivate enzymes. Puree is typ-

Major fruit processing techniques in order of im-

ically 10–12°Brix, but can be concentrated. For mak-

portance are canning, freezing, drying, preserva-

ing juice, berries are pressed, filtered and concen-

tion with sugar syrups, concentrating by moisture

trated to 45–65% soluble solids.

removal, preservation with chemicals, fermentation

with yeasts and bacteria, pickling with vinegar, sugar

Raspberries and Other Berries

and spices, reduction of oxidation with antioxidants,

reducing agents and vacuum treatment, and screen-

Raspberries come in many varieties, mostly based

ing of fruit from light exposure (Woodroof, 1990).

on color: red, black, purple, or golden. They grow

The industry utilizes a combination of two or more

on canes and, depending on the variety, produce one

of these techniques. Some processing methods are

crop midsummer or a second, smaller crop in the

more suitable for certain fruits.

fall. The fruit is soft and easily damaged; therefore, *it must be harvested by hand. The berries are washed*

with gentle water sprays, then drained and inspected

Strawberries

for leaves and other foreign debris. Frozen berries

In the United States 75% of strawberry production is

are processed as IQF, unsweetened bulk or 3 + 1

from California, followed by the Northwestern re-

sweetened pack. Raspberries are pulped to produce

gion. Of the total frozen strawberries used in the

puree with or without seeds. For seedless puree, the

United States, about 25–30% are imported, mostly

pulped puree is put through a sieve to remove the

from Mexico and Poland. Strawberries are hand har-

seeds. Raspberry juice is typically

concentrated to the

vested in the winter and spring in the southern States,

68–70° Brix.

and spring and summer in the northern areas. Straw-

Blackberries, boysenberries and loganberries are

berries for processing are washed, inspected for green

grown and processed in a manner similar to raspber-

and defective fruit, and then sorted for quality. Typi-

ries.

cal packs include IQF and bulk frozen, with and with-

out sugar. Sugar levels most commonly available are

Peaches

4 + 1 and 3 + 1 (fruit to sugar) and the berries may be

whole, sliced or crushed. The berries that do not meet

There are many varieties grown in the United States,

grade standards are used for production of puree or

but they fall into two classifications: clingstone or

freestone. The name indicates whether or not the flesh

Organic fruits

adheres tightly to the pit. Freestones *are usually sold*

Almost all variety of fruits can be found in organic

in the fresh market, but some are processed. Cling-

form. Depending on the fruit, the cost premium for

stones are typically used for processing and these are

organic fruits is as much as 30–50% higher compared

canned or frozen. When the fruit is ripe but firm, *to conventional. Much of this cost is associated with*

it is harvested by hand. Peaches for either canning

the strict requirements that must be followed in pro-

or frozen processing are inspected, graded for size,

duction. Organic fruits must be grown and handled

and put through a pitting machine that automatically

under the requirements of FDA 7 CFR

Part 205 Na-

halves the fruit. The pitted halves are processed in a

tional Organic Program; Final Rule (FDA 2004). For

lye solution to loosen the skins, which are then re-

the land to qualify for organic certification, it must

moved by shaker-washers. The halves may be sliced

be free of prohibited substances, as listed in 205.105 *or diced in the desired size. Canned peaches are made*

for a minimum of 3 years. For the crops, there are

from fruit and juice or syrups with 20–55% sugar.

specific requirements for soil and crop nutrient man-

Frozen peaches may be packed as IQF or as syrup

agement practice standards 205.203, seeds and plant-

pack, in halves, slices or dices. The

fruit-to-sugar ra-

ing stock practice standards 205.204, crop pest, weed

tios vary from 3–1 to 9–1. They may receive an ascor-

and disease management practice standards 205.206,

bic acid or citric acid treatment to preserve color.

and wild-crop harvesting practice standards 205.207.

Puree is obtained from the machine pitting process

The synthetic substances that are allowed for use in

or from whole fruit that is pulped, mixed with citric

organic production are listed in 205.601. The pro-

acid and ascorbic acid, and then pumped through two

ducer must develop an organic system handling plan

finishers, 0.25 and 0.02 inches.

to outline how they plan to manage the land, crops, *and harvesting within the organic regulations. The*

Cherries

producer then files an application for organic cer-

tification with an Accredited Certification Agency

There are many varieties of cherries but there are two

(ACA), a third party that has been accredited by the

main categories: tart or sweet. Tart cherries provide

USDA to conduct certification activities as a certified

the majority of the fruit for the US processing. Har-

agent under the rule. The organic system plan, facil-

vesting, typically in late June through August, is by

ities, and appropriate records are then inspected by

hand for the fresh market, or by mechanical shak-

the ACA and considered for approval.

After organic

ers for processing cherries. Tart cherries for process-

certification is granted, there are detailed yearly in-

ing are first placed in a cool water bath, destemmed,

spections to assure compliance with the regulations.

washed, inspected, sorted, and then mechanically pit-

All relevant records must be maintained for a mini-

ted. The pitting process is not 100% effective and one

mum of 5 years.

pit typically appears in 100 to 1,000 ounces of pro-

cessed fruit. Many processors of yogurt fruit prepa-

ration further hand sort cherries before processing to

Formulation of Fruit Preparations

highly reduce the risk of a pit in their products. Most *cherries are packed as IQF or as a frozen 5 + 1 pack*

Typical fruit base formulation for use in yogurt us-

or puree. Some cherries are canned in juice or syrup.

ing modified starch (MFS) or Pectin is shown in

Juice and concentrate (typically 68◦Brix) are pressed

Table 9.1.

from whole frozen or fresh cherries.

In the formulation of fruit preparation, the ingredi-

ents of choice are: fruit, fruit puree and juice, sweet-

ener, stabilizer(s), acidifying/buffering agent, color,

Bananas

flavor, and sometimes a preservative. In addition, the

Bananas are grown in tropical areas of Mexico, Cen-

fruit preparation can be used as a vehicle to incorpo-

tral and South America, the Caribbean and Asia.

rate vitamins, minerals, intensive sweeteners or func-

Bananas are harvested when mature but green. To

tional ingredients (i.e., fiber, nutraceuticals).

ripen quickly, they are held at 60◦F with ethylene gas

The various forms of fruit, fruit purees, and juices

added. Bananas can be processed into

many forms—

used in fruit preparations have been mentioned ear-

frozen whole fruit and slices and puree, canned slices,

lier. The manufacturer of yogurt fruit preparation

and puree, all with or without syrup, and aseptically

will set raw material specifications based on their

processed and concentrated purees.

customers need in the finished yogurt. In general,

Table 9.1. *Formulation of Fruit Base Using*

material specification would include concentration,

Modified Food Starch or Pectin

°Brix, flavor, color, and microbiological parameters.

Percentages

Ingredients

Starch

Pectin

Sweeteners

Fruit

35–40

35–40

The next major component of fruit preparations are

Sugar

35–45

35–45

sweeteners. The standard of identity for yogurt, low

Water

12–18

12–18

fat yogurt and nonfat yogurt (FDA CFR Parts 131.200

Modified starch

3–4%

0

to 206) (FDA 2004) specifies the allowable nutri-

LM pectin

0

0.5–0.7

tive sweeteners that can be used. Generally most

Flavors

< 1

< 1

fruit preparations for FOB or Swiss/blended style yo-

Color (optional)

< 1

< 1

gurt applications, which are sweetened using nutri-

Citric acid (to desired pH)

< 0.5

< 0.5

tive sweeteners, use blends of sugar and high fructose

Sodium citrate (as needed for

< 0.5

< 0.5

corn syrup (HFCS). The sugar can be in granulated

pH control)

or liquid form. For liquid sugar (67.5°Brix of a su-

Preservatives (optional)

< 0.1

< 0.1

crose solution) the facility must be equipped with an

appropriate storage tank to maintain a 70–100◦F tem-

for fruit particulates, the manufacturer requires fruit

perature. Usually a 42% HFCS is used and it must

“practically” free from defects and extraneous mate-

also be stored in an appropriate tank to maintain a

rial, of good character and color, and normal flavor

90–100◦F temperature. From these storage tanks the

and odor. In addition, they also specify fruit variety,

syrup is pumped to the batch/mixing kettles.

size, form, and microbiological limits. The following

The most common blends of sugar and

HFCS are

is an example of a typical raw material specification

made up in a 50 : 50 mix based on solids. This blend

for blueberries (Table 9.2).

provides a good balance between clean flavor release

There would be similar raw material specifica-

and cost. Increasing the portion of HFCS will provide *tions for puree that would include form (i.e., canned,*

a lower cost, but can mask some of the flavor release.

frozen, concentration, added sugar), flavor, color, and

Some private label or economy brands could utilize

microbiological parameters. For fruit juices, the raw

100% HFCS as the sweetener. On the other hand,

***Table 9.2.** Typical Specification of*

Blueberries for Manufacture of Fruit Preparation Designed for Use in Yogurt

Company Information

Date :

Raw Material Specification

Material item number :

Material :

Wild blueberries.

1. Fruit variety: Wild blueberries (no specific variety) sourced from the Northwest or Canada.

2. Form: IQF or frozen straight bulk pack

3. Character: The berries should have reasonably uniform dark blue-purple color with no more than 8%

red-purple color. Berries should be firm, reasonably fleshy, practically all whole with no more than 5% by weight that are crushed, mushy or broken.

4. Size: 1 / 4 to 3 / 8 inch preferred. 1000 berries per pound with a range of 900 to 1200.

5. Extraneous material: Per 30 pound box. No more than 3 whole leaves or 8 stems (larger than 1 / 2 inch) and no *more than 3 stem clusters. No more than 25 green, undeveloped edible berries.*

6. Foreign material: No insects, nonberry related wood, debris or dirt of any kind.

7. Microbiological:

Standard plate count—10,000 CFU/g max

Yeast and mold—2,000 CFU/g max

Coliform—50 CFU/g max

Salmonella—Negative

Listeria—Negative

Hepatitis—Negative

156

Part II: Manufacture of Yogurt

for those looking to get a cleaner ingredient label

Ace-K is a white, odorless, crystalline sweetener

for their consumer and to provide a sharp, cleaner

that is not metabolized by the body and is therefore *flavor release, 100% sugar can be used in the fruit*

classified as nonnutritive. It is 200 times sweeter than

preparation.

sucrose and remains stable under high temperatures.

Other nutritive sweeteners that might be used in

Studies have shown that after several months of stor-

fruit preparations include crystalline fructose, fruit *age at room temperature, virtually no change in Ace-*

juice concentrate, tapioca or rice syrup, agave, honey

K concentration was found in the pH range common

or maple syrup. The choice of these sweeteners is

in fruit preparations. Ace-K has a slight aftertaste;

usually determined by marketing considerations for

however blending with other

sweeteners can improve

the label declaration. In addition to providing a “clean

the taste profiles, in addition to offering economic and

label,” crystalline fructose provides more sweetness

stability advantages. Ace-K is commonly blended

at the same solids level as sucrose and a cleaner flavor

with APM or sucralose in fruit preparations for yo-

release, but at a higher cost.

gurt.

The total sweetness of the fruit preparation must

Sucralose is made from sugar through a patented

be balanced with the usage rate and sweetness, if

process involving the selective chlorination of su-

any, of the yogurt base. Most fruit preparations for *crose replacing three hydroxyl groups of the sugar*

Swiss or blended yogurts are used at 12–18% and

molecule with chlorine atoms. It is 600 times sweeter

are formulated for a 36–55◦Brix. For FOB fruits, the

than sucrose and does not break down in the body

most common usage is from 15% to 20% with fruit

(nonnutritive). Sucralose has excellent

stability un-

preparation formulated for a 45–50∘Brix.

der a broad range of processing, pH, and tempera-

ture conditions and does not lose sweetness over ex-

High Intensity Sweeteners.

There are several high

tended periods of time. Because of these attributes,

intensity and noncaloric or

nonnutritive sweeten-

it is an excellent sweetener for fruit preparations that

ers used as sweeteners in fruit preparations used

are designed for use in low sugar yogurt products. It

in yogurt. Some of the FDA approved high inten-

can be used alone or sometimes it is combined with

sity or nonnutritive sweetener options are: aspartame *other nonnutritive sweeteners like Ace-K. There is*

(APM), sucralose, and acesulfame-K (Ace-K). These

a synergistic effect using the sucralose-ace-k com-

can be used alone or in combination with nutritive or

bination that improves the taste profile and limits

other nonnutritive sweeteners.

the lingering aftertaste sometimes associated with

Aspartame was one of the first high intensity

sucralose.

sweeteners used in yogurt fruit preparations. APM is

made from two amino acids (L-phenylalanine and L-

Stabilizers

aspartic acid) and, therefore contributes four calories

per gram. But since it is 180 to 200 times sweeter than

The most common stabilizer used for both blended

sugar, the usage levels are so low that it contributes

and FOB yogurts is modified food starch (MFS) usu-

essentially no calories. Limitations of APM include

ally derived from corn. The starch undergoes a two

lack of stability and loss of sweetness when exposed

step chemical modification that

provides resistance to

to high temperatures over extended periods. For best

shear, and stability against retrogradation and synere-

results, it is recommended not to process APM con-

sis during long term storage in fruit preparation. In

taining fruit preparations above 96.1◦C (205◦F) for

addition to its excellent functionality, MFS is easy to *more than 5 minutes. In addition, the fruit should be*

handle in processing and is cost effective. One disad-

cooled down to 32.2◦C (90◦F) or lower, immediately

vantage of some modified food starches, particularly

after heat treatment. Therefore its use is limited to

cook-up starches, is their tendency to mask flavor

aseptic fruit processing systems, and

the packaged

release. MFS that is derived from tapioca is some-

fruit is recommended to be stored refrigerated dur-

times desired for labeling purposes and it can exhibit

ing its code life. Because of these limitations, today

less flavor masking. There are also organic and natu-

most yogurt products add the APM as a sweetener *ral starches that have not been chemically modified.*

during the time of yogurt manufacturing. In yogurt

These have been evaluated in fruit preparations, but

products, the stability of APM is increased due to re-

to date, because of their lack of stability, they have

frigeration and the pH range of yogurt. Today, APM

had limited success in commercial

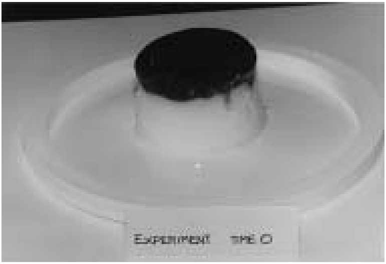
production.

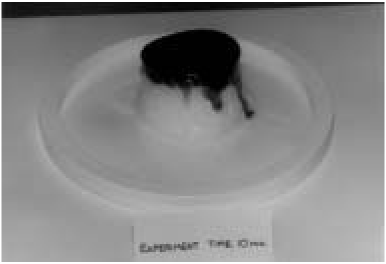
is used in combination with Ace-K, HFCS or crys-

Another popular stabilizer used in fruit prepara-

talline fructose in yogurt.

tions is pectin derived from either citrus peel or apple


EXPERIMENT TIME 0



pomace. Pectin is more expensive but is preferred in

wide pH range (from pH 2.9 to 5.6) and soluble solids

applications that require a natural label perception.

content from 10% to 80%. LM pectins offer the fol-

Many FOB fruit preparations use pectin or a blend of *lowing advantages in fruit preparations:*

pectin and locust bean gum as the stabilizer of choice.

r Setting temperature is independent of cooling rate

(Hoefler, 2004). Various pectins are primarily poly-

r The final product is thermo-reversible

mers of polygalacturonic acid, which are esterified to

r The fruit preparation has an excellent *resistance*

different degrees. Pectin functions as a gelling agent,

to shearing during mixing or pumping and

thickener, and suspending agent in fruit preparations.

exhibits no syneresis

They are processed to yield two general types of com-

mercial pectin products—high and low methoxyl.

When using LM pectin in FOB yogurt fruit prepa-

High methoxyl (HM) pectins are characterized by

rations, it is essential to obtain the right level of

an esterification degree of greater than 50% and are

calcium saturation to avoid problems with the fruit

capable of forming gel networks at high acid pH's *texture and degradation of yogurt white mass at the*

(around pH 3) in the presence of high soluble solids

interface. If the LM pectin is too short in calcium sat-

(greater that 55%). HM pectins are used as the stabi-

uration, the fruit preparation will form a firm “hockey

lizer for traditional fruit preserves.

puck” at the bottom of the cup and the resulting

Most modern fruit preparations use low methoxyl

stir-out will contain small colored gelled lumps. If

(LM) pectins either alone or in combination with lo-

the LM pectin is fully saturated, free ionic calcium

cust bean gum or a small amount of HM pectin. LM

from the yogurt, along with citric acid and other con-

pectins require only a controlled

amount of calcium

stituents from the fruit will result in white mass degra-

ions to form gels. Gelation can take place across a

dation or a "leathery–gritty" interface. The ideal fruit

***Figure 9.1.** Effect of low methoxy pectin on the properties of fruit. The Control FOB yogurt fruit contains high methoxy fruit. Following inversion of yogurt cup, notice the fruit flows freely around the yogurt gel. When low methoxy pectin is used in the Experimental samples, the fruit forms a*

cohesive mass on the top of yogurt layer.

preparation will not cause white mass degradation

fruit preparation that they are purchasing. With this

and will stand upon the inverted white mass with

syrup, it is possible to produce both vanilla and fruited *only minimal run off (Fig. 9.1). It will appear to be*

yogurts using one plain yogurt base.

a soft hockey puck and can be easily stirred into the

Some yogurt producers prefer powdered vanilla

yogurt, resulting in a smooth appearance.

because it does not cause dilution of yogurt with

Locust bean gum (LBG), at range of 0.2–0.3%, *vanilla solvent, alcohol. To prepare the powder,*

is sometimes used in combination with 0.5–0.6%

vanilla beans are ground with sugar. Specks of vanilla

LM pectin. Locust or carob bean gum is a hydro-

beans are visible in this type of powder. If no specks

colloid produced from the seeds of the evergreen lo-

are required, the powder is obtained by *drying un-*

cust bean tree, which grows in the coastal regions of

der vacuum a blended paste of single strength vanilla

the Mediterranean. Chemically, LBG is classed as a

extract and sugar. The proportion of vanilla extract

galactomannan. It is primarily used for its ability to

and sugar is designed to yield single strength vanilla *increase viscosity and it is helpful in preventing fruit*

powder.

flotation especially in large size containers. When

Artificial vanilla flavor is prepared from synthetic

used in combination with pectin, it results in a differ-

methyl vanillin. This flavoring offers cost savings be-

ent gel set, usually softer, and provides a slight cost *cause of its flavor potency but the label of the product*

savings.

must indicate artificial flavor. Furthermore, its flavor

balance and aroma are considered less desirable than

natural vanilla. In relation to flavor strength, 0.7%

Flavor Preparations

solution of vanillin is equivalent to one pound of dry

Flavor preparations used in yogurt manufacturing

vanilla beans. Pure vanilla flavoring has a standard of

consist of vanilla or fruit flavors.

identity (FDA 21 CFR 169.175) (FDA 2004). Mix-

tures of pure vanilla and vanillin are covered in FDA

Vanilla.

This flavor is the second best selling fla-

21 CFR 169.177 (FDA 2004). Imitation vanilla is

vor of commercial yogurt accounting for more than

identified in FDA 21 (FDA 2004) CFR .169.181.

$200 million in total sales. Most of the vanilla beans

(65–70%) come from Bourbon islands (Madagascar,

Fruit Flavors.

The flavor options commonly used

Comro, Reunion, and the Seychelles). Indonesia and

in fruit preparations or flavored syrups are natural,

India supply 25–30% of the world's bean produc-

natural/WONF (with other natural flavors), N&A

tion. However, Bourbon beans are considered as the

(natural and artificial) or artificial. The majority of

source of finest vanilla. Vanilla beans *are derived*

fruit preparations today use natural/WONF. Most

from the fruit of Vanilla fragrance. This plant belongs

manufacturers will custom-formulate the flavor sys-

to orchid family. The beans are harvested, and cured.

tem to meet the customer's need. Usually the purpose

During this process, fermentation and "sweating" of *of using N&A or artificial flavors is to reduce the fla-*

beans gives rise to methyl vanillin, the predominant

vor cost. Drinkable yogurts might use flavored syrups

flavor principal of natural vanilla extract. To prepare

that consist of sugar or HFCS, a small amount of sta-

the extract, beans are extracted with a mixture of wa-

bilizer for viscosity and flavoring.

ter and alcohol. Optional ingredients of extracting

solvent are glycerin and sugar. One gallon of standard

Colors

strength vanilla extract is equivalent to 13.34 oz. of

vanilla beans. Alcohol content of the extract ranges

The color of the fruit preparation is usually used to

from 30% to 50%. By evaporating solvent, con-

color the finished yogurt. The options include, no

centrated extracts (2 to 5 fold) are also available

color added therefore relying on the natural color of

(Marshall and Arbuckle, 1996).

the fruit, or color added, natural colors, or artificial

It is most common to use vanilla extract added

colors. Artificial colors (red #40, blue #1, and yellow *in yogurt production after fermentation for blended*

#5 & #6) are very stable during processing, fruit shelf

yogurts or added prior to fermentation for cup set yo-

life and during code life of the yogurt. These are the

gurt. Some manufacturers prefer to obtain vanilla in

most economical choice, but have fallen out of favor

processed syrup from a typical fruit

preparation sup-

for labeling reasons.

plier. To prepare these vanilla syrups, vanilla extract

The use of natural colors in fruit preparations is

is processed with sugar and/or HFCS to a finished

more common. Natural colors used in the finished

Brix of 50–60◦, usually at a similar Brix level to the *yogurt, added either through the fruit preparation*

or to the yogurt directly, are considered "color ad-

flavor notes. The high acidity level helps bring out the

ditives" and must be declared as "color added" or

fruit flavor and is more compatible with the acidity *by the ingredient name in the ingredient declaration.*

of the yogurt. When using acids in fruit preparations,

Color additives not subject to certification may be de-

it is common to also add buffering agents such as

clared as "Artificial Color," "Artificial Color Added,"

sodium citrate.

or "Color Added." Alternatively, such color additives *may be declared as "Colored with*

" or "color,"

Preservatives

the blank to be filled with the name of the color ad-

ditive listed in the applicable regulation in part 73 of

Some fruit preparations contain added preservatives.

this chapter FDA 21 CFR 101.30(k)(2) (FDA 2004).

This is especially the case for fruit

preparations that

Some of the natural colors that are preferred because

are processed using the "hot pack" method. The most

of their heat stability during processing are black

common preservative used is potassium sorbate, ei-

carrot, grape extract (Kosher or non-Kosher), choke

ther alone or in combination with sodium benzoate.

berries, elderberry, red cabbage, radish, black cur-

The total usage rate will range from 0.075% to 0.20%

rent, carmine, annatto, and turmeric. Some of these

in the fruit preparation. Fruit processed using an asep-

colors that are used will simply appear as "vegetable

tic system does not require added preservatives, but

color" in the ingredient declaration.

Beet juice is

some product manufacturers will add them for added

sometimes used in fruit preparations, but because of

protection. Most fruit preparations have a 4-month

its instability to heat processing, many times it will

shelf life, but some formulations that use artificial

be added at the yogurt manufacturing step.

colors and/or flavors can have as much as a 6-month

shelf life.

A sample specification sheet for a raspberry fruit

Acidulants

preparation for blended or Swiss style yogurt is

Fruit preparations are generally acidified to pH 3.4–

shown in Table 9.3.

4.1. The most commonly used acidulant

is citric acid.

If a more natural label is desired, lemon juice con-

Specialty Fruit Preparations

centrate, a more costly alternative, can be used. For

some fruits, such as strawberry, blueberry, or rasp-

There are also other specialty fruit preparations that

berry, malic acid can be used to help enhance certain *are produced for a specific application, or market,*

Table 9.3. *Typical Specification Sheet for Fruit Preparation Designed for Use in Blended/Swiss-Style Yogurt*

Company Information

Date:

Product: Raspberry swiss-style fruit for yogurt

Product code #:

Recommended usage: 15% in a yogurt with 3% added sugar

Ingredient statement: Sugar, water, raspberries, pectin, locust bean gum, natural flavors Physical Specifications:

◦Brix: 50 ± 2 . 0

pH: 3 . 6 ± 0 . 02

%Fruit: 30%

Appearance: Red, opaque viscous liquid without seeds.

Microbiological Specifications:

Total plate count: < 10 CFU per gram

Yeast & mold: < 10 CFU per gram

Coliform: < 10 CFU per gram

E. coli: Negative

Salmonella: Negative

Staphylococcus: Negative

Shelf life & Storage: 150 days refrigerated; 90 days between $60-90^{\circ}$F

Packaging: 2000 lb stainless steel tote

160

Part II: Manufacture of Yogurt

***Table 9.4.** Organic Ingredients as Defined by FDA 7 CFR 205 (FDA 2004)*

Organic fruits, fruit puree, and fruit juice/concentrate

Organic sugar or organic evaporated cane juice

Organic Compliant Ingredients (as defined by 7 CFR 205)

Citric acid—allowed 205.605 (a) (1) (ii)—produced by microbial fermentation of carbohydrate substances Calcium chloride—allowed 205.605 (a) (4)

Vegetable colors—allowed 205.605 (a) (5)—nonsynthetic sources only

Flavors—allowed 205.605 (a) (9)—

nonsynthetic sources only and must not be produced using synthetic solvents and carrier systems or any artificial preservatives.

Ascorbic acid—allowed 205.605 (b) (4)

LM pectin—allowed 205.605 (b) (21)

Sodium citrate—allowed 205.605 (b) (31)

Locust bean gum—allowed 205.606 (b) —gums water extracted only

HM pectin—allowed 205.606 (e)

such as organic or unsweetened/concentrated fruit *essential function in a system of organic production*

preparations. Unsweetened fruit preparations are

or handling, as determined by the certifying agent in

very low Brix (12–30◦), have a high concentra-

the course of reviewing the organic plan. Today an or-

tion of fruit (40– 60%), and are processed asep-

ganic LBG is being produced, and will

be tested in

tically. They are added at lower usage rates (10–

organic formulations to assess its function and qual-

12%) in a yogurt sweetened with nutritive or high

ity as a replacement for conventional LBG currently

intensity/nonnutritive sweeteners. They can pro-

being used.

vide in-plant flexibility to be used in an array of

Table 9.5 shows more popular fruits and fla-

product formulations, and offer freight and storage

vors/colors used in yogurt. This list contains an array

savings.

of fruits and flavor combinations to offer a wide va-

The organic yogurt market is growing at 22% per *riety of innovative selections for various segments of*

year in dollar sales, and is gaining interest from yo-

yogurt consumers.

gurt producers. Because fruit preparations are formu-

lated using some ingredients that are nonagricultural,

they can not be made to meet the 100% organic la-

PROCESSING YOGURT FRUIT

bel. However, it is very possible to produce organic

PREPARATIONS

fruit preparations that meet the 95% minimum of or-

There are two basic processes used in the manufac-

ganic agricultural products by weight, excluding wa-

ture and packaging of yogurt fruit preparations. The

ter and salt. This is possible because the remaining *conventional "hot pack" processes using open cook-*

5% or less of the necessary ingredients needed are

ing kettles, and the closed aseptic process and pack-

allowed in 7 CFR 205.605—nonagricultural (nonor-

aging system.

ganic) substances allowed as ingredients in or on pro-

In the conventional hot pack process (Figure 9.2) *cessed products labeled as “organic”. . . . . (a) nonsyn-*

using modified food starch as the stabilizer, the basic

thetics allowed and (b) synthetics allowed and 7 CFR

processing steps are:

205.606—nonorganically produced agricultural al-

lowed as ingredients in or on processed products la-

1. Add fruit, 75% of the sugar, 50% of the water, *beled as “organic” . . . . . .*

and preservatives to a steam jacketed kettle with

Table 9.4 lists organic and organic compliant

agitation.

ingredients typically used in the preparation of an

2. In a second kettle, add the starch to the remaining

organic fruit preparation.

water. Mix well and then add the starch *slurry to*

It should be noted that if any agricultural ingre-

the first kettle.

dient, including those listed in 205.606, becomes

3. Heat to 85– 87.8◦C (185–190◦F) with continuous

available commercially it must be used in an organic

agitation.

product. Commercially available is

defined in 7 CFR

4. Add the remaining sugar to cool the batch.

205.2 as the ability to obtain a production input in an

5. Add flavor and color and mix well. At this point,

appropriate form, quality, or quantity, to fulfill an

the quality control check is applied. Pull sample

9 Yogurt: Fruit Preparations and Flavoring Materials

Table 9.5. *Various Fruit Flavors Used in Commercial Yogurt*

Style of Yogurt

Flavors Available

Fruit-on-the bottom

Apple cinnamon, blueberry, boysenberry, cherry, mixed berry, peach,

raspberry, strawberry, strawberry banana, tropical blends

Stirred/blended

Strawberry, strawberry banana, blueberry, cherry, raspberry, peach, raspberry

banana crème, berry banana, blackberry harvest, blueberry crumble,

boysenberry, cherry orchard, coconut cream pie, french vanilla, harvest

peach, key lime pie, lemon burst, mandarin orange, mixed berry, mountain

blueberry, orange crème, peach cobbler, pina colada, pineapple, red

raspberry, strawberry, strawberry banana, strawberry cheesecake, *strawberry*

kiwi, strawberry mango, tropical peach, white chocolate raspberry

Whipped

Strawberry, strawberry mist, raspberry mousse, cherry chiffon, french vanilla,

key lime pie, orange crème, peaches n' cream, blueberry mist, strawberry

banana bliss

Drinks/smoothies

Strawberry, strawberry banana, tropical, raspberry, peach, mixed *berry, peach*

passion fruit

Extra-thick

Banana, blackberry harvest, blueberries 'n cream. crème caramel, key lime pie,

lemon supreme, orange crème, peaches n' cream, royal raspberry,

strawberry, strawberry banana, vanilla

Light

Apple turnover, apricot mango, banana crème pie, berries n' cream, *blackberry,*

blackberry pie, blueberry, blueberry patch, boston cream pie, cherry vanilla,

harvest peach, key lime pie, lemon cream pie, lemon chiffon, orange crème,

orange mango, peach, raspberry, red raspberry, strawberry, strawberry kiwi,

strawberries n' banana, strawberry orange sunrise, very cherry, very vanilla,

white chocolate raspberry, white chocolate strawberry

Children's dual color

Cotton candy/strawberry kiwi, raspberry rainbow/strawberry bash, rockin'

rainbow sherbet/outrageous bubble gum, triple cherry/wild berry blue,

watermelon burst/strawberry punch

Toddler's

Strawberry-banana, strawberry-strawberry vanilla, strawberry banana-peaches

n' cream, peach, pear

Lo carb

Strawberry crème, peach crème, blueberry crème, raspberry crème, peaches 'n

cream, raspberry 'n cream, strawberries n' cream, vanilla cream

Probiotic/bio-yogurt

Strawberry, vanilla, orange

Yogurt in a tube/portable

Strawberry milkshake/banana split, red raspberry/paradise punch, strawberry

banana burst/watermelon meltdown,

strawberry kiwi kick/chill out cherry,

strawberry splash/berry blue blast,
cool cotton candy/burstin’ melon berry,

crazy berry bolt/extreme red rush

from fully batched and mixed kettle and check

1. Add fruit, sugar and 50% water to a steam jacketed

◦Brix, pH and color, as per specification.

kettle with agitation.

6. Pack the product at 71.1–73.9◦C

(160–165◦ F) into

2. In a second kettle, add starch to the remaining

the appropriate container.

water and mix well. Add starch slurry to the first

7. Cool the product in the container with blast cool-

kettle.

ing.

3. Preheat ingredients to 37.8◦C(100◦F).

4. Add flavor and color and mix well.

Generally preservatives, such as potassium sor-

Quality Control check: Pull sample from fully

bate, are added to the fruit preparation that is pro-

batched and mixed kettle and check °Brix, pH, and

duced using the conventional hot pack process.

color as per specification.

In the aseptic process (Figure 9.3) and packaging

system, using modified food starch as the stabilizer,

5. Pump mixture through an aseptic system capable

the basic processing steps are:

of rendering the finished product commercially

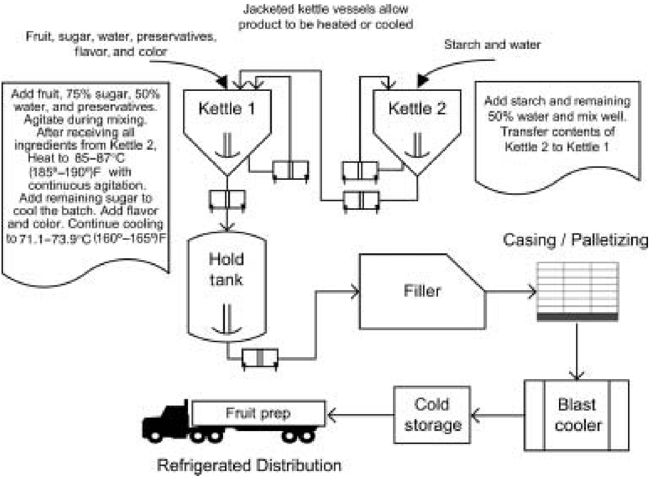


Figure 9.2. *Process flow sheet for fruit preparation using the Hot Pack kettle procedure.*

sterile. Most systems use scraped-surface heat

while with high methoxyl pectin it must be added

exchangers to achieve temperatures of at least

near the end of the boil. The same high speed mixer-

87.8◦C (190◦F) (usually 90.6–93.3◦C (195–

kettle/tank set-up can be used for addition of other

200◦F) with continual agitation to

insure thorough

hydrocolloids such as locust bean gum or guar gum.

heating and mixing. After heating, the product is

Hermetically sealed container means a container

held for 3 minutes to allow heat penetration of the

that is designed and intended to be secure against the

largest particulates.

entry of microorganisms and thereby to maintain the

6. The product is then cooled by scraped-surface heat

commercial sterility of its contents after processing.

exchangers to 26.7–32.2◦C (80–90◦F).

[FDA 21 CFR 113.3(j) (FDA 2004)]

7. Pack the product using filling equipment designed

Aseptic processing and packaging means the fill-

to maintain commercial sterility into a hermeti-

ing of a commercially sterilized cooled product into

cally sealed container of choice.

presterilized containers, followed by aseptic hermet-

ical sealing, with a presterilized closure, in an at-

When pectin is used as the stabilizer for the fruit

mosphere free of microorganisms. [FDA 21 CFR *preparation, it is prepared as a solution in hot wa-*

113.3 (a) (FDA 2004)]

ter using a high speed mixer and a separate kettle or

"Commercial Sterility" of thermally processed

slurry tank. The high speed mixer is necessary be-

food means the condition achieved by the applica-

cause pectins swell very fast and lumps may occur.

tion of heat, which renders the food free of:

The pectin solution is then added to the hot mix be-

fore addition of the bulk of the sugar. If low methoxyl

r Microorganisms capable of reproducing in the

pectin is used, any additional acid should be added

food under normal nonrefrigerated conditions of

with the fruit at the beginning of the *boil (cooking),*

storage and distribution; and

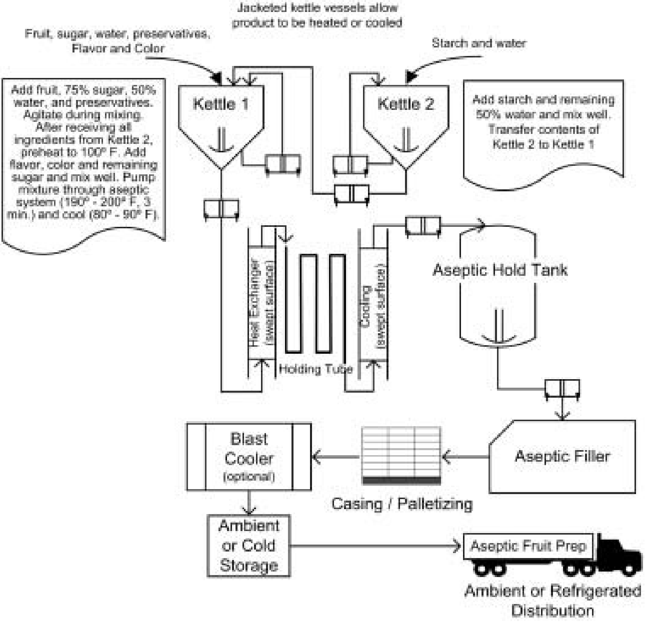


***Figure 9.3.** Flow diagram for Aseptic process of manufacturing fruit preparation for yogurt.*

r Viable microorganisms (including spores) of

nonrefrigerated conditions of storage and

public health significance.

distribution. [FDA 21 CFR 113.3 (e) (FDA 2004)] *r Commercial Sterility of equipment and containers*

used for aseptic processing and packaging of food

In aseptic processing systems the heating and cool-

means:

ing is usually performed in either vertical or horizon-

r The condition achieved by application of heat,

tal scraped-surface heat exchangers constructed of a *chemical sterilant(s), or other appropriate*

hollow stainless steel or nickel. The heat exchange

treatment that renders the equipment and

cylinder is most often six inches in diameter. Around

containers free of viable microorganisms having

the heat exchange tube, another cylinder is welded

public health significance, as well as *or attached creating space for a heat exchange me-*

microorganisms of nonhealth significance,

dia such as steam for heating, or water, glycol, or

capable of reproducing in the food under normal

ammonia, for cooling. Product is pumped through *the inner tube while heat exchange media is circu-*

The need for preservatives is eliminated because

lated in the annular space between the tubes.

the product has been heated for sterilization, cooled

To prevent the product from burning or freezing on

and filled in a sterile atmosphere, and packaged asep-

the heat exchange wall, a mutator with *blades is con-*

tically. This also means that the product does not

centrically positioned inside the inner cylinder. As

require refrigeration in transportation and storage of-

the mutator turns within the tube, the scraper blades

fering refrigeration savings.

lightly and continuously scrape the wall. This action

A more consistent product can be produced by

assures less damage to the particulate identity of the

aseptic fruit processing. Fruit flotation in the package

fruit in suspension during heating and cooling.

is virtually eliminated by the rapid cool down and

The filler used in aseptic packaging is indepen-

accompanying viscosity build-up

possible through

dently sterilized by circulating 121.1◦C (250◦F)

room temperature packing.

steam for approximately 30 minutes. Sterile, heated

The aseptic process is energy efficient. Approxi-

air is then introduced into the filling chamber of the

mately 50% of the thermal energy of open kettle heat *machine. When filling bags (from 5 to 200 gal), the*

processing is lost to the atmosphere. In addition less

bags come to the processor presterilized by gamma

thermal energy usage is required to get the aseptic

radiation. During filling, the bag is put inside the ster-

product back to room temperature.

ile filling chamber, the bag cap is removed, the filling *head is inserted into the spout area of the bag, and*

Packaging of Fruit Preparations

the product flow begins. When the proper amount of

product is in the bag as determined by a scale or flow

Fruit preparations for yogurt can be packaged into a

meter, the product flow stops, the filling head is re-

variety of sizes and container styles (Fig. 9.4).

moved form the bag, and the cap is replaced. The bag

Sizes generally range from 50 lb bag-in-box to

is then ejected from the filling chamber.

2000 lb aseptically filled containers. The 50 lb

Using fruit preparation that is aseptically pro-

bag-in-box filled either aseptically or "hot packed"

cessed, not only assures the

microbiological steril-

is still a popular container choice for yogurt manu-

ity of the fruit, but improves the overall quality and

facturers. It provides flexibility in the plant for pro-

greatly helps improve convenience, transportation,

duction of small flavor runs. However, it is labor in-

and in-plant handling. There are advantages using *tensive, creates a potential source of contamination*

aseptic processing and packaging as compared to

when unloading, despite the best efforts to sanitize

open-kettle or hot-pack processing for the manufac-

both bag and hands and it can introduce unwanted

ture of yogurt fruit preparation. These include:

corrugated packaging material into the *filler room.*

r

The next size to consider is the 400–500 lb bag-

Greater retention of natural fruit color. Open

in-drum. This container is usually aseptically pro-

kettle/hot pack processing requires a 30–40

cessed where it can be filled at 80–90◦F. There are *minute heating period to reach the 87.8–93.3°C*

some "hot packed" bag-in-drum products manufac-

(190–200°F) cook temperature with a packaging

tured, but cooling is a challenge and it may not work

temperature of 60.0–71.1°C (140–160°F),

for all formulations. The 400–500 lb bag-in-drum

depending on the total solids,

preservatives, and

can be the traditional type bag that is opened at the

pH. After hot filling, the bulk container (5–55

top and evacuated using a Graco-type fruit pump, or

gallons) takes from 4 to 36 hours to bring the

it can be equipped with a bottom unloading valve

equilibrium temperature of the product in the *that can be attached and unloaded with a positive*

package to 37.8◦C (100◦F) or below. In an aseptic

pump.

process system, continuous heating and cooling

Large volume yogurt manufacturers prefer to re-

within required sterilization time exposes the

ceive and handle fruit preparation in 1800–2000 lb *product to considerably less heat, resulting in a*

tote containers. Because this size container would not

retained natural color.

r

be able to be cooled efficiently and quickly, it is filled

Improved flavor—Since heating takes place in a

using an aseptic processing system. There are gener-

completely closed heat exchanger, the volatile

ally three types of these containers used, the one-way

flavor components or essences of the fruit cannot

tote, the collapsible tote, and the returnable stainless

escape into the atmosphere.

steel tote. The one-way tote uses a large multilayered

Better retention of nutrients also results from an *laminate bag equipped with both a filling cap and an*

enclosed heat exchanger. As much as 90–95% of the

evacuation fitting that has been sterilized prior to de-

nutrients can be retained.

livery to the fruit processor. This bag is then filled

Figure 9.4. *Packaging containers of fruit-for-yogurt. Courtesy of Eric Ducey, Fruit Crown.*

aseptically and placed into a large heavy corrugated

r Viscosity/Consistency—The best method for

container and delivered on a pallet. The yogurt man-

products containing fruit particulates is a

ufacturer will recycle the corrugated and dispose of

Bostwick consistometer measuring device, where

the plastic liner. The collapsible tote *uses a similar*

the sample is measured at a specific temperature

inner bag but uses a custom crate to hold the bag in

and time, i.e., 21.1◦C (70◦F) for 30 seconds. The

place during shipping and use at the yogurt manufac-

Bostwick consistometer provides accurate

turing plant. After use, the inner bag is disposed at *determination of sample consistency by*

the plant and the crate “breaks down” or collapses for

measuring the distance, which a material flows

easier and more economical shipping back to the fruit

under its own weight during a given time interval

preparation supplier. The stainless steel tote is steam

and temperature. It consists of a level, *sterilized at the fruit preparation manufacturing plant*

stainless-steel trough with two compartments.

and then filled on the aseptic process system. The tote

The first compartment, which holds the sample at

is equipped with an outlet that is used for unloading

a predetermined temperature, is separated from

at the yogurt plant. Because the outlet *is stainless*

the second compartment by a spring loaded gate.

steel, it is possible to attach a steam barrier prior to

The second compartment is 24 cm long and has

unloading to establish a sterile connection. Because

graduated parallel lines at 0.5 cm intervals. The

the empty stainless steel totes must be returned to *measurement is taken by fully filling the first*

the fruit processor, it is generally not economical to

compartment with the sample to be tested,

use them when the yogurt manufacturer is located

releasing the gate, and letting the fruit preparation

more than 500 miles from the fruit processor.

flow freely down the slope. The

distance that

Twenty four hours after packaging, first prepara-

the fruit preparation flows from the gate after

tion samples are evaluated to assure compliance to

30 seconds is measured in centimeters as the

the product specification prior to release of the prod-

Bostwick reading. A Brookfield viscometer can *uct. The following are usually the criteria used for*

be used for products without particulates or

evaluation:

flavored syrups. Brookfield instruments utilize a

principle of rotation viscosity measurement in

r ◦Brix (by refractometer)

centipoises. The device consists of a spindle *r pH—Must use a consistent temperature for*

immersed in the fluid sample to sense torque

product testing.

resistance when running at a constant speed.

Color.

It is usually done visually comparing fruit

Chandan RC, Shahani KM. 1993. Yogurt. In:

color in relation to a control sample. Sometimes the

YH Hui (Ed), Dairy Science and Technology

fruit is mixed in the finished product to augment the

Handbook, Vol. 2. VCH Publications, New York,

color. Some companies use pantone charts for this

pp. 1–56.

evaluation, while other companies might use instru-

Food and Drug Administration (FDA), 2004. U.S.

ments like colorimeters or spectrophotometers that

Department of Health and Human Services. Code of

quantify color by assigning a numerical description

Federal Regulations. Washington DC.

as opposed to a qualitative description.

Hoefler AC. 2004. Hydrocolloids. Eagen Press, St.

Paul, MN, pp. 78–82.

Marshall RT, Arbuckle WS. 1996. Ice Cream. 5th ed.

Organoleptic.

Sensory evaluation is conducted to

Chapman and Hall, New York, pp. 91–103.

insure that the product complies with sensory stan-

Tamime AY, Robinson RK. 1999. Yogurt

Science

dards.

and Technology, 2nd ed. Woodhead Publ,

Cambridge, England, and CRC Press, Boca Raton,

Microbiological testing.

Standard Plate count,

FL.

Yeast & Mold count and Coliform count.

Woodroof JG. 1990. 50 years of fruit and vegetable

processing. Food Technology, pp. 92–95.

REFERENCES

Chandan RC. 1982. Fermented Dairy Products in

ACKNOWLEDGEMENT

Prescott and Dunn's Industrial Microbiology, 4th ed.

AVI Publ, Westport, CT, pp. 113–184.

We are grateful to Andrew Hoefler for

sharing his

Chandan RC. 2004. Dairy: yogurt. In: P Smith, YH

expertise on the use of LM pectin for sundae style

Hui (Eds), Food Processing, Blackwell, Publishing

yogurt. We also appreciate the contribution of Brent

Co., Ames, IA.

Cannell for preparing flow sheet diagrams.

Edited by Ramesh C. Chandan

10

Milk and Milk-Based Dairy

Ingredients

Isabelle Sodini and Phillip S. Tong

Introduction

COMPOSITION AND

Composition and Specifications

SPECIFICATIONS

Performance in Yogurt Formulation

Fresh Milk

Table 10.1a gives the composition of a wide range of

Cream

dairy ingredients, which have been and are available

Milk Powders

and evaluated in yogurt formulations.

The impact of

Condensed Milk

these ingredients on the observed properties of yogurt

Buttermilk Powder

is presented in Performance in Yogurt Formulation

Milk Protein Concentrates

section . Broadly speaking, the major differences in

Whey Products

the effect of such products on yogurt can be attributed

Caseinates

to differences in composition (proximate, ratios of

Conclusion

protein to lactose, mineral content, and ratio of casein

References

to whey proteins). However, the physical state of the

constituents of these ingredients is also *important to*

their observed behavior in yogurt. This can be related

INTRODUCTION

to the ingredients thermal history, morphology, and

Milk is the primary ingredient in fermented milk

particle size distribution—particularly in the case of

manufacturing. Historically, fresh milk was concen-

dry dairy ingredients.

trated by evaporation (reduction of 1/3) to increase

Therefore, specifications usually detail the prox-

the dry matter before fermentation and coagulation.

imate composition, microbiological quality, and as-

Now, this practice is limited to rural communities and

pects of the physical properties of the ingredient. In *the standardization of the fat content, protein content,*

many cases industry standards (e.g., American Dry

and dry matter in industrial yogurt manufacture is re-

Products Institute) are used to facilitate a common

alized by the addition of dairy ingredients (powders

language of communication regarding specification.

or concentrates). Furthermore, high

quality, readily

In addition, customer specific standards can be devel-

available, convenient dairy-based concentrates, and

oped to provide additional specifications not covered

powdered ingredients can be used to replace (par-

by various industry standards.

tially or totally) fresh milk when it is not available

Nonetheless, one key standard that has been com-

(e.g., recombined milk yogurts). The choice of the

monly used is the whey protein nitrogen index

dairy ingredients used in yogurt formulation has an

(WPNI). This is a test, which measures the amount

impact on yogurt characteristics (acidification, flavor,

of soluble nitrogen in a fixed weight of *an ingredient*

texture).

(ADPI, 1990). Although the test is not without its

***Table 10.1a.** Proximate Composition of Select Dry Dairy Ingredients*

Ingredient

Fat

Protein

Lactose

Ash

Moisture

Sweet whey

1–1.5%

11–14.5%

63–75%

8.2–8.6%

3–4.5%

Reduced lactose whey

1–4%

18–24%

52–58%

11–22%

3–4%

Demineralized whey

0.5–1.8%

11–15%

70–80%

1–7%

3–4.5%

Whey protein concentrate 34

5–6%

34–36%

48–52%

6.5–8%

3.5–4.5%

Whey protein concentrate 80

4–8%

80–82%

4–8%

3–4%

3.5–4.5%

Whey protein isolate

0.5–1%

90–92%

0.5–1%

2–3%

4–5%

Nonfat dry milk

0.7–1.5%

34–37%

48–52%

8.2%

3.5–55

Milk-protein concentrate

3.0%

65%

22%

6%

4.0%

Source: ADPI Bulletin 916, 1990; Chandan, 1997.

limitations, it continues to be widely utilized to pro-

exhibits a slower acidification rate than in cow, sheep,

vide a basic "heat classification" of milk powders.

or goat milk (Fig.10.1). This could be due to a higher

Table 10.1b gives the basic classification of these

concentration of lysozyme in camel milk as com-

powders based on WPNI.

pared to the other milks (El-Agamy, 2000).

The texture and the flavor of the fermented milks

are dependent on the protein and fat content, which

PERFORMANCES IN YOGURT

shows strong differences according to the species.

FORMULATION

Sheep and buffalo milk exhibit very high fat con-

Fresh Milk

tent, more than 7%; whereas horse milk contains less

than 2% fat. Sheep milk has the highest protein con-

Fresh milk is the major ingredient in yogurt manufac-

tent (4.6%), and mare's milk has the lowest (1.3%).

ture. Its chemical composition fluctuates depending

This leads to differences in the quality of the yo-

on various factors as species, breed, and season of

gurts. For example, a yogurt from sheep or buffalo

the year. This can affect the fermentation, as well as

milk will present a creamy texture and *a buttery fla-*

the properties of the yogurts.

vor associated with the high fat content (Aneja, 1991;

Anifantakis, 1991). If the milk is not homogenized,

a layer of cream will occur in the manufacture of set-

Effect of the Species of Mammals on

type yogurt (Anifantakis, 1991). Yogurt from sheep

Yogurt Properties

milk, because of the high protein content, does not

The gross composition of the milk of different species

require milk fortification (Muir and Tamime, 1993).

of mammals used for manufacture of fermented milks

On the other hand, a yogurt from mare's milk will

is given in Table 10. 2. The dry matter is very differ-

have a very thin texture, and the

blending with cow

ent according to the species, from 18.8% for sheep

or sheep milk, or the addition of caseinates or thick-

milk to 10.8% for mare's milk. Carbohydrate con-

eners, is recommended to afford a convenient texture

tent ranges from 4.6% to 6%. They are in excess for

(Di Cagno et al., 2004). Figure 10.2 illustrates the ef-

fermentation, so their variation does not affect the

fect of milk source (cow, sheep, and goat) on yogurt

acidification of the milk. However, naturally present

viscosity and syneresis.

inhibitory substances in milk can affect the rate of

Finally, the content of minor components also has

acidification. It has been reported that camel milk *an impact on the yogurt flavor. For example, a "goaty"*

Table 10.1b. *Heat Classification of Nonfat Dry Milk*

Classification

Whey Protein Nitrogen Index (mg/g)

Solubility

Application

High heat

< 1.5

Least

Baked goods, meats confections

Medium heat

1.51–5.99

Average

Ice cream

Low heat

> 6.0

Most

Recombined milk dairy products,

Source: ADPI Bulletin no. 916, 1990.

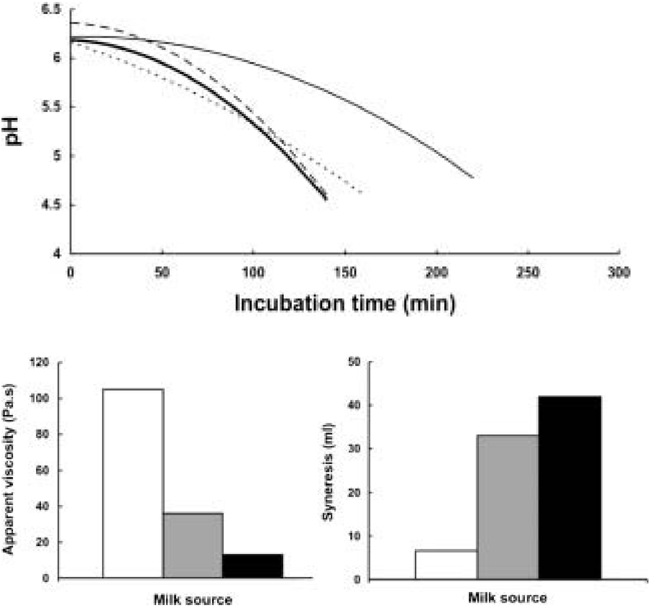


Table 10.2. *Approximate Average Composition (%, w/w) of Milk of Different Species of Mammals Used in Yogurt and Fermented Milk*

Manufacture

Specie

Dry Matter

Fat

Casein

Whey Protein

Lactose

Ash

Sheep

18.8

7.5

4.6

1

4.6

1

Buffalo

17.5

7.5

3.6

0.7

4.8

0.8

Camel

13.4

4.5

2.7

0.9

4.5

0.8

Goat

13.3

4.5

3

0.6

4.3

0.8

Cow

12.7

3.9

2.6

0.6

4.6

0.7

Horse

10.8

1.7

1.3

1.2

6.0

0.5

Source: After Walstra et al., 1999.

Figure 10.1. *Effect of milk source on yogurt acidification. ——, cow milk; – – – –, sheep milk; ------, goat milk;*

——, camel milk. After Jumah et al., 2001.

Figure 10.2. *Effect of milk source on yogurt apparent viscosity (A) and syneresis (B). Yogurt viscosity was measured by Brookfield LV viscometer using spindle n◦ 3 at 0.6 rpm. Yogurt syneresis was determined by draining 180 mL of yogurt on stretched cheese cloth.*

, sheep milk;

, cow milk;

, goat milk. After Kehagias et al., 1986.

169

170

Part II: Manufacture of Yogurt

flavor noticeable in the yogurt from goat milk, has

variant of β-lactoglobulin compared with those con-

been associated with a high amount of free fatty acids *taining only the A variant. The use of milk containing*

in goat milk (Abrahamsen and Rysstad, 1991). Ac-

–casein variant AA or BB does not affect the vis-

etaldehyde is one of the major aromatic components

cosity or the texture of yogurts (Allmere et al., 1998;

characteristic of yogurt flavor. It is produced mainly

Muir et al., 1997). However, Muir et al.

(1997) ob-

from the conversion of threonine into acetaldehyde

served that the serum leakage was lower for yogurts

and glycine during fermentation. Threonine aldolase

made from milk with the □-casein variant AA than

is the key enzyme in this conversion. Low amount of

yogurts containing the □-casein variant BB.

acetaldehyde observed in goat milk yogurt has been

attributed to high amount of free glycine in goat milk,

Effect of the Seasonal Variation in Milk

which causes a feedback inhibition of the threonine

Composition on Yogurt Properties

aldolase (Rysstad et al., 1990). The addition of threo-

nine to milk has been recommended in the manufac-

The composition of milk can vary across the seasons.

ture of yogurt from goat milk (Rysstad et al., 1990),

For instance, approximately a 10% variation in fat

as well as mare's milk (Di Cagno et al., 2004,) in

and protein is observed in milk received in July and

order to improve yogurt flavor.

August (lowest level) compared to that received in

October and November (highest level) in the United

States (Chandan, 1997). These variations of compo-

Effect of the Breed and Genetic Variant on

sition are known to affect the consistency and the

Yogurt Properties

quality of the manufactured dairy products. Seasonal

Table 10.3 shows the gross composition of milk pro-

variation of sheep milk in Scotland has been shown

duced by four breeds of cows, Friesian, Holstein,

to change viscosity, serum separation, and acidity in

Brown, and Jersey. Fat and protein content varies de-

yogurts (Muir and Tamime, 1993). Seasonal variation

pending on the breed. This affects the textural prop-

of cow milk in Australia has been

reported to affect

erties of the yogurt resulting due to the relationship

the viscosity and serum separation in both set and

between protein content in milk and yogurt viscos-

stirred yogurts (Cheng et al., 2002). Standardization

ity (Schkoda et al., 2001b). For example, Allmere

of the protein content by addition of milk protein in *et al. (1999) observed a strong difference in elastic*

various forms (powders or concentrates, fractionated

modulus for yogurts made with milk from individual

or whole milk protein) reduces the effects of milk

cows from two breeding selection lines. An increase

seasonality in yogurt manufacture.

of 40% was observed with yogurt made with milk *from one selection line as compared to the other.*

Cream

This was correlated to a difference in protein con-

tent (3.71% versus 3.37%). Furthermore, an effect of

Yogurt can have a fat content ranging from 0% to

the genetic variants on the physical properties of yo-

10%, with most common values comprised between *gurt has been demonstrated for β-lactoglobulin and*

0.5% and 3.5% (Tamime and Robinson, 1999). In the

□-casein variants. Allmere et al. (1998) and Bikker

United States, regulations distinguish three types of

et al. (2000) reported higher elastic modulus with

yogurts: regular yogurts (more than 3.25% milkfat),

milk gels containing β-lactoglobulin B *and C than*

low-fat yogurts (between 0.5% and 2% milkfat), and

the ones containing β-lactoglobulin A. For instance,

non-fat yogurts (less than 0.5% milkfat).

Allmere et al. (1998) observed a 30% higher storage

The effect of cream addition on yogurt texture is

modulus in acidified milk gels containing only the B *linked to the integration of the fat globules into the*

Table 10.3. *Approximate Average Composition (%, w/w) of Milk of Different Breeds of Cow Breed*

Dry Matter

Fat

Crude Protein

Lactose

Ash

Friesian (in the Netherlands)

13.3

4.4

3.4

4.6

0.75

Holstein (in the US)

12.1

3.4

3.3

4.5

0.75

Brown Swiss

12.9

4.0

3.3

4.7

0.72

Jersey

15.1

5.3

4.0

4.9

0.72

Source: After Walstra et al., 1999.

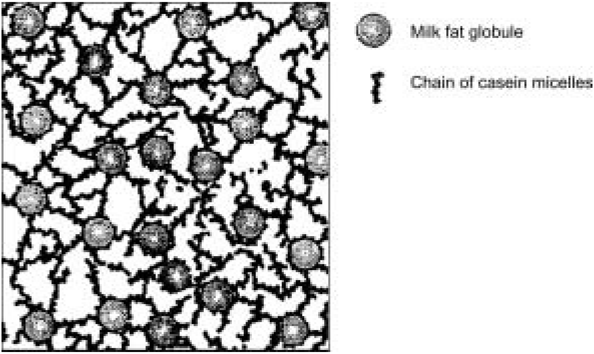


Figure 10.3. *Simplified structure of full fat yogurt issued from homogenized milk. Note that fat globules are integrated into the gel structure. After Schkoda et al., 2001a.*

gel structure. This integration does not occur if the

removed and a new membrane is formed, which sta-

cream is added after the fermentation (Schkoda et al.,

bilizes the homogenized fat globules. The new layer

2001a), or if the milk is not homogenized (van Vliet

covering the fat globules is predominantly composed

and Dentener-Kikkert, 1982). In this case, addition of

of micellar casein. Cano Ruiz and Richter (1997) de-

cream decreases the viscosity of the yogurt, because

termined the percentage distribution of proteins in the

milk fat globules act as "structure

breakers" (Schkoda

milk fat globule membrane of homogenized milk and

et al., 2001a; van Vliet and Dentener-Kikkert, 1982).

found a repartition between caseins, whey protein,

On the other hand, when the cream is added in milk

and proteins from native membrane equal to 67%,

before fermentation, and when milk is then submit-

10%, and 13%, respectively. The new layer of the

ted to homogenization before inoculation with starter

milk fat globules interacts with the casein micelles

culture and acidified, which is the usual practice in

during acidification (Barrantes et al., 1996; Lucey

yogurt manufacture, the addition of milk fat increases

et al., 1998) and acts as a "structure *promoters" in*

the yogurt viscosity and firmness, and decreases the

this case (van Vliet and Dentener-Kikkert, 1982), as

serum separation. For instance, Martens (1972) re-

reported in Figure 10. 3.

ported an increase of 44% in the consistency score

of stirred yogurt when the fat content varied from

0% to 3.9%. Becker and Puhan (1989) found that gel

Milk Powders

firmness was increased by 23% in whole milk yogurt

(3.5% fats) compared to nonfat yogurt. De Lorenzi

Milk powders can be used to enrich the protein con-

et al. (1995) observed a higher (23%) apparent vis-

tent of the milk before fermentation and increase the *cosity at 100 s−1 in full-fat yogurts (4% fat content)*

viscosity of the yogurts. This allows the standard-

as compared to a nonfat yogurt. Finally, Becker and

ization of the protein content of the milk and helps

Puhan (1989) observed that yogurts made from whole

to maintain a constant quality of the products. Skim

milk did not show any whey separation, *while in 63*

milk powder or whole milk powder can be used. How-

nonfat yogurt samples, 15 showed a whey layer on

ever, it is more common to use skim milk powder,

the surface after 14 days of storage.

which has no effect on the fat content of the milk

The effect of cream addition on yogurt physical *base compared to whole milk powder. Hence, the fat*

properties can be explained by the integration of the

content can be entirely controlled by the addition of

milk fat globules in the gel network. During homog-

cream, while the addition of the milk powder allows

enization, the native milk fat globule membrane is

for adjustment of the protein content.

The level of addition of milk powder determines

Condensed Milk

the viscosity, gel strength, and ability to retain the

Fresh liquid condensed skim milk can be used instead

whey of the yogurt. Several studies have established

of skim milk powder to enrich milk in

yogurt man-

a positive relationship between the addition of milk

ufacture. There is no difference in quality between

powder, and the rheological and physical properties

these two methods of enrichment (Guzman-Gonzalez

of yogurt (Becker and Puhan, 1989; Harwalkar and

et al., 1999). The choice between one and the other is

Kalab, 1986; Rohm, 1993; Wacher-Rodarte et al.,

dictated by the easiest way for providing the factory

1993). Rohm (1993) compared the viscosity of yo-

between these two ingredients. The incorporation of

gurts without adding skim milk powder and also with

condensed milk, on a liquid form, into yogurt milk,

1%, 2%, and 3% of added skim milk

powder. The

is easier than the dissolution of skim milk powder.

apparent viscosities measured at 10 s^{-1} were respec-

However, it requires specific equipment for storage

tively, 0.53 Pa.s, 0.65 Pa.s, 0.77 Pa.s, and 0.91 Pa.s,

and blending.

for yogurts prepared with a classical yogurt culture.

In this case, a 1%, 2%, and 3% skim milk powder ad-

dition allows an increase of viscosity of respectively

Buttermilk Powder

22%, 43%, and 70%. In another work, Becker and

Puhan (1989) reported an increase in the gel strength

Buttermilk powder has been used successfully to re-

of 25% and an increase of viscosity as measured with *place skim milk powder for milk fortification in yo-*

the posthumus funnel of 15% with an addition of 1%

gurt manufacture (Guinée et al., 1995; Trachoo and

skim milk powder compared to yogurt made without

Mistry, 1998). No significant differences were ob-

added skim milk powder. Finally, the susceptibility

served in viscosity and water-holding

capacity of

to syneresis has been shown to be decreased with a

low-fat stirred yogurt stabilized with skim milk pow-

higher addition of milk powder. Harwalkar and Kalab

der or buttermilk powder at a 5% protein content

(1986) reported a percentage of whey drained in a

(Guinée et al., 1995). Trachoo and Mistry (1998)

drainage test equal to 31%, 24.5%, 13.5%, and neg-

compared the firmness and sensorial properties of

ligible when the total solid content of the yogurt was

nonfat and low-fat set yogurts enriched with skim

10%, 12.5%, 15%, and 20%, respectively.

milk powder and buttermilk powder at a 3.7% and

A low-heat or a medium-heat powder is

usually

4.4% protein level, respectively. They reported that

recommended for yogurt fortification (Tamime and

for the both types of yogurts, enrichment with butter-

Robinson, 1999). However, it has been reported that

milk powder yielded a smoother product as compared

recombined milk from low-heat skim milk powder *to yogurts enriched by addition of skim milk powder.*

gives lactic gels with a lower elastic modulus as com-

Sensorial score for smoothness were respectively 8.2

pared with lactic gels made from recombined milk

and 7.8 for nonfat yogurt, and 8.3 and 6.9 for low-fat

from high-heat and medium-heat skim milk powder

yogurt. For the low-fat yogurt, the

fortification with

(50% decrease) (Cho et al., 1999). The reason is prob-

buttermilk powder led to a slightly softer product as

ably the difference in the composition of the fat glob-

compared with skim milk powder.

ule surfaces. Fat globules stabilized by high-heat and

medium-heat skim milk powder have a higher con-

Milk Protein Concentrates

centration of denatured whey protein on their sur-

face compared to those stabilized by low-heat skim

The replacement of skim milk powder by milk protein

milk powder. Higher denatured whey proteins pro-

concentrates in yogurt manufacture has been stud-

vide additional cross-links in the yogurt gel (Cho *ied by Guzman-Gonzalez et al. (1999), Mistry and*

et al., 1999). The type of the powder also can impact

Hassan (1990), Modler and Kalab (1983a), Modler

the flavor of the yogurt. It has been demonstrated

et al. (1983b), and Rohm (1993). When the protein

in yogurts fortified with four different commercial

content of the yogurt is kept the same, *the substi-*

low-heat skim milk powders that there were signif-

tution of skim milk powder by milk protein con-

icant differences of flavor according to the choice

centrates does not change the firmness (Mistry and

of the skim milk powder (Drake, 2004). Among the

Hassan, 1990; Modler et al., 1983b), the viscosity *four milk powders tested, one presented an off-flavor*

(Guzman-Gonzalez et al., 1999; Rohm, 1993), the

characterized as animal/barny flavor. The acceptabil-

syneresis (Modler et al., 1983b), the texture (Mistry

ity of the yogurt fortified with the defected powder

and Hassan, 1992), and the flavor of the yogurts

was significantly lower than for the

other samples.

(Mistry and Hassan, 1992; Modler et al., 1983b). This

substitution does allow one to two-thirds reduction in

When whey powder is used to substitute skim milk

the amount of powder required for fortification, be-

powder on a dry matter basis, it decreases the firm-

cause the protein content of milk protein concentrates

ness of the gel and lowers the viscosity of the yo-

is between 50% and 85%, as compared to 34–36%

gurt because of the lower protein content of whey

protein for a typical skim milk powder.

powder (6% protein) as compared to skim milk pow-

Another option is to use milk protein concentrate

der (34% protein) (Bhullar et al., 2002; Dave and

directly as the yogurt milk. Some authors have stud-

Shah, 1998). For instance, for a plain set yogurt for-

ied the properties of yogurts produced from ultra-

tified with 2% powder, whey powder-fortified yogurt

filtered milk at protein levels varying *from 3.3% to*

was less viscous than skim milk powder-fortified yo-

11.8% (Becker and Puhan, 1989; Biliaderis et al.,

gurt. The viscosity, as determined with a Brookfield

1992; Lankes et al., 1998; Savello and Dargan, 1995).

viscosimeter, was respectively 14 Pa.s and 25 Pa.s.

When compared to the yogurts produced from milk

However, at the same time, protein level was lower in

fortified with skim milk powder at the same dry mat-

case of the whey powder-fortified yogurt than in skim

ter level, the viscosity and firmness of yogurts pro-

milk powder-fortified yogurt, respectively 3.47% and

duced from ultrafiltered milks are higher because of

3.70% protein (Bhullar et al., 2002).

the higher proportion of the protein in the milk base

When whey powder is used instead of skim milk

(Becker and Puhan, 1989; Biliaderis et al., 1992;

powder to fortify protein content of the milk, some

Lankes et al., 1998). Biliaderis et al. (1992) noticed an

defects have been observed (yellow color, increased

increase of elastic modulus from 511

Pa to 1220 Pa

syneresis) (González-Mart ́ınez et al., 2003). How-

between yogurt enriched to 14% dry matter by ad-

ever, texture defects are less pronounced, because

dition of skim milk powder or by ultrafiltration of

whey proteins have a texturing effect in yogurt man-

skim milk, respectively. The corresponding protein *ufacture, where the high heat treatment applied al-*

levels were respectively 5.3% and 9.5%. Savello and

lows their denaturation and their involvement in the

Dargan (1995) compared yogurts produced from ul-

building of the protein network. González-Martínez

trafiltered milk and skim milk powder-fortified milk

et al. (2003) reported that substitution *of skim milk*

at a same protein content of 5%. They reported a

powder by whey powder in a yogurt formulated at

higher viscosity and higher gel strength (100% and

4.2% protein gives a more firm and viscous yogurt,

50% increase, respectively) for the yogurt produced

showing better flow properties (more homogeneous *from the ultrafiltered milk. However, no explanation*

fluid, without lumps) than the control. This has to be

was proposed to explain this phenomenon.

put in relation with the results of other works involv-

ing whey protein concentrates demonstrating higher

gel strength when the ratio between casein and whey

Whey Products

protein was lowered by the addition of whey pro-

tein concentrates (Augustin et al., 2003; Cheng et al.,

Whey Powders

2000; Greig and Harris, 1983; Modler et al., 1983b;

The use of whey powder is limited in yogurt man-

Puvanenthiran et al., 2002; Remeuf et al., 2003). The

ufacture because it can be associated with some de-

positive effect of whey protein on the firmness of the

fects in texture, flavor, and appearance when added

network was attributed to the size of the particles con-

at a high level. Nonetheless, because it is a relatively

stituting the gel network. They are larger in case of

inexpensive functional dairy solid, its use has been

addition of whey protein because of the *binding of*

well-studied.

the denatured whey protein on the casein micelles.

Shah et al. (1993) studied whey powder to replace

These larger particles are suspected to absorb more

skim milk powder in yogurt prepared from reconsti-

of an applied force by flexing without breaking the *tuted milk. They reported that it was feasible to manu-*

intraparticle cross-link bonds. This leads to higher

facture yogurt with reconstituted skim milk and with

gel strength (Puvanenthiran et al., 2002).

25% of whey powder replacing the skim milk powder.

Replacement of skim milk powder by 50% with whey

Whey Protein Concentrates

powder resulted in lower flavor scores and affected

body and texture. González-Martínez et al. (2003)

Whey protein concentrates are very commonly used

reported a yellowish color developed in yogurt when

in yogurt manufacture to replace skim milk powder

whey powder was added, and the yellow color inten-

because it can be less expensive than

using the skim

sity was proportional to the amount of whey added.

milk powder. Furthermore, whey proteins are highly

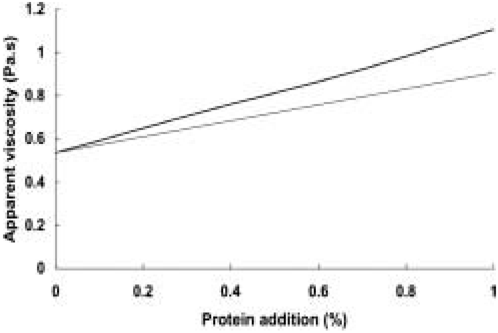


Figure 10.4. *Effect of source of protein*

fortification on yogurt apparent viscosity.

Apparent viscosity has been calculated

at 10 s^{-1} using the flow curve

parameters. ——, addition of skim milk

protein; ——, addition of Na-caseinate.

After Rohm et al., 1993.

functional in yogurts. The substitution of skim milk

Remeuf et al. (2003) observed higher apparent vis-

powder by whey protein concentrates in yogurts usu-

cosity at 10 s−1 in yogurt fortified at 4.5% protein

ally increases the water-holding capacity of the yo-

level with whey protein concentrates at 84% protein

gurts and reduces ability to syneresis (Augustin et al.,

than in yogurt fortified with skim milk *powder, re-*

2003; Cheng et al., 2000; Remeuf et al., 2003). How-

spectively 3.5 Pa.s and 2 Pa.s.

ever, at a high level substitution (more than 1% on a

This inconsistency between results in literature

protein basis), defects as lack of bright and graininess

can be explained by differences between the reports *have been reported (Greig and Harris, 1983; Kailas-*

in quality of the whey protein concentrates (Augustin

apathy and Supriadi, 1998; Remeuf et al., 2003).

et al., 2003; Guinée et al., 1995; Sodini et al., 2005),

The results on the texturing effect of whey protein

level of addition of whey protein concentrates in milk

concentrates in yogurt, as compared to *skim milk*

(Greig and Harris, 1983), pH of the milk (Augustin

powder, on a constant protein basis, are contradic-

et al., 2003; Vasbinder and De Kruif, 2003), and in-

tory in literature. Some report an increase of firm-

tensity of the heat treatment applied to the milk (Jelen,

ness and viscosity when fortification is done with

1997).

whey protein concentrates instead of skim milk pow-

Whey protein concentrates can also be added in

der (Augustin et al., 2003; Cheng et al., 2000; Greig

the yogurt after the fermentation and gelation in the

and Harris, 1983; Modler et al., 1983b; Puvanen-

case of stirred yogurt manufacture. In this case, it has *thiran et al., 2002; Remeuf et al., 2003); whereas*

been shown that any texturing effect is very different.

other researchers report a loss of consistency when

Patocka et al. (2004) reported a strong thinning effect

whey protein concentrates are used to replace skim

of the addition of whey protein hydrolysate when it

milk powder in yogurt formulation

(Greig and Harris,

was added from 2% to 8% level in a stirred yogurt.

1983; Guinée et al., 1995; Guzman-Gonzalez et al.,

The thinning effect was not only due to dilution of

1999; Modler et al., 1983b).

the protein matrix, because the addition of sugar de-

For instance, comparing the viscosity of yogurt for-

creased the viscosity to a lesser extent.

tified at a 5% protein level with three different kinds

of whey protein concentrates (35–75% protein) or

Microparticulated Whey Protein

with skim milk powder, Guinée et al. (1995) reported

A microparticulation process has been developed by

no difference of viscosity at 116 s^{-1} for yogurt forti-

Kelco Ltd to produce microparticulated whey pro-

fied with skim milk powder or whey protein concen-

tein (1□m average) enhancing the properties of low-

trates at 45%, 60%, and 75% protein (viscosity 0.25–

fat foods. The commercial name of the product is

0.28 Pa.s). But a much lower viscosity (0.06 Pa.s) was

Simplesse r . Some works have

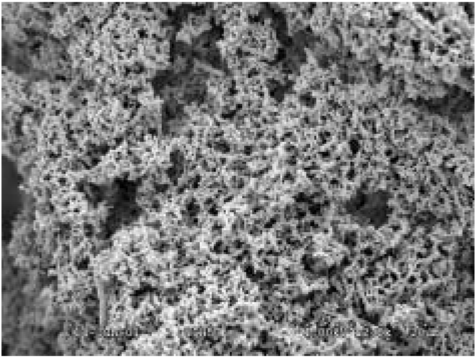
demonstrated their

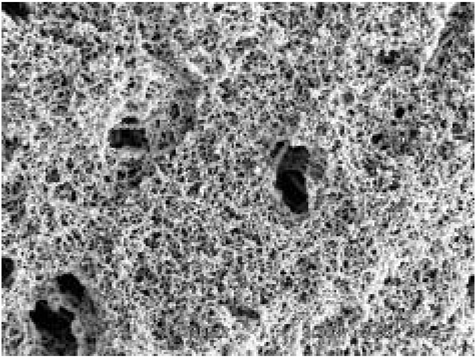
observed when whey protein concentrate at 35% pro-

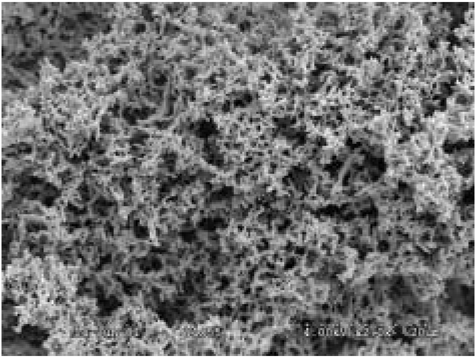
ability to improve the consistency of nonfat (Tamime

tein was used to fortify the milk. On the other hand,

et al., 1984) and low-fat yogurts (Sandoval-Castilla







(a)

(b)

(c)

Figure 10.5. *Microstructure of yogurts obtained from milk base enriched with skim milk powder (a), whey protein concentrates (b), and Na-Caseinate (c).*

Bar-20 □m. After Remeuf et al., 2003.

175

176

Part II: Manufacture of Yogurt

et al., 2004). Tamime et al. (1984) and Sandoval-

three yogurts fortified with skim milk powder, whey

Castilla et al. (2004) showed the particles integrate

protein concentrates, and Na-caseinate. Large and ex-

in the protein matrix of the yogurt; they were found to

tensively fused casein are noticeable in Na-caseinate

be a part of the casein micelle chains or spanned ad-

fortified yogurts (Fig. 10.5c), while a fine network

jacent chains. They were not freely dispersed into the

with small pore size is observed in WPC-fortified

aqueous phase, maintaining their

corpuscular nature.

yogurt (Fig. 10.5b), as compared to SMP-fortified

The microparticulated whey protein seems to limit

yogurt (Fig. 10.5a). This can be explained by the

the casein aggregation in clusters. A low-fat yogurt

coverage of casein micelle by denatured whey pro-

containing 1% microparticulated whey protein pre-

tein during the heat treatment, which is not the same

sented the same profile analysis as a full fat yogurt

depending on the casein/whey protein ratio (Puva-

(Sandoval-Castilla et al., 2004).

nenthiran et al., 2002).

Caseinates

CONCLUSION

Na, Ca, or Na-Ca-caseinates have been used in yo-

There is a wide range of dairy ingredients that can

gurt formulation to increase the protein content, alone

impact the properties of yogurt texture, flavor, and

(Guinée et al., 1995; Guzman-Gonzalez et al., 2000;

appearance. Continued advances in the technologies

Modler and Kalab, 1983a; Modler et al., 1983b;

for fractionation and purification of

milk into these in-

Remeuf et al., 2003; Rohm, 1993; Tamime et al.,

gredients will offer yogurt manufacturers better tools

1984) or in combination with whey protein concen-

to manipulate and tailor the properties of yogurt for

trates (Guzman-Gonzalez et al., 2000; Remeuf et al.,

the desired end use.

2003) to control the casein/whey protein ratio.

When compared with skim milk powder enrich-

REFERENCES

ment, fortification with caseinate gave a more rough

and less smooth yogurt texture (Modler et al., 1983b;

ADPI. 1990. American Dairy Products Institute

Remeuf et al., 2003), with a higher gel firmness and

Standards for Milk Powders. Chicago, IL.

viscosity (Guinée et al., 1995; Guzman-Gonzalez

Abrahamsen RK, Rysstad G. 1991. Fermentation of

et al., 2000; Modler et al., 1983b; Remeuf et al.,

goats' milk with yogurt starter bacteria: A review.

2003; Rohm, 1993; Tamime et al., 1984). Figure

Cultured Dairy Products J. 26:20–26.

10.4 reports the apparent viscosity of yogurts for-

Allmere T, Akerlind M, Andren A. 1999. Rheological

tified with skim milk powder or Na-caseinate. It has

properties of acidified gels of skim milk from cows

been noticed by some researchers that texturing effect

selected for high or low milk fat concentration. Int.

is different between Na- and Ca-

caseinates. Higher

Dairy J. 9:703–707.

viscosities were reported for Na-caseinates than Ca-

Allmere T, Andren A, Lindersson M, Björck L. 1998.

caseinates fortified yogurts (Guzman-Gonzalez et al.,

Studies on rheological properties of stirred milk gels

2000; Remeuf et al., 2003). For instance, Remeuf *made from milk with defined genetic variants of*

et al. (2003) determined complex viscosities of

kappa-casein and beta-lactoglobulin. Int. Dairy J.

8:899–905.

40 Pa.s, 55 Pa.s, and 100 Pa.s respectively for yogurts

Aneja RP. 1991. Processing and distribution of buffalo

enriched to 4.5% protein with skim milk powder, *milk. In: Proceeding of the XXIII International*

Ca-caseinate, and Na-caseinate. Guzman-Gonzalez

Dairy Congress, Montreal, Canada. International

et al. (2000) showed yogurts enriched at 4.3% pro-

Dairy Federation, Brussels, Belgium, pp. 383–396.

tein with skim milk powder, Ca-caseinate and Na-

Anifantakis, E. M. 1991. Manufacture

of sheep's milk

caseinate had apparent viscosities of 34 Pa.s, 53 Pa.s,

products. In: Proceeding of the XXIII International

and 63 Pa.s, respectively.

Dairy Congress, Montreal, Canada. International

Microstructure studies showed that the structure of

Dairy Federation, Brussels, Belgium, pp. 420–432 *the network is different when adding caseinates in-*

Augustin MA, Cheng LJ, Glagovskaia O, Clarke PT,

stead of skim milk, with a more open and loose struc-

Lawrence A. 2003. Use of blends of skim milk and

ture. This difference of structure explains while lower

sweet whey protein concentrates in reconstituted

water holding capacity is reported in

case of caseinate

yogurt. Aust. J. Dairy Technol. 58:30–35.

fortification (Guzman-Gonzalez et al., 2000; Remeuf

Barrantes E, Tamime AY, Sword AM, Muir DD, Kalab

et al., 2003). Figure 10.5 reports the microstructure of

M. 1996. The manufacture of set-type natural

10 Milk and Milk-Based Dairy Ingredients

yoghurt containing different oils – 2. Rheological

powder for whey powder on yoghurt quality. Trends

properties and microstructure. Int. Dairy J.

in Food Sci. & Technol. 13:334–340.

6:827–837.

Greig RIW, Harris AJ. 1983. Use of whey protein

Becker T, Puhan Z. 1989. Effect of

different processes

concentrate in yogurt. Dairy Industries Int.

to increase the milk solids non fat content on the

48:17–19.

rheological properties of yoghurt.

Guinée TP, Mullins CG, Reville WJ, Cotter MP. 1995.

Milchwissenschaft. 44:626–629.

Physical properties of stirred-curd unsweetened

Bhullar YS, Uddin MA, Shah NP. 2002. Effects of

yoghurts stabilised with different dairy ingredients.

ingredients supplementation on textural

Milchwissenschaft. 50:196–200.

characteristics and microstructure of yoghurt.

Guzman-Gonzalez M, Morais F, Amigo L. 2000.

Milchwissenschaft. 57:328–332.

Influence of skimmed milk concentrate replacement

Bikker JF, Anema SG, Li Y, Hill JP. 2000. Rheological

by dry dairy products in a low-fat set-type yoghurt

properties of acid gels prepared from heated milk

model system. Use of caseinates, co-precipitate and

fortified with whey protein mixtures containing the

blended dairy powders. J. Sci. Food

and Agric.

A, B and C variants of beta-lactoglobulin. Int. Dairy

80:433–438.

J. 10:723–732.

Guzman-Gonzalez M, Morais F, Ramos M, Amigo L.

Biliaderis CG, Khan MM, Blank G. 1992. Rheological

1999. Influence of skimmed milk concentrate

and sensory properties of yogurt from

skim milk and

replacement by dry dairy products in a low fat

ultrafiltered retentates. Int. Dairy J. 2:311–323.

set-type yoghurt model system. I: Use of whey

Cano Ruiz ME, Richter RL. 1997. Effect of

protein concentrates, milk protein concentrates and

homogenization pressure on the milk fat globule *skimmed milk powder. J. Sci. Food and Agri.*

membrane proteins. J. Dairy Sci. 80:2732–2739.

79:1117–1122.

Chandan R. 1997. Dairy-based ingredients. Eagan

Harwalkar VR, Kalab M. 1986. Relationship between

Press, Saint-Paul, MN.

microstructure and susceptibility to syneresis in

Cheng LJ, Augustin MA, Clarke PT. 2000. Yogurts

yoghurt made from reconstituted nonfat dry milk.

from skim milk – whey protein concentrate blends.

Food Microstructure. 5:287–294.

Aust. J. Dairy Technol. 55:110.

Jelen P. 1997. Texture of fermented milk products and

Cheng LJ, Clarke PT, Augustin MA. 2002. Seasonal *dairy desserts. Trends in Food Sci. & Technol.*

variation in yogurt properties. Aust. J. Dairy

8:345–347.

Technol. 57:187–191.

Jumah RY, Shaker RR, Abu-Jdayil B. 2001. Effect of

ChoYH, Lucey JA, Singh H. 1999. Rheological

milk source on the rheological properties of yogurt *properties of acid milk gels as affected by the nature*

during the gelation process. International Journal of

of the fat globule surface material and heat treatment

Dairy Technology. 54:89–93.

of milk. Int. Dairy J. 9:537–545.

Kailasapathy K, Supriadi D. 1998. Effect of partially

Dave RI, Shah NP. 1998. The influence of ingredient *replacing skim milk powder with whey protein*

supplementation on the textural characteristics of

concentrate on the sensory qualities of lactose

yogurt. Aust. J. Dairy Technol. 53:180–184.

hydrolysed acidophilus yoghurt. Milchwissenschaft.

De Lorenzi L, Pricl S, Torriano G. 1995. Rheological

53:385–389.

behaviour of low-fat and full-fat stirred yoghurt. Int.

Kehagias C, Komiotis A, Koulouris S, Koroni H,

Dairy Journal. 5:661–671.

Kazazis J. 1986. Physico-chemical properties of set

Di Cagno R, Tamborrino A, Gallo G, Leone C, Angelis

type yogurt made from cow's, ewe's and goat's

MD, Faccia M, Amirante P, Gobbetti M. 2004. Uses *milk. Bull. Int. Dairy Fed. 202:167–169.*

of mares' milk in manufacture of fermented milks.

Lankes H, Ozer HB, Robinson RK. 1998. The

Int. Dairy J. 14:767–775.

effect of elevated milk solids and incubation

Drake MA. 2004. Flavor of dried dairy ingredients. In:

temperature on the physical properties of natural

Proceeding of the 4th International Symposium on

yoghurt. Milchwissenschaft Milk Sci. Int.

Recombined Milk and Milk Products, Cancun,

53:510–513.

Mexico. U.S. Dairy Export Council, Arlington, VA.

Lucey JA, Munro PA, Singh H. 1998. Rheological

El-Agamy EI. 2000. Effect of heat treatment on camel *properties and microstructure of acid milk gels as*

milk proteins with respect to antimicrobial factors: a

affected by fat content and heat treatment. J. Food

comparison with cows' and buffalo milk proteins.

Sci. 63:660–664.

Food Chemistry. 68:227–232.

Martens R. 1972. Influence de quelques facteurs sur la

González-Mart´ınez C, Cháfer M, Albors A, Carot JM,

consistance et le goût du yoghurt brassé. Revue de

Chiralt, A. 2003. Influence of substituting milk

l'agriculture. 3:461–480.

Mistry VV, Hassan HN. 1990. Manufacture of low fat

Savello PA, Dargan RA. 1995.

Improved yogurt

yogurt using a high protein powder. In: Proceeding

physical properties using ultrafiltration and

of the XXIII International Dairy Congress,

very-high temperature heating. Milchwissenschaft.

Montreal, Canada. International Dairy Federation,

50:86–89.

Brussels, Belgium, p. 518.

Schkoda P, Hechler A, Hinrichs J. 2001a. Improved

Mistry VV, Hassan HN. 1992. Manufacture of nonfat

texture of stirred fermented milk by integrating fat

yogurt from a high milk protein powder. J. Dairy

globules into the gel structure. Milchwissenschaft.

Sci. 75:947–957.

56:85–89.

Modler HW, Kalab M. 1983a. Microstructure of yogurt

Schkoda P, Hechler A, Hinrichs J. 2001b. Influence of

stabilized with milk proteins. J. Dairy Sci.

the protein content on structural characteristics of

66:430–437.

stirred fermented milk. Milchwissenschaft.

Modler, HW, Larmond ME, Lin CS, Froelich D,

56:19–22.

Emmons DB. 1983b. Physical and sensory

Shah NP, Spurgeon KR, Gilmore TM. 1993. Use of

properties of yogurt stabilized with milk proteins.

dry whey and lactose hydrolysis in yogurt bases.

J. Dairy Sci. 66:422–429.

Milchwissenschaft. 48:494–498.

Muir DD, Horne DS, West IG. 1997. Genetic

Sodini I, Montella J, Tong PS. 2005. Physical

polymorphism of bovine kappa-casein: Effects on

properties of yogurt with various commercial whey

textural properties and acceptability of plain, set

protein concentrates. J. Sci. Food Agric.

yoghurt. In: Proceeding of the IDF Seminar on Milk

85:853–859.

Protein Polymorphism, Palmerston North, New

Tamime AY, Kalab M, Davies G. 1984. Microstructure

Zealand. International Dairy Federation, Brussels,

of set-style yoghurt manufacture from cow's milk

Belgium, pp. 182–184

fortified by various methods. Food Microstructure.

Muir DD, Tamime AY. 1993. Ovine milk. 3. Effect of

3:83–92.

seasonal variations on properties of set and stirred

Tamime AY, Robinson RK. 1999. Yoghurt : Science

yogurts. Milchwissenschaft. 48:509–513.

and Technology, 2nd ed. Woodhead Publishing

Patocka G, Cervenkova R, Jelen P. 2004. Textural

Limited, Cambridge, England, UK.

effects of soluble whey protein isolate in stirred

Trachoo N, Mistry VV. 1998. Application of

yogurt. Milchwissenschaft. 59:37–40.

ultrafiltered sweet buttermilk and sweet buttermilk

Puvanenthiran A, Williams RPW, Augustin MA. 2002.

powder in the manufacture of nonfat and low fat

Structure and visco-elastic properties of set yoghurt

yogurts. J. Dairy Sci. 81:3163–3171.

with altered casein to whey protein ratios. Int. Dairy

van Vliet T, Dentener-Kikkert A. 1982. Influence

J. 12:383–391.

of the composition of the milk fat globule

Remeuf F, Mohammed S, Sodini I, Tissier JP. 2003.

membrane on the rheological properties of acid

Preliminary observations on the effects of milk

milk gels. Netherlands Milk and Dairy

fortification and heating on microstructure and

J. 36:261–265.

physical properties of stirred yogurt. Int. Dairy

Vasbinder AJ, De Kruif CG. 2003. Casein-whey

J. 13:773–782.

protein interactions in heated milk: the influence of

Rohm H. 1993. Influence of dry matter fortification on

pH. Int. Dairy J. 13:669–677.

flow properties of yogurt. 2. Time-dependent

Wacher-Rodarte C, Galvan MV, Farres A, Gallardo F, *behaviour. Milchwissenschaft. 48:614–617.*

Marshall VME, Garcia-Garibay M. 1993. Yoghurt

Rysstad G, Knutsen WJ, Abrahamsen RK. 1990. Effect

production from reconstituted skim milk using

of threonine and glycine on acetaldehyde formation

different polymer and non polymer forming starter

in goats' milk yogurt. J. Dairy Res.

57:401–411.

cultures. J. Dairy Res. 60:247–254.

Sandoval-Castilla O, Lobato-Calleros C,

Walstra P, Geurts TJ, Noomen A, Jellema A,. van

Aguirre-Mandujano E, Vernon-Carter EJ. 2004.

Boekel MAJS. 1999. Dairy technology, principles of

Microstructure and texture of yogurt as influenced *milk properties and processes. Marcel Dekker, New*

by fat replacers. Int. Dairy J. 14:151–159.

York, NJ, pp. 15–16.

11

Ingredients for Yogurt Manufacture

Ramesh C. Chandan and Kevin R. O'Rell

Dairy Ingredients and Their Origin

selected for high bacteriological quality for secur-

Condensed Skim Milk

ing best flavor potential in yogurt. Milk should come

Nonfat Dry Milk

from healthy cows that are fed wholesome feed and

Whey Solids

kept in clean surroundings. The flavor, consistency,

Milk Protein Concentrate (MPC) (or Ultrafiltered Milk)

and acid production is adversely affected by using

Sweeteners

milk from cows with infected udders (mastitis), gen-

Stabilizers

eral sickness, or in early or late stages of lactation, in-

Native and Modified Starch

cluding milk containing high bacterial count, abnor-

Gums and Pectins

References

mal somatic cell count, and antibiotics, disinfectants

or sanitizers. This is related to the fact that growth of

yogurt culture is affected adversely in milk partially

Previous chapters have offered

valuable information

fermented by contaminating organisms and in milk

on the quality attributes, including chemical and mi-

containing high somatic cells, or antibiotics and sani-

crobiological characteristics and specifications, of

tizing chemical residues. Therefore, such milk cannot

the raw materials used to formulate yogurt mixes.

be used for yogurt production. For the most part, in

The manufacture of yogurt starts with a judicious se-

bulk milk, the adverse effects of the quality of milk

lection of raw materials, accurate formulation, and

from a single cow or a small herd of cows can be

processing of yogurt mix.

balanced through dilution. Chapter 10 contains de-

tailed information related to dairy ingredients used

in yogurt manufacture.

DAIRY INGREDIENTS AND

The major concern in milk for yogurt production

THEIR ORIGIN

is the bacterial quality which is discussed in detail

elsewhere (Chandan, 1982, 1997, 2004; Chandan and

Various dairy raw materials for

formulating yogurt

Shahani, 1993, 1995; Tamime and Robinson, 1999)

mixes consist of fresh milk, skim milk, cream, con-

and the presence of inhibitors. The inhibitory ac-

densed milk, and nonfat dry milk. In the United

tion of antibiotics against lactic cultures has been

States, Yogurt is a Grade A product (United States *responsible for production losses in the manufacture*

Department of Health and Human Services, 1999).

of cultured products. One of the two organisms in

Chapter 3 details the requirements for milk produc-

yogurt culture, Streptococcus thermophilus is par-

tion, transportation, and processing. Grade A implies

ticularly sensitive to antibiotics (0.01–

0.05 IU/ml of

that all dairy components used must come from The

penicillin). Regular testing for antibiotics in milk in

Food and Drug Administration (FDA) supervised

the plant laboratory and other measures connected

Grade A dairy farms and Grade A manufacturing

with the use of antimastitis drugs on the farm repre-

plants, as per regulations enunciated in Pasteurized

sent a good system for controlling these residues.

Milk Ordinance. The basic raw material is milk. It

In addition to antibiotics, residual disinfectants and

is emphasized that all dairy raw materials should be

sanitizing chemicals may inhibit the growth of starter *cultures. Chlorine compounds such as hypochlorites*

count plates incubated at 32–35◦C is an indication

and iodophors may partially inhibit starter cultures at

of thermophilic organisms, since they grow better at

a level of 6 mg/l to 10 mg/l of milk. Normal precau-

40–45◦C.

tions regarding their use on the farm should greatly

Also, if the milk has been contaminated with a

reduce the chance of obtaining residual levels affect-

high number of bacteria, it is possible that these bac-

ing yogurt cultures. On the other hand, quaternary

teria might be psychrophiles or psychrotrophs. These *ammonia compounds inhibit lactic acid bacteria at*

organisms grow well in cold conditions. They grow

concentrations as low as 0.1–1.0 mg/l, depending on

slowly in milk held at 3◦C, but the growth may be

particular strain sensitivity. On the farm, these com-

rapid as the temperature rises to 10◦C or higher.

pounds should be used with great

caution and their

Although psychrophiles are readily destroyed by

use followed by thorough drainage and rinsing with

pasteurization temperature, if allowed to grow in

clean water. Preferably, these compounds should be

significant numbers, they can produce heat-stable

avoided in plants manufacturing yogurt and cultured *proteolytic enzymes, which would degrade the pro-*

dairy products.

tein. This protein degradation results in slow, weak

The microbiological quality of milk for yogurt

sets, and possible off-flavors. There is a procedure

should contain a low bacterial count, coliform count,

for detecting psychrofilic organisms outlined in the *and mold and yeast count. Standard Plate count and*

Standard Methods for Analysis of Dairy Products

coliform tests should be performed on each load of

(American Public Health Association). However, a

milk to be used for yogurt production. A yeast and

quicker modified version can be performed by incu-

mold test should be done on a random

basis. Although

bating pour plates at 21◦C for 25 hours.

coliform, yeast, and mold are readily destroyed by

The procurement of all ingredients should be done

pasteurization, their presence along with significant

on the basis of specifications and standards, which

number of bacteria is an indication that the milk was *are checked and maintained with a systematic sam-*

handled in unclean equipment, or held under warm

pling and testing program by the quality control

conditions. When milk comes into contact with un-

laboratory.

clean surroundings, it is very possible that it has be-

Yogurt mix composition regarding milk fat and *come contaminated with thermoduric/thermophilic*

milk solids nonfat is generally standardized from

organisms, which are capable of withstanding de-

whole, partially defatted milk, condensed skim milk,

struction at pasteurization temperatures. If present,

cream, and/or nonfat dry milk. The chemical compo-

these bacteria will grow rapidly during *the incuba-*

sition of dairy ingredients commonly used in yogurt

tion period of yogurt fermentation and compete with

manufacture is given in Table 11.1. Formulating yo-

the yogurt culture. This would result in slow fer-

gurt mix to desired fat and milk solids-not-fat by the

mentation time and/or weak body of the yogurt. The *use of these ingredients can be easily accomplished*

formation of pin-point colonies on Standard Plate

by appropriate soft ware programs.

Table 11.1. *Typical Chemical Composition of Dairy Ingredients Used in Formulating Yogurt Mix Ingredient*

%Total Solids

%Fat

%Protein

%Lactose

%Ash

Whole milk

12.6

3.8

3.2

4.9

0.7

Skim milk

9.1

0.1

3.3

5.1

0.7

Whipping cream

42.7

36.8

2.2

3.2

0.5

Condensed skim milk

40.1

0.4

14.4

22.3

3.0

Nonfat dry milk

96.5

0.8

35.9

52.3

8.0

WPC a–34

96.5

4.0

34.5

51.0

7.0

WPC–50

96.5

4.0

50.5

36.0

6.0

WPC–80

96.5

6.0

80.5

5.0

5.0

Whey protein isolate

96.5

0.5

93.0

1.0

2.0

Fluid UF milk

25–30

11–14

10–12

< 5

> 2.5

Fluid UF skim milk

15–20

< 0.5

10–12

< 5

> 2.5

Fluid UF skim milk, with diafiltration

18–20

< 0.5

16–17

< 1

> 1.5

Adapted from Chandan, 1997.

a Whey Protein Concentrate

11 Ingredients for Yogurt Manufacture

181

The current FDA specification calls for a minimum

in large yogurt manufacturing plants is condensed *of 8.25% nonfat milk solids (SNF) in the fermented*

skim milk.

mix prior to fruit or flavor addition. In a typical nonfat,

low fat, or full fat yogurt formulation, the total milk

Condensed Skim Milk

serum solids (or solids-not-fat) content of yogurt mix

ranges from 8.25% to 12%, depending on the choice

Condensed skim milk process begins with liquid raw

of stabilization. The serum solids associated with the

whole milk, which is stored at the processing plant

fluid portion of milk is usually 8.8–9%. Additional

at temperatures below 7◦C. Raw whole milk has a

nonfat dry milk (NFDM) solids are added to the yo-

variable fat content and is separated

into cream and

gurt mix to build up the total solids and to increase the

the nonfat milk using a centrifugal separator. This

protein content. In late spring and summer months,

separation step facilitates standardization of the fat

the protein content of milk is about 10% lower than

content prior to further processing. Centrifugal sepa-

the rest of the year. Consequently, the viscosity of

rators used also serve to further clarify the milk. The

yogurt declines during this period unless additional

skim milk is pasteurized (high-temperature, short-

nonfat solids are added to compensate for the sea-

time) by heating to at least 71.7◦C, and holding at or

sonal dip in protein content. Therefore, *depending on*

above this temperature for at least 15 seconds. In its

the stabilization system, additional 0.5–1.0% nonfat

production, the original skim milk volume is reduced

solids may be needed to maintain the consistent vis-

to about one-third to yield about 35–40% solids in the

cosity of the finished product during late spring and *final product using energy efficient multieffect evap-*

summer months.

orators that operate in high vacuum condition to boil

In general, the level of added NFDM will vary,

off water at moderate temperatures of 46–55°C. The

depending on the desired mouth feel of the finished

condensed milk is continuously separated from wa-

product, the processing conditions, the fat content,

ter vapor to achieve a desirable concentration of milk

the culture, and type of stabilizer used, if any. Gen-

solids. It is cooled to 4◦C or below and pumped to in-

erally, the addition of 2–4% NFDM solids raises

sulated trucks for transportation to yogurt plants. The

the protein level sufficiently so that *with the proper*

cream produced from the separator is HTST pasteur-

heat treatment, there is an increase in bound wa-

ized, cooled, and transferred to cream storage tanks

ter leading to improved firmness and consistency

for use as a manufacturing ingredient.

of the coagulum. Another benefit is the control of *wheying-off or syneresis on the surface of yogurt.*

Nonfat Dry Milk

Thus, the consistency of yogurt is dependent on the

nonfat solids portion, as well as the use of appropri-

Nonfat dry milk is made from condensed skim milk.

ate stabilizers and heat treatment of the mix. Gen-

Spray drying involves atomizing condensed milk *erally, the added NFDM solids will contribute to*

into a hot air stream at 180–200◦C. The atomizer

heavier mouth feel, which cannot be achieved with

may be either a pressure nozzle or a centrifugal

stabilizers alone. Higher nonfat solids will also pro-

disc. By controlling the size of the droplets, the

vide additional buffering capacity to

the mix, which

air temperature, and the airflow, it is possible to

in comparison with a mix containing lower non-

evaporate almost all the moisture while exposing the

fat solids would lead to higher lactic acid content

solids to relatively low temperatures. Spray drying

when the fermentation end point of the mix is deter-

yields concentrated and dry milk ingredients with

mined by the same pH. Therefore, the higher nonfat

excellent solubility, flavor, and color. This is the most

solids mix will result in comparatively sourer tast-

common procedure for manufacturing concentrated

ing yogurt. In commercial practice in North Amer-

and dry milk ingredients.

ica, supplementation of milk solids-not-fat with some

The spray drying process is typically a two-stage

solids from condensed skim milk or nonfat dry milk

process that involves a spray dryer at the first stage

and/or whey protein concentrate is the most common

with a static fluid bed integrated in the base of the

procedure.

drying chamber. The second stage is an external vi-

Removal of a significant portion of water from milk

brating fluid bed. The product is moved through the

yields a series of dairy ingredients (Chandan, 1997).

two-stage process quickly to prevent overheating of

Details are given in Chapter 10. Consequently, these

the powder. The powder leaves the

dryer and enters

ingredients offer tangible savings in costs associ-

a system of cyclones that simultaneously cools it.

ated with storage capacity, handling, packaging, and

Heat treatment affects the functional properties of

transportation. A concentrated dairy ingredient used

NFDM, so the temperature and time combinations

Table 11.2. *Approximate Composition of*

Whey Solids

Grade A Nonfat Dry Milk

The addition of whey solids in the form of sweet

Constituents

Amount

Typical Range

whey or acid whey to replace NFDM in yogurt should

Protein (N × 6.38)%

36.0

34.0–37.0

be avoided. Whey solids will contribute to the total

Lactose (Milk sugar)%

51.0

49.0–52.0

solids content of yogurt mix; however, *because of*

Fat%

0.7

0.6–1.25

lower protein content (13–15%) for whey solids as

Moisture%

3.0

3.0–6.0

compared to 35–36% for NFDM solids, and lower

Minerals (Ash)%

8.2

8.2–8.6

protein functionality in terms of water binding ca-

Source: American Dry Milk Products Institute, with permis-

pacity, the addition of whey solids can be detrimen-

sion.

tal to the consistency and firmness of the body of

yogurt.

can vary widely depending on the required proper-

On the other hand, whey protein concentrates

ties. The milk heat treatment determines the kind of

(WPC), in relatively undenatured form, furnish excel-

powder produced. For nonfat dry milk produced by

lent water binding properties and are a useful func-

a "low-heat" method, the milk is simply pasteurized

tional protein source in yogurt mix. Whey-protein

and no preheating is done. However, heat treatment

concentrates are products derived from cheese whey

for a "high-heat" method requires heating milk to

by removal of minerals and lactose. The process

85–88◦C for 15 to 30 minutes in

addition to pasteur-

of protein concentration utilizes membrane filtration

ization. Heat treatment in between pasteurization and

(ultrafiltration), which uses a semipermeable mem-

"high-heat" treatment yields "medium-heat" powder.

brane of appropriate pore size to retain large protein

Tables 11.2, 11.3, and 11.4 contain information on the *molecules while letting small molecules consisting of*

characteristics of nonfat dry milk, which are impor-

water, lactose, minerals, small peptides, and amino

tant from yogurt formulation standpoint.

acids to selectively go into the permeate. On a dry

Typical composition of nonfat dry milk is shown in

basis, the WPC contains 34%, 50%, or

80% protein,

Table 11.2. The standards for extra-grade spray-dried

and whey protein isolate contains at least 92% pro-

nonfat dry milk are given in 11.3. The requirements

tein. In addition, WPC-80 is available as gel type,

for low-heat nonfat dry milk are shown in Table 11.4.

which is designed to generate more viscosity in liq-

The extent of heat treatment can be measured by

uid foods. WPC-34 is commonly used in yogurt for-

the whey protein nitrogen index, which measures the

mulation, while WPC-50 is occasionally used. Since

amount of undenatured whey protein. For use in yo-

Whey protein isolate and WPC-80 contain low levels

gurt, only low-heat (WPN ≥6.0 mg/g)

NFDM is used.

of lactose, they are important ingredients in the for-

mulation of "low-carb" yogurt. The use of WPC-34

allows the yogurt processor to reduce the ingredient

***Table 11.3.** Standards for Extra Grade Spray*

cost and at the same time provides unique functional

Dried Nonfat Dry Milk

properties including desirable nutrients, namely, high

Parameter

Not Greater Than

quality whey proteins and calcium. Since yogurt is

classified as a Grade A product in the United States,

Milkfat

1.25%

only Grade A whey-protein concentrate produced in

Moisture

4.0%

a Grade A cheese plant can be used. WPC helps in

Titratable acidity

0.15%

heat-set gelation. Whey protein gets denatured by the

Solubility index

1.25 ml a

heat treatment used in yogurt mix

preparation. The

Bacterial estimate

10,000 cfu per g

denatured protein has desirable water binding and

Scorched particles

Disc B (15.0 mg)

adhesion characteristics. In addition, as a dairy prod-

a Except product designated as "high-heat" which shall not *uct, it has a favorable image because of a clean label.*

be greater than 2.0 ml.

WPC should be free of bixin or β-carotein colorant

Note: Extra Grade nonfat dry milk shall be entirely free from

generally used in Cheddar cheese manufacture. To

lumps, except those that break up readily under slight pres-

remove the colorant, the whey is bleached with ben-

sure. The reliquefied product shall have a sweet and desirable

zoyl peroxide during the WPC process. Cheese plants

flavor, but may possess the following flavors to a slight de-

gree: chalky, cooked, feed, and flat.

manufacturing Swiss and mozzarella cheese use no

Source: American Dry Milk Products Institute, with permis-

colorants, but do use thermophilc cultures identical to *sion.*

those used in yogurt production. Accordingly, there

Table 11.4. *Heat–Treatment Classification of Nonfat Dry Milk*

Undenatured Whey-Protein

Classification

Processing Treatment

Nitrogen a(mg/g)

Low heat

Cumulative heat treatment of milk not over

Over 6.0

71.1◦C (160◦F) for 2 minutes

Medium heat

Preheat to 71.1◦C–79.4◦C (160◦–175◦F) for

1.51–5.99

20 minutes

High heat

Preheat to 87.8◦C (190◦F) for 30 minutes

Under 1.5

Adapted from: American Dry Milk Products Institute, with permission. Chandan 1997.

a Higher temperatures and/or extended holding times contribute directly to whey protein denaturation. This index is used as a measure of the cumulative heat effects during processing.

is a possibility of phage carryover from such cheese

milk may be partly concentrated by

removal of

manufacturing plants to yogurt production. To avoid

15–20% water in a vacuum pan. In such a specialty

phage contamination, WPC ingredient should come

yogurt, the mix is formulated to contain high nonfat

from cheese plants, where only mesophilic cultures

solids as much as 12% to provide a desirable body *are used, (e.g., Cheddar or Cheddar-type varieties.)*

and texture and freedom from syneresis.

In general, whey proteins of WPC lack opacity

Since yogurt is a manufactured product, its chem-

and white appearance as compared to caseins present

ical composition is likely to vary depending on the

in NFDM. However, whey proteins

have fewer ten-

quality standards established by marketing consider-

dencies to mask flavor in yogurt than caseins. Ac-

ations. Nonetheless, it is extremely important to stan-

cordingly, more fruit flavor will be perceived in fruit

dardize and control the day-to-day product to meet

flavored yogurt when skim milk solids are partially

the consumer expectations and regulatory obligations

replaced with WPC. In general, WPC (with 34%

associated with a certain brand or

label. The mix is

protein level) concentration in yogurt mix ranges

formulated to predetermined milk fat and milk solids-

from 0.5% to 1% level. In yogurt beverage, a higher

not-fat content and the weights of each ingredient are

amount up to 6% may be used.

calculated with the aid of computer software. Most *yogurt plants are equipped with computer programs*

to calculate the amount of each ingredient needed

Milk Protein Concentrate (MPC) (or

to achieve target levels of milk fat, milk SNF, to-

Ultrafiltered Milk)

tal solids, sugar, stabilizers, and other ingredients.

Milk protein concentrate obtained by ultrafiltration

The program usually also calculates the cost of the

of skim milk is a functional ingredient to raise pro-

mix.

tein level of the mix, but the main reason for its use is

The level of milk fat found in commercial sam-

to reduce lactose content of the mix to produce “low-

ples of yogurt ranges from 0.05% to 3.60%. Gen-

carb" yogurt. As yogurt is a Grade A product in the

erally, consumers view milk fat negatively from the

United States, the MPC must be derived from a Grade

caloric standpoint. Consequently, 90% of the refrig-

A process. The labeling for this ingredient is "ultrafil-

erated cup yogurt sold in the United States today is

tered skim milk." It contains 80–85%

water, 10–12%

either low fat or nonfat. The fat level in yogurt has a

protein, < 0.5% fat, < 5% lactose, and > 2.5% ash.

favorable effect on texture quality of the yogurt. Milk

In the formulation of yogurt, the lactose level can

fat also has a masking effect on the perception of yo-

be reduced significantly, as much as 70%, by judi-

gurt acidity. It has been observed that nonfat yogurt

cious use of lactose-reduced MPC and high-protein

(< 0.5% fat) tastes more acidic and less mild than the

WPC in the formulation, replacing milk and NFDM.

same pH yogurt with a fat content of > 1.5%. There-

To conform to the legislation in certain countries or

fore, it is important to use a "mild"

yogurt culture in

to satisfy the consumer demand, yogurt with no sta-

nonfat and 1% low-fat yogurt to maintain the finished

bilizers can be produced. In such products, the con-

pH above 4.2 to please today's consumer tastes. It has

sistency and stability of texture are accomplished by

also been concluded that milk fat stabilizes the con-

addition of nonfat dry milk, condensed skim milk,

traction of the protein gel formed after fermentation

and/or whey protein concentrates. In rare practice,

of the yogurt mix and hinders whey separation. Thus,

in yogurt with little or no stabilizer, a low fat content *r The consistency of yogurt is better when sugar is*

in milk encourages whey separation, while a high

added to the milk rather than into the coagulum,

fat content prevents the separation. As the fat con-

unless the formulation has been adjusted to allow

tent is increased, there is a significant improvement

for this dilution.

in flavor, viscosity, and taste. However, there is also

an increase in the caloric value. In most low-fat and

If it is necessary to add sweeteners after fermenta-

nonfat yogurts produced today, stabilizers are used

tion, only pasteurized liquid sugar or flavored sweet-

to compensate for the loss of the stabilizing effect of

ened syrups should be used. When

using this method,

milk fat. For products produced in the United States,

the total solids of the yogurt mix must be adjusted for

the milk fat levels are standardized to a minimum of

the dilution associated with these liquid sweeteners.

3.25% before the addition of bulky flavors for full-fat

Also, Good Manufacturing Practices and HACCP *yogurt. Low-fat yogurt is manufactured from the mix*

control should be practiced to minimize the potential

containing not less than 0.5%, nor more than 2.00%

risk of microbiological or physical contamination.

milk fat before the addition of bulky flavors. Nonfat

Refined crystalline sucrose is manufactured in-

yogurt mix has milk fat level not

exceeding 0.5%.

dustrially from sugar cane or sugar beet processing.

These fat levels correspond to the Food & Drug Ad-

Both sources give identical sucrose with no chemical,

ministration requirement for nutritional labeling of

physical, or structural differences. Crystalline sugar

nonfat yogurt, low-fat yogurt and yogurt. (Chandan, *is either refined from crude raw sugar or is processed*

1997, 2004).

from sugar cane juice. The first step is to extract

juice from sugar cane using a series of roller presses.

Nonsugar impurities are removed by mechanical fil-

Sweeteners

tration, followed by lime-carbon dioxide purifica-

tion step. The juice is allowed to settle and then fil-

tered to get purified juice. In some factories, this step

In the manufacture of flavored yogurt, it is usually de-

involves lime-phosphoric acid floatation procedure.

sirable to add a sweetening agent to the yogurt base.

Furthermore, purification of the juice is achieved by

The standard of identity for yogurt, low-fat yogurt

treatment with activated charcoal and ion exchange

and nonfat yogurt (FDA CFR Parts 131.200 to 206)

reactors. This juice (12–15% total solids, 91–92% pu-

specifies the allowable nutritive sweeteners that can

rity) is evaporated in multistage vacuum evaporators

be used. The level of sweetness in the *yogurt mix will*

to get sugar concentrate containing 65–71% solids.

depend on the Brix of the fruit or flavoring ingredi-

Furthermore, crystallization of sugar is effected in

ent and the desired level of sweetness in the finished

vacuum pans under controlled conditions of temper-

product. Most fruit-flavored yogurts contain approx-

ature, pressure, density, and viscosity. The resulting

imately 10–13% sugar equivalent, whereas flavored

sugar crystals are separated from mother liquor by

yogurts (vanilla, lemon, coffee etc.) contain 8–10%

centrifugation at 1,000–2,500 x g. The semidry sugar

sugar. The sweetener most commonly used in the in-

is rinsed with water and dried further *with hot air in a*

dustry is sucrose in either liquid (65–67% total solids)

rotating drum, cooled, classified on vibrating screens,

or granulated form. When liquid sugar is used, the

and packaged. The mother liquor goes through a

added water is taken into consideration to avoid di-

series of crystallization steps to harvest maximum *lution of the total solids of the mix. The total amount*

yield of premium quality sugar. The left over liquor

of sugar solids in yogurt mix should not exceed

is a by-product of sugar industry, called blackstrap

10–11% because of the inhibitory effect on the tradi-

molasses.

tional yogurt culture. Depending on the culture, some

Refined cane sugar is also manufactured from raw

inhibitory effect will be seen with sugar solids con-

sugar produced at the point of origin. In this case, raw

tent between 7% and 10%. The addition of the sugar

sugar is refined by extracting cane sugar juice, clar-

generally occurs before pasteurization due to follow-

ification, concentration, and

crystallization. Other

ing reasons:

products from raw sugar production are white sugar,

r Heat treatment of the milk destroys any

turbinado sugar, and various grades of molasses. Raw

osmophilic yeasts and molds that might be

sugar is then shipped to sugar refineries where it *present in the sugar ingredient.*

is subjected to a series of purification steps, such

r Potential source of postpasteurization

as centrifugation, filtration, decolorization, evapora-

contamination (HACCP).

tion, and crystallization. The by-products of refining

Table 11.5. *Various Sugar Products Used in Formulation of Foods*

Sucrose Product	*Sucrose Content(%)*	*Moisture Content(%)*
High-purity sucrose	*99.90–99.95*	*0.02–0.04*
Brown/soft sugars	*92.00–98.00*	

3.5–4.0

Raw sugar

96.50–97.50

0.5–0.7

Blackstrap molasses

38.00–45.00

12–18

Raw molasses

56.00–62.00

14–18

steps are brown sugar, refinery syrups, liquid sugar,

#100 mesh screens. It is preferred by yogurt proces-

and molasses.

sors for its bulk handling properties and resistance to

Beet sugar is produced in a single step. Beets are

caking or lumping during storage.

sliced, followed by diffusion of sugar in water, clari-

The rating for sweetness varies according to the

fication, concentration, and crystallization directly to

crystalline form and size. It is related to the stereo-

white sugar. Purity and moisture content of various

chemistry of the structural units in the sugar.

sucrose products are shown in Table 11.5.

When granulated sugar (High Purity) is *used for*

Liquid Sugar

yogurt production, it is purchased in 50–100 pound

bags, 1,000–2,000 lb tote bags or in bulk. In large

Many large yogurt plants prefer using liquid sugar

plants, bulk sugar is stored in silos. The color of

because it lends itself to an efficient handling (meter-

sugar is measured by procedures approved by Inter-

ing and pumping ability). Although liquid sugar may

national Commission for Uniform Methods of Sugar

be economically priced, conversion from dry sugar

Analysis. The procedure involves measuring the ab-

to liquid sugar set up requires capital cost for sugar

sorbance of 50% sugar solution

(filtered through 0.45

storage tanks, appropriate pumps, heaters, strainers,

micron membrane filter) at 420 nm wavelength. The

and meters. The storage space and the inventory con-

absorbance is converted to International Color Units

trol of liquid sugar must be coordinated with plant

(ICU). The higher the ICU number, the darker is the

production volumes. If the delivery of liquid sugar is

sugar color. Generally, most granulated sugars fall

by tank cars, storage capacity requirements are of the

below 35 ICU. The inorganic ash content of sugar is

order of at least 1.5 cars or 12,000 gallons. If truck

approximately 0.02%.

delivery is convenient, the volume per delivery may

The moisture level in sugar is less than 0.04%. Part

be in the range of 1,000 to 3,000 gallons. To cope up

of the moisture in sugar results from the syrup trapped

with emergencies like delays and increased usage,

within the crystal during its formation, which can be

the inventory should be adjusted accordingly.

removed only by grinding sugar

crystals. Another

Liquid sugar is obtained by dissolving refined

type of moisture is bound water associated with sat-

granulated sugar in water. Some cane sugar refining

urated syrup enveloping the crystals. Free moisture

plants produce liquid sugar directly prior to crystal-

is attributed to a supersaturated solution coating the *lization and drying. It is delivered in tanks and stored*

sugar crystal during rapid drying process of sugar

in yogurt plant in specific tanks equipped with ultra-

manufacture. Furthermore, crystallization of super-

violet light to control growth of yeasts and molds.

saturated solution during the storage of sugar causes

Adequate ventilation of the tanks is

necessary to

the free water to be released in the surrounding air.

avoid moisture condensation and resulting microbial

The dried granulated sugar is conditioned by the man-

growth. Storage temperature range is 30–32◦C. This

ufacturer to reach equilibrium with the surrounding

ingredient contains 66–67% solids (67◦Brix) consist-

atmosphere.

ing of minimum of 99.7% sucrose and invert sugar

The size of crystals is selected for quick dissolution

level < 0.35%. The ash content is restricted to less

during the mix preparation. The crystal size distribu-

than 0.04% and iron content may not exceed 0.5 ppm.

tion is normally defined by the percent of the crystals

The pH is within the range of 6.7–8.5. A gallon of liq-

retained on the standard U.S. mesh screen. The higher

uid sugar has 7.42–7.55 pounds of solids and weighs

the mesh number, the finer would be the crystal size.

11.08–11.12 pounds. The viscosity of liquid sugar is

Regular fine and extra fine grade of sugar has fine

around 2 poises. The color of liquid

sugar is similar

crystals. The grain size ranges from U.S. #20/40 and

to that of granulated sugar (less than 35 ICU).

Conversion of mix formula from dry sugar to liquid

consisting of monosaccharide glucose. The hydroly-

sugar can be done as follows:

sis is accomplished by treatment of starch slurry with

hydrochloric acid, followed by enzymatic action of

Pounds of liquid sugar required

⎵-amylase. If the reaction is stopped at an intermedi-

$=$

Pounds of dry sugar required

.

ate point, the end products are composed of an assort-

Percentage of solids in liquid sugar

ment of sugars and oligosaccharides (maltodextrins).

Normally, for 100 lbs of dry sugar, 149.25 lbs of

The degree of hydrolysis or conversion is termed by a

liquid sugar is needed to add the same amount of

number "dextrose equivalent," (D.E.) which is used to

sucrose in the formula.

signify the percent reducing sugars calculated as dex-

More often, conversion of dry sugar to gallons of

trose. Hydrolysis of each glucoside linkage liberates

liquid sugar is required. To calculate gallons of liq-

a free aldehyde group that displays the same reducing

uid sugar to replace dry sugar, divide the pounds of

ability as dextrose (glucose). Thus,

reducing ability

dry sugar with pounds of sugar solids per gallon. To

is an indicator of the progress of starch hydrolysis.

replace 100 lbs of dry sugar, gallons of liquid sugar

For instance, 42 D.E. corn syrup is a product made

required would be: 100 / 7 . 42 = 13 . 48 gallons of liq-

from corn starch that has reducing sugars in such pro-

uid sugar.

portions as to be equivalent to 42% dextrose. If the

The level of sucrose in yogurt mix appears to affect

conversion is complete at 100% D.E., the product is

the production of lactic acid and flavor by yogurt

dextrose.

culture. A decrease in characteristic flavor compound *(acetaldehyde) production has been reported at 8% or*

Maltodextrins

higher concentration of sucrose (Chandan, 2004), but

cultures capable of growth at higher sugar levels are

Maltodextrins are products of very low hydrolysis of

available.

starch. Their D.E. ranges from 4 to 20. They are only *slightly sweet. Hydrolysis of starch is random result-*

ing in the formation of smaller chain oligosaccharides

Corn Sweeteners

to saccharide polymers of varying chain length. They

Corn sweeteners are normally not used in the man-

are made from common corn starch, as well as from

ufacture of yogurt per se, but are commonly the *waxy starch. The maltodextrins from each of these*

constituents of frozen yogurt mixes, where they are

starting materials display slightly different function-

blended after fermentation. They are also sweeten-

ality. In general, their pH value ranges from 4.4 to

ers of choice in the preparation of fruit-for-yogurt

5.0 and moisture level is 5–6%.

Maltodextrin 5 D.E.

(Chapter 9). The corn sweeteners offer savings in in-

from waxy starch has an actual D.E. range of 5–8,

gredient costs. Nonetheless, they do exert much more

contains < 0.5% dextrose, 1% maltose, and > 98.5%

inhibitory effect on fermentation rate as compared to

higher polymers of dextrose. On the other hand, Mal-

sucrose. This is attributed to higher osmotic pressure

todextrin 5 D.E. derived from common starch has

exerted by monosaccharides contained in corn syrup

an actual D.E. range of 4–7 and contains < 1% dex-

sweeteners. In comparison, sucrose being a disac-

trose, < 1% maltose, and > 98% higher polymers of

charide is less inhibitory to yogurt

culture growth.

dextrose. Maltodextrins of 10 D.E. have actual D.E.

The corn-derived sweeteners, fructose and glucose,

range of 9–13 and contain 0.5–1.0% dextrose, 2%

usually enter yogurt via the processed fruit flavor in

maltose, and 96–97% higher polymers of dextrose.

which they are extensively used for cost efficiency

Finally, maltodextrins D.E.15 have an actual D.E.

and flavor enhancing characteristics. It is desirable

range of 13–18 and contain 2% dextrose, 3% maltose,

for a yogurt manufacturer (especially if frozen yo-

and > 94% higher polymers of dextrose (Alexander,

gurt is a part of the product profile or fruit-for-yogurt

1997). It is good to remember that

lower the D.E., the

is a part of the plant operation) to be knowledgeable

higher the molecular weight of the product and lower

about basics of corn sweeteners.

the intensity of sweetness. To enhance dispersability,

Sweeteners can be made by hydrolyzing any food

maltodextrins are agglomerated. Agglomeration of *starch. In the United States, corn starch is an econom-*

corn-derived 10 D.E. maltodextrins reduces the bulk

ical starting material to manufacture corn sweeteners.

density from 0.54 to 0.34 g/cc. In dry mixes, they

The 1, 4 glucoside linkages holding together dextrose

promote flowablity and reduce dust during handling.

molecules in starch are broken down to *smaller frag-*

They are also good bulking agents in the formulation

ments and eventually to individual building blocks

of low/non fat frozen yogurt.

Table 11.6. *Properties of Liquid and Dry Corn Sugars*

Relative

Sweetness:

Type

Actual DE % Moisture % Dextrose % Maltose DP3 a

Higher DP b Sucrose = 1

Corn syrup 36 D.E.

35–37

20

13–14

11–12

10

64–66

0.40

Corn syrup 42 D.E.

41–43

18–20

19

13–14

12

55

0.50

Corn syrup solids

34–38

4–5

13–14

11–12

10

64–66

0.40

36 D.E.

Corn syrup solids

40–44

4–5

19

12–14

11–12

55–58

0.50

42 D.E.

Dextrose

100

0.5

99.5

0

0

0

0.8

Adapted from Alexander, 1997.

a Degree of polymerization, 3 dextrose units.

b Degree of polymerization.

Corn syrups are defined as the products in

1996). The corn syrup solids ingredient is a white

which 20–70% of the glucoside linkages have been

powder and is susceptible to caking when exposed

hydrolyzed. Three types of corn sweeteners are com-

to moist air. Since too much corn syrup in the mix *mon in the frozen yogurt industry. They are classified*

may impart a flavor defect, its use in frozen dessert

as low conversion (28–38 D.E.), regular conversion

is limited to one-third of the total sweetener level.

(38–48 D.E.), intermediate conversion (48–58 D.E.)

Crystalline dextrose is a white powder with 80% of

and high conversion (58–68 D.E.).

High-conversion

the sweetening power of sucrose. Dextrose, being a

syrups may be obtained by a combination of acid

monosaccharide of molecular weight nearly one-half

and enzyme action on starch. High maltose syrup is

of sucrose, depresses the freezing point of the mix

made from a combination of acid and -amylase hy-

twice as much as sucrose. Frozen yogurt from a mix

drolysis. The disaccharide maltose consists of two

containing corn syrup displays less stiff consistency

molecules of glucose. Dry corn syrups are obtained

as it extrudes from the ice cream freezer. Accord-

by spray drying partially hydrolyzed corn starch of

ingly, its usage level is adjusted not to *exceed 25%*

various D.E. Crystalline dry forms of refined dextrose

of the total sweetener level.

and fructose are available. Generally, frozen yogurt

High fructose corn syrups (HFCS) and crystalline

producers use 36 or 42 D.E. corn syrup in liquid form

fructose equal or exceed the sweetness of sucrose *or as dry corn syrup solids. Since the liquid form is*

(Table 11.7). HFCS production involves dextrose

very viscous, to facilitate their pumping and meter-

conversion to fructose in corn syrup by enzymatic

ing, this ingredient is stored in heated tanks at 32◦C.

means. They also lower the freezing point of frozen

Corn syrup solids are economical to

use. They

dessert mixes to the same extent as the original corn

contribute firmness and extend the shelf life of the

syrups.

frozen dessert. The sweetness and other proper-

Crystalline fructose is commonly used to effect

ties of corn sweeteners are shown in Tables 11.6.

flavor improvement in light yogurt by rounding off

The high-polymer content contributes adhesive and

sweet flavor of aspartame and other nonnutritive

cohesive properties to mix (Marshall and Arbuckle,

sweeteners.

***Table 11.7.** Properties of High Fructose Corn Syrups and Crystalline Fructose*

Relative

%Higher

Sweetness:

Type of HFCS

%Moisture

%Fructose

%Glucose

Polymers

Sucrose = 1

42

20–29

42

53

5

0.9–1.0

55

23

55

41

4

1.0–1.2

90

20

90

7

3

1.4–1.6

Crystalline Fructose

0.05

99.5

0.5

0

1.2–1.6

Source: Adapted from Alexander, 1997.

Other nutritive sweeteners for use in specialty yo-

include using a nonstandardized name for the food or

gurt manufacture are honey, maple sugar, and brown *using the two-food concept (i.e., nonfat yogurt with*

sugar. Honey is used in honey-flavored natural yo-

aspartame). Currently these sweeteners are used to

gurt. Honey has a pH of 3.9 and consists of 17.1%

produce "Light" and "low-carbohydrate" products.

moisture, 38.5% fructose, 31% glucose, 7.2% mal-

Today, the use of aspartame alone or in *combination*

tose, 1.5% sucrose, 4.2% higher chain sugars, 0.5%

with crystalline fructose or other nonnutritive sweet-

protein, 0.6% acids, and trace amounts of minerals,

eners is common in the marketing of low-calorie or

vitamins, enzymes and amino acids. Due to the high

“low-carb” yogurt.

fructose content, honey is sweeter than sugar. The

Regular low-fat and nonfat yogurts contain ap-

colors of honey form a continuous range from water

proximately 43 g of sugar per 8 oz. cup. By replacing

white to dark amber. In general the flavor of honey

the sucrose in yogurt, the sugar content drops to 13 g.

is related to its color. Dark colored

honey is more

This reduction in sugar content is of the order of 70%.

intense in flavor while lighter honey is usually mild.

The remaining sugar is lactose, part of which may be

Honey flavor is the result of a number of variables

removed by using 80% milk protein concentrate ob-

such as the floral source, the geographical region, *tained by ultrafiltration and diafiltration of skim milk.*

sugars, acids, tannins, and volatile and nonvolatile

This approach is the basis of "low-carbohydrate"

constituents. Honey can be used as the sole sweet-

yogurt. Concomitantly, reduction in sugar in yogurt

ener source or in combination with equal parts of

results in significant reduction in

calories as well.

sucrose for a honey flavor in yogurt.

Regular low-fat yogurt contains 230 calories per 8

Maple sugar comes from the sap of sugar maple

oz. cup. By replacing added sugar, the calories drop

and black maple trees. The sap is 98% water. The sap

to 130. Similarly, the calories in nonfat yogurt drop *is concentrated in open kettles to 65.5% solids. Typ-*

from 207 to 102 per cup by sugar replacement.

ical composition of maple syrup is: 34% moisture,

The following high intensity sweeteners are ap-

58–66% sucrose, 0–8% glucose, fructose and other

proved by the Food and Drug Administration for use

hexoses, 0.09% malic acid, 0.01%

citric acid, and var-

in yogurt (Table 11.8).

ious minerals. The flavor of maple syrup is attributed

to ligneous materials present in sap and caramelized

Aspartame

sugars produced during the concentration step. The

color of maple syrup can range from light amber to

Aspartame is a dipeptide. It is L- ␣ -

aspartyl-L phenyl

dark amber. Maple sugar is the end product of further

alanine methyl ester. Intestinal esterases hydrolyze

evaporation of maple syrup and contains 92% solids.

to individual peptides and methanol. The end prod-

Brown sugar is described in the sucrose section. It

ucts do have calories, but since the level used is so *is basically unrefined sugar and has flavor similar to*

small, the calorie contribution is essentially zero.

molasses.

The stability of aspartame to heat, yogurt fermen-

Fruit and grain sweeteners are used in products

tation and acidic conditions must be understood.

marketed with a no added sugar label. They are con-

Aspartame breaks down with excessive heat ex-

centrates of apple, grape, and other juices. Syrups

posure to diketopiperazine, but is reasonably sta-

made from rice, oats, and other grains are used in yo-

ble at dairy processing temperatures. It is partially

gurts identified as containing natural ingredients and

metabolized by yogurt cultures during

fermenta-

no sugar added label.

tion. Accordingly, pasteurized aspartame solution is

Sweeteners such as crystalline fructose, glucose,

blended with yogurt base after fermentation. Use of

lactose, invert sugar, or honey are not often used ex-

cept in certain circumstances, such as manufacture *of dietetic yogurt or yogurts marketed with an "all*

Table 11.8. *High Intensity Sweeteners*

natural" or health food appeal.

Approved by FDA for Use in Yogurt

Non-Nutritive

Sweetness Factor,

High Intensity Sweeteners

Sweetener

Sucrose = 1

Because the U.S. standards of identity for yogurt,

Aspartame

160–220

low-fat yogurt and nonfat yogurt do not allow non-

Sucralose

600

nutritive sweeteners to be used, there are labeling op-

Acesulfame K

200

tions that must be considered. Two of these options

Neotame

7,000–13,000

11 Ingredients for Yogurt Manufacture

189

aspartame requires the statement "Phenylketonurics:

Acesulfame-K

Contains phenyl alanine." Aspartame

degrades

Acesulfame-K is 5.6-dimethyl-1,2,3,-oxathiazine-

slowly during storage and shelf life of yogurt. Studies

4(3H)-one-2,2-dioxide. In general, the potassium salt

have shown that about 7% aspartame is inactivated in

is used. It provides no calories because 95% or more

yogurt stored at 4◦C for 8 weeks. To compensate for *is excreted, unchanged in the urine. It is 200 times*

expected loss in sweetness, it is advisable to adjust

sweeter than sucrose. It is stable to baking and cook-

aspartame level for incorporation into yogurt.

ing temperature. It works well with other nonnutri-

Granular or liquid aspartame preparations may be

tive sweeteners by providing sweetness *synergy and*

used in manufacturing light yogurt and smoothies.

masking unpleasant flavors.

Aspartame is dissolved in water along with an acidu-

lant (for example, citric acid). To obtain optimum

sweetness control, it is preferable to add aspartame

in the granular form at the first point of breaking and

NeotameTM

cooling the yogurt coagulum. It requires 30–45 min-

NeotameTM was approved by the Food and Drug Ad-

utes of swept-surface agitation to properly disperse

ministration on July 5, 2002. It is 7,000 to 13,000

the granular aspartame. A less preferred route is to

times sweeter than sucrose. Like aspartame, it is a *incorporate aspartame in fruit preparation during the*

derivative of dipeptide of aspartic acid and pheny-

cooking step. Addition of this fruit adds appropri-

lalanine. Since it is rapidly metabolized by esterases

ate level of aspartame to the fruit flavored yogurt or

and the end products are excreted in body wastes,

smoothie. However, since the level of

fruit prepa-

it is noncaloric. Compared to aspartame, phenylala-

ration in finished yogurt varies considerably due to

nine released in plasma is not significant. Therefore,

mechanical variations in dosing of fruit preparation,

neotameTM requires no warning label for PKU. Its

the sweetness level in yogurt would vary accordingly.

flavor is clean and sweet with no off-flavors. It lacks

For processing yogurt fruit as a carrier of aspartame,

metallic flavor. It enhances other flavors. It is heat

cooking at 96◦C for 5 minutes, followed by quick

stable and can be incorporated directly in yogurt

cooling to 32◦C or lower maximizes the stability of

products. Alternatively, it can be

incorporated in fruit

aspartame. The shelf life of the processed fruit is

preparations and then blended with fermented yogurt

6 months at 4◦C or below.

base. Adding the sweetener through fruit preparation

is not preferred because of inconsistency of mechan-

Sucralose

ical dosing of the fruit in each cup.

Compared to

aspartame, neotameTM is stable to yogurt process-

Sucralose is another high intensity sweetener which

ing temperature and fermentation conditions. Studies

is truly nonnutritive. It is poorly absorbed in the

have shown that 99% of neotameTM survived UHT

gastrointestinal tract (11–27%). The absorbed sucra-

pasteurization conditions and 88% survived after yo-

lose is excreted intact in the urine; the unabsorbed

gurt fermentation and subsequent storage for 5 weeks

portion is excreted in the feces. This is how it pro-

at 4◦C.

vides no calories. It is synthesized from sucrose

Usage level of neotameTM and aspartame to *by replacing three hydroxyl groups with chlorine.*

achieve 6–10% sucrose level in yogurt is shown in

Chemically speaking, it is 1,6-dichloro-1,6-di-

Table 11.9.

deoxy-NL-D-fructofuranosyl-4-chloro-4-deoxy-␣-D-

galactpyranoside. It is three times sweeter than

aspartame or 600 times sweeter than sucrose. It is

Saccharin

stable to heat and acidic conditions prevalent in food

processing and storage. Currently, it is being used

Saccharin is a synthetic compound that is 300 times

in light and "low carbohydrate" yogurt, drinks and

sweeter than sucrose. It provides no calories. It

smoothies.

is excreted unchanged through the kidneys. It has

Table 11.9. *Usage Levels of Neotame and Aspartame in Yogurt*

Product	*NeotameTM*	*Aspartame*
Fruit flavored yogurt	*0.0011–0.0017% (11–17 ppm)*	*0.055–0.08% (550–800 ppm)*
Fruit-for-yogurt preparation		

0.006–0.012% (60–120 ppm)

0.25–0.35% (2500–3500 ppm)

relatively bitter taste but is widely used as sugar re-

easily dispersed in the normal working temperatures

placer in beverages, cooking, and table top sweetener.

in a yogurt plant. In addition, the stabilizer should be

However, it has little or no use in yogurt processing.

easily soluble, display good water holding capacity,

There are several nonnutritive sweeteners await-

and aid in forming stable emulsion. Furthermore, it

ing approval by the FDA. Alitame is a peptide of

should promote stable foam formation (in whipped

L-aspartic acid and D-alanine with a

C-terminal moi-

yogurt), gelation, and adhesion.

ety. It is 2000 times sweeter than sucrose. It has no

Preferably, the incorporation of the stabilizer

metallic or bitter taste. It blends with other high in-

should take place using a high shear-type blender that

tensity sweeteners to maximize quality of sweetness.

has strong agitation resulting in complete dispersion

However, it is pending approval. Cyclamates are used

and a uniform suspension (Chapters 5 and 13). An al-

in 50 countries worldwide, but were banned by the

ternative method would be to use a pump and funnel,

FDA in 1969. Cyclamates are 30 times sweeter than

but care must be taken to avoid lumps.

To minimize

sucrose. The application for reapproval is pending

potential lumps or "fish eyes," it is best to disperse

with the FDA. Neohespridene dihydrochalcone is a

the stabilizer in granulated sugar or NFDM during

by-product of the citrus industry. It is 1500 times

addition. Once dispersed in the mix, it is necessary *sweeter than sucrose. It has licorice flavor. It is ap-*

to have continuous agitation to keep the stabilizer in

proved by the FDA as a flavor ingredient, but not

suspension until it is fully hydrated while receiving

as a sweetener. However, in the EU countries, it

proper heat treatment.

is approved as a sweetener. Another high-intensity

There are many stabilizers and their combinations

sweetener, not yet approved by the FDA, is ste-

available in the industry for use in yogurt. For choos-

via or stevioside. It is obtained from South African

ing a stabilizer, the following areas should be consid-

shrub. Similarly, thaumatin has Generally-Regarded-

ered:

As-Safe status for use as flavor adjunct in the United

r Type of yogurt being produced: vat/cup set,

States. It is a mixture of proteins with tight disulfide

Swiss/blended type or drink/smoothie,

bonds. It has an intense sweet flavor but used as a

mousse/whipped type.

flavor enhancer.

r Formulation: fat content, total solids.

Current trend in the use of high-intensity sweeten-

r Desired firmness and consistency of the finished

ers in yogurt is to blend two or more sweeteners to

product as per marketing objectives.

optimize the flavor profile of yogurt. A combination

r Desired ingredient labeling (natural, organic,

of acesulfame-K with aspartame, or sucralose can en-

kosher, etc.).

hance perceived sweetness, optimize flavor, reduce

r Processing equipment available: batch process

cost, and improve sweetness stability. However, re-

(ease of incorporation), continuous heating

search is required to determine the right combination

system, in-line dosing and mixing, cooling, and

and ratio in yogurt or fruit for yogurt formulation to

pumping of coagulum.

achieve optimum sensory quality of the product.

r Possible masking effect on the flavoring system.

Stabilizers

Gelatin

They are hydrocolloids of plant and animal origin. In

North America, they are commonly

used in the manu-

Gelatin has been extensively used as a stabilizer in

facture of yogurt. The primary purpose of adding sta-

various styles of yogurt. It is derived by irreversible

bilizers in yogurt is to improve consistency and build

hydrolysis of the proteins collagen, and ossein. It

viscosity, to minimize whey separation and bind free *is used at a level of 0.1–0.5%, depending on the*

water, and to maintain the gel structure after pumping,

firmness desired in refrigerated yogurt. Gelatin is a

mixing, and cooling. The stabilizer increases shelf

good stabilizer for frozen yogurt as well. The term

life of the product and provides a reasonable degree

Bloom refers to the gel strength as

determined by a

of uniformity from batch to batch. Stabilizers func-

Bloom gelometer under standard conditions. Gelatin

tion through their ability to form gel structures in

of Bloom strength of 225 or 250 is commonly used.

water, thereby leaving less free water for syneresis.

The gelatin level should be geared to the consistency

In addition, some stabilizers complex with casein.

standards for yogurt. The amount of gelatin above

A good yogurt stabilizer should not impart any flavor,

0.35% tends to give yogurt of relatively high milk

should be effective at low pH values, and should be

solids a curdy and lumpy appearance upon stirring.

Gelatin tends to degrade during processing at ul-

food systems. This functional native starch can be de-

trahigh temperatures and its activity is temperature

rived form corn or tapioca. They have been used alone

dependent. At temperatures below 10◦C, the yogurt

or in combination with WPC or gums in specially *acquires a pudding-like consistency. The yogurt gel*

marketed yogurt products with some success. Al-

developed by gelatin is considerably weakened by a

though these specially processed native starches are

rise in temperature.

designed to resemble the textural properties of modi-

Gelatin is desirable because of its sheen-like ap-

fied starches, they have both product and process lim-

pearance and its ability to take a lot of abuse and

itations. For most applications, starch products that

still produce a good product. However, when using

have been subject to chemical and physical modifica-

only gelatin, the product could have a jelly-like body

tion, result in starch gels that are made *to withstand*

which tends to stir out lumpy, which is undesirable

processing conditions involving high heat, shear, and

in most markets. For this reason, it is more common

acidic environment. Improvement in gelatinization

to use gelatin in combination with other stabilizers to

and pasting characteristics, solubility, and clarity are *lessen the stiff jelly effect and produce a body which*

possible with appropriate modification. Furthermore,

stirs out smooth and is free of lumps. Two combi-

modification of starch can lead to viscosity gener-

nations are commonly used: modified starch-gelatin

ation or reduction, freeze-thaw stability, increased

and gelatin-pectin. When the objective *is to produce*

gel strength and enhanced appearance, and synere-

a "natural" Swiss style yogurt with medium viscos-

sis control, making them versatile for use in food

ity without the use of conventional stabilizers, the

processing. Chemical modification is effected by es-

addition of WPC and MPC is helpful. Their addi-

terifying hydroxyl groups of starch with acetic anhy-

tion increases the protein content and water binding

dride, succinic anhydride, phosphoryl chloride, var-

capacity.

ious phosphates or by etherification with propylene

The stabilizers generally used in yogurt are shown

oxide, or by reaction with hydrochloric/sulfuric acid, *in Table 11.10.*

or by bleaching with hydrogen peroxide, hypochlo-

For effective use of stabilizers, it is imperative to

rite, etc. A combination of these treatments may be

understand their interactions with milk constituents

applied. In addition, cross-linking of starch chains

for possible synergy or interference with the ingredi-

with phosphate diester reduces the degree and rate of

ents of yogurt mix.

granule swelling, which helps stabilize the yogurt and

provide resistance to break down during mechanical

shearing.

Native and Modified Starch

Modified corn/tapioca starch suitable for use at

A new technology has been developed

for produc-

low pH is commonly used in yogurt formulation. For

ing native starches without chemical modification

instance, stabilized and medium cross-linked waxy

that have properties similar to modified starches for

maize starch (hydroxypropyl distarch phosphate) is

application in low to moderate temperature and shear *a viscosity generator and a stabilizer. It has a bland*

Table 11.10. *Common Stabilizers for Yogurt and Yogurt Drinks*

Stabilizer

(%) Concentration in Yogurt Mix

Whey protein concentrate (34%, 50%, or 80%

0.7–1.5

protein) or/and milk-protein concentrate

Starch, modified (tapioca/corn)

0.8–2.0

Gelatin (225/250 Bloom)

0.1–0.5

Agar

0.25–0.70

Pectin (low methoxy for yogurt)

0.08–0.20

Pectin (high methoxy for yogurt beverages)

0.30–0.50

Locust bean gum (in combination)

0.3–0.5

Xanthan gum (in combination)

0.01–0.05

Carrageenan (in combination)

0.01–0.05

Natural corn starch

1.5–2.0

Carboxymethyl cellulose

0.1–0.2

flavor, gives clear paste, smooth short texture, and

r Heat treatment

can withstand severe processing conditions of low

r Length of shelf life

pH, high heat and extreme shear.

Among the seed gums, locust bean gum or carob *gum is derived from the seeds of a leguminous tree.*

Carob gum is a neutral polysaccharide and therefore,

Gums and Pectins

pH has little effect on viscosity in the range pH 3–11.

Frozen yogurt contains plain yogurt of the order of

It is insoluble in cold water and must be heated to

10–20%, while the rest of the product is constituted *be dissolved. It does not have gelling properties on*

from ice milk mix. The ice milk mix is designed for

its own and is used primarily in yogurt to add vis-

optimum freezing characteristics, as well as for de-

cosity or increase gel strength in combination with

sirable texture during shelf life of composite frozen

other stabilizers. It is commonly used *in frozen yo-*

yogurt product. Various gums are used to achieve

gurt where its principal function is stabilizing and the

these effects. The seaweed gums impart a desirable

binding of water, which provides heat-shock resis-

viscosity as well as gel structure to yogurt. Algin

tance and a slow creamy meltdown. Guar gum is also *and sodium alginate are derived from giant sea kelp.*

obtained from seeds and can be used in stabilizer sys-

Carrageenan is made from Irish moss and compares

tems for frozen yogurt. Guar gum is readily soluble

with 250 Bloom gelatin in stabilizing value. These

in cold water and is not affected by high temperatures

stabilizers are heat stable and promote *stabilization*

used in the pasteurization of yogurt mix. Guar gum is

of the yogurt gel by complex formation with Ca+2

nongelling and is used mainly as a viscosity builder,

and casein.

stabilizer, and moisture-binding agent. Guar gum im-

Pectins are commonly used alone or in combi-

parts body, texture, chewiness, and heat-shock resis-

nation with other hydrocolloids to stabilize stirred

tance to frozen yogurt. Carboxy methyl cellulose is a

and set yogurt. The source, structure, and type of

derivative of the natural product cellulose. It is readily

pectins are discussed in Chapter 12. Low Methoxy

soluble in either hot or cold water and *is effective at*

(LM) pectin is the preferred type for (refrigerated)

high processing temperatures. Its primary function in

cup yogurt. Very small amount (0.07–0.15%) mod-

yogurt would be as a thickener and moisture-binding

ifies the consistency of the yogurt making it stiffer

agent. In frozen yogurt, it functions to bind water, *and preventing any syneresis that might arise during*

thus preventing the formation of large ice crystals

handling, transportation, and distribution. LM pectin

that can develop during temperature fluctuations in

retains the lactoserum in a very flexible network that

storage. The result is a frozen yogurt with smoother

is formed in reaction with calcium ions *present in the*

texture and improved melt down characteristics.

yogurt. The maximum amount of pectin to be added

The stabilizer system used in yogurt mix prepara-

to yogurt is 0.20%, as higher concentrations could

tions is generally a combination of various vegetable

result in a chalky or sandy texture and decreased vis-

stabilizers. Their ratios as well as the final concentra-

cosity in stirred yogurt.

tion (generally 0.5–2.00%) in the product are care-

High Methoxy (HM) pectin is preferred to ensure

fully controlled to get desirable effects.

stability and control viscosity in acidified milk drinks.

Other important ingredients used in yogurt man-

HM pectin stabilizes the milk proteins to produce

ufacture are fruits and flavors. They are described

products without sedimentation and whey separation

separately in Chapter 9.

and ensures a smooth mouth feel without "sandi-

ness." The stabilization is obtained by absorption of

pectin onto the surface of the protein particles with

REFERENCES

the proper application of shear force. The absorbed

pectin imparts a similar charge to all particles caus-

Alexander RJ. 1997. Sweeteners: Nutritive. Eagan

ing repulsion between particles preventing agglomer-

Press, St. Paul, MN, pp. 17–43.

ation that would result in sedimentation, separation, *American Dairy Products Institute. 1990. Standards for*

and a sandy texture. The optimum HM pectin level

grades of dry milks including methods of analysis.

is determined by:

Bulletin 916 (Revised). Elmhurst, IL, 60126.

r

pp. 1–56.

Protein concentration

Chandan RC. 1982. Fermented dairy products. In: G

r Protein particle size

Reed (Ed), Prescott & Dunn's Industrial

Microbiology. Avi Publishing, Westport, CT,

(Eds), Biotechnology, Vol. 9, 2nd ed. VCH

pp. 113–184.

Publishers, Weinheim, Germany, pp. 386–418.

Chandan RC. 1997. Dairy-Based Ingredients. Eagan

Marshall RT, Arbuckle WS. 1996. Ice Cream.

Press, St. Paul, MN, pp. 48–49.

Chapman and Hall, NY, pp. 317–318.

Chandan RC. 2004. Dairy: yogurt. In: JS Smith, YH

Tamime AY, Robinson RK. 1999. Yogurt Science &

Hui (Eds), Food Processing: Principles and

Technology, 2nd ed. Woodhead Publishing Limited,

Applications, Blackwell Publishing, Ames, IA,

Cambridge, England and CRC Press, Boca Raton,

pp. 297–328.

Florida.

Chandan RC, Shahani KM. 1993. Yogurt. In: YH Hui

United States Department of Health and Human

(Ed), Dairy Science and Technology Handbook, Vol.

Services. 1999. Public Health Services, Food and

2. VCH Publishers, New York, New York, pp. 1–56.

Drug Administration. Grade "A" Pasteurized Milk

Chandan RC, Shahani KM. 1995. Other fermented

Ordinance. Revision. Publication no.

229.

dairy products. In: G Reed, TW Nagodawithana

Washington, DC.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

12

Principles of Yogurt Processing

Ramesh C. Chandan and Kevin R. O'Rell

Mix Preparation

inactivated. From microbiological standpoint, de-

Heat Treatment

struction of competitive organisms produces condi-

Homogenization

tions conducive to the growth of desirable yogurt bac-

Yogurt Starter

teria. This contributes to the long shelf life as well as

Factors Influencing Growth of Yogurt Starter

to food safety aspects of yogurt. Furthermore, the

Yogurt Strain Selection

heat processing results in the expulsion of oxygen,

Changes in Milk Constituents During Yogurt Production

creation of reducing conditions (sulfhydryl genera-

References

tion), and production of protein-cleaved nitrogenous

compounds. All these effects enhance nutritional sta-

Yogurt is a fermented, low to high acid semisolid

tus of the medium for growth of the yogurt culture.

cultured milk product (Chandan, 2002; Shah, 2003;

Physical changes in the proteins as a result of heat

Vedamuthu, 1991). The sequence of stages of pro-

treatment have a profound effect on the viscosity of

cessing in a yogurt plant is given in Table 12.1.

yogurt (Shah, 2003). Optimum results are obtained

by using a heat treatment of 90–95◦C and a hold-

MIX PREPARATION

ing time of 5–10 minutes (Robinson, 2003a). Con-

sequently, whey protein denaturation of 70–95% en-

During standardization of the mix for yogurt man-

hances water absorption capacity, thereby creating

ufacture, the contribution of common dairy ingredi-

smooth consistency, high viscosity and stability from

ents to the milk fat and milk solids-not-fat portion

whey separation in yogurt.

of yogurt mix is given in Chapter 11 (Table 11.1). In

Nutritional changes include ease of digestion of

most yogurt formulations, standardization of milk for

denatured whey proteins in the gastrointestinal tract,

fat and solids-not-fat content results in fat reduction

soft curd in the stomach, and rapid gastric emptying

and a possible 30–35% increase in

lactose, protein,

rate attributed to viscous nature of yogurt.

mineral, and vitamin content (Chandan and Shahani,

Heat treatment of yogurt mix can be conducted

1993, 1995; Chandan, 1997, 2004). The nutrient den-

using a variety of methods:

sity of yogurt mix is thus increased over that of milk.

r Jacketed mix/processing tank

Specific gravity changes from 1.03 to 1.04 at 20◦C.

r Plate heat exchanger

Addition of stabilizers (gelatin, starch, pectin) and

r Tubular heat exchanger

sweeteners further impacts physical properties.

r Scraped-surface heat exchanger.

In most yogurt manufacturing facilities today the

HEAT TREATMENT

heat treatment of the yogurt mix is accomplished us-

Yogurt processing requires intense heat treatment,

ing plate heat exchangers. The plate heat exchanger

which destroys all the pathogenic flora and most veg-

consists of a pack of stainless steel plates clamped in

etative cells of all microorganisms contained therein.

a frame. The frame may contain several plate packs

In addition, milk enzymes inherently present are

or sections in which different stages of treatment such

Table 12.1. *Sequence of Processing Stages in the Manufacture of Blended Style Yogurt.*

Step

Salient Feature

Milk procurement

Sanitary production of Grade A milk from healthy cows is necessary. For

microbiological control, refrigerated bulk milk tanks should cool to

10◦C in 1 hour and < 5◦C in 2 hours. Avoid unnecessary agitation to

prevent lipolytic deterioration of milk flavor. Milk pickup from dairy

farm to processing plant is in insulated *tanks at 48-hour intervals, as*

appropriate.

Milk reception and storage

Temperature of raw milk at this stage should not exceed 7◦C. Insulated or

in manufacturing plant

refrigerated storage up to 72 hours helps in raw material and process

flow management. Quality of milk is checked and controlled.

Centrifugal clarification and

Leucocytes and sediment are removed. Milk is separated into cream and

separation

skim milk or standardized to desired fat level at 5◦C.

Mix preparation

Various ingredients to secure desired formulation are blended together at

5◦C in a mix tank equipped with powder funnel and an agitation system.

Heat treatment

Using plate heat exchangers with

regeneration systems, milk is heated to temperatures of 95–97∘C for 7–10 minutes, well above pasteurization treatment. Heating of milk kills contaminating and competitive microorganism, produces growth factors by breakdown of milk proteins, generates microaerophilic conditions for growth of lactic organisms, and creates desirable body and texture in the cultured dairy products.

Homogenization

Mix is passed through extremely small orifice at a pressure of approx.

1,700 MPa (2,000–2,500 psi), causing extensive physicochemical

changes in the colloidal characteristics of milk. Consequently, creaming

during incubation and storage of yogurt mix is prevented. The

stabilizers and other components of a mix are thoroughly dispersed for

optimum textural effects.

Inoculation and incubation

The homogenized mix is cooled to an optimum growth temperature

(41–42◦C). Inoculation is generally at the rate of 0.5–5% and the

optimum temperature is maintained throughout incubation period to

achieve a desired titratable acidity or pH. A pH of 4.5–4.6 is commonly

used as an endpoint of fermentation. Quiescent incubation is necessary

for product texture and body development.

Cooling, fruit incorporation

The coagulated product is cooled down to 5–22◦C, depending upon the

and packaging

style of yogurt. Using fruit feeder or flavor tank, the desired level of

fruit and flavor is incorporated. The blended product is then packaged.

Storage and distribution

Storage at 5◦C for 24–48 hours imparts in several yogurt products

desirable body and texture. Low temperatures ensure desirable shelf life *by slowing down physical, chemical, and microbiological degradation.*

Source: Chandan, 2004.

as preheating, final heating, and cooling take place.

on water and energy. Regeneration efficiencies of up

The plates are corrugated in a pattern designed for

to 94–95% can be achieved using efficient plate heat

optimum heat transfer as the liquid product enters *exchangers. Proper heat treatment of the yogurt mix*

and leaves the channels on one side and the heating

requires that the mix be held for a specified time at a

or cooling medium on the opposite side. Most heat

desired final heating temperature. This is usually ac-

plate exchangers contain a section that is used for re-

complished in an external holding tube.

The holding

generation. Regeneration is a process using the heat

tube consists of stainless steel pipe arranged in either

of a hot liquid (yogurt mix) to preheat the cold in-

a spiral or zigzag pattern. The tube can be insulated

coming liquid (yogurt mix). The cold liquid (yogurt

or contained in an insulated box to minimize heat loss *mix) is also cooling the hot liquid (yogurt mix) saving*

during the extended hold time. The length of the pipe

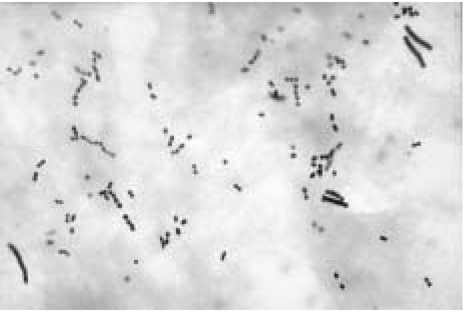


***Figure 12.1.** Stained cells of yogurt*

bacteria

under microscope. 1,000 × magnification.

and flow rate is calculated to give the desired hold

yogurt should have a custard-like or soft spoonable

time in the tube.

consistency that is free from syneresis or wheying

off. The coagulum should be smooth without grains *or lumpiness and break cleanly when spooned from*

HOMOGENIZATION

the container. The coagulum should also have a close

Homogenization treatment reduces the fat globules

texture with complete absence of any gas space or

to an average of less than 1 □m in diameter and as-

open texture. The activity of yogurt culture plays a *sures a uniform distribution of the milk fat in the yo-*

key role in getting the required texture and flavor. The

gurt. Consequently, no distinct creamy layer (crust)

fermentation is carried out by yogurt starter.

is observed on the surface of yogurt produced from

homogenized mix. There is also an improvement in

YOGURT STARTER

the consistency of the yogurt and greater stability

of the coagulum against whey separation. In gen-

Starters for yogurt production are discussed in detail

eral, homogenized milk produces soft coagulum in

in Chapter 6. A starter culture consists of food-grade

the stomach, which may enhance digestibility.

microorganism(s), which when allowed

to grow in

Homogenization temperatures used are usually

milk produce predictable attributes characterizing

from 55◦C to 80◦C with homogenization pressures

yogurt (Fig. 12.1).

between 10 and 20 MPa (100–250 bar). In general

The composition of yogurt starter is shown in *the homogenizer is placed after the first regenerative*

Table 12.2.

section and before the final heating. This is because

Also, shown in this table are some additional or-

homogenization is most efficient when the fat phase

ganisms found in yogurt or yogurt-like products mar-

is in a liquid state.

keted in various parts of the world.

Most yogurt facilities use a two-stage homoge-

All types of yogurt in the United States are

nizer to achieve optimal homogenization. Although

fermented with the yogurt characterizing cultures

homogenization always takes place in the first stage,

mandated by FDA regulations. The yogurt culture *the second stage serves two basic functions: (a) It sup-*

contains Streptococcus thermophilus (ST) and Lacto-

plies a constant and controlled back-pressure to the

bacillus delbrueckii subsp. bulgaricus (LB). Further-

first stage that improves homogenization efficiency;

more, a majority of the yogurt sold contains optional

(b) it prevents the clumping of fat

globules that can

bacteria, especially those of intestinal origin. The op-

occur immediately following the first-stage homog-

tional organisms include Lactobacillus acidophilus,

enization.

bifidobacteria, and other lactobacilli that are often

Yogurt is traditionally made from fortified whole *referred to as probiotic bacteria. Their inclusion in*

milk, low-fat milk or skim milk to which a yogurt

yogurt starter is motivated by their unique health-

culture is added and allowed to grow. In general,

promoting effects. Such effects include improvement

Table 12.2. *Required and Optional*

whereas the volatile by-products contribute to its

Composition of Yogurt Bacteria.

pleasant and characteristic aroma. Of the volatile

flavor components, acetaldehyde accounts for al-

Required by FDA

Optional Additional

most 90%. However, bifidobacteria produce more

Standard of Identity

Bacteria Found in Yogurt

acetic acid than lactic acid. Therefore, if they are

Streptococcus

Lactobacillus acidophilus

used in the culture makeup, the overall flavor pro-

thermophilus (ST)

Lactobacillus casei

file will change as a result of higher

acetic acid

Lactobacillus

Lactobacillus casei subsp.

content.

delbrueckii subsp.

rhamnosus

With the advice of culture suppliers, the proper

bulgaricus (LB)

Lactobacillus reuteri

culture can be selected that yields a finished yogurt

Lactobacillus helveticus

with desirable flavor and consistency and is suitable

Lactobacillus gasseri ADH

for the plant equipment and production schedule.

Lactobacillus plantarum

The physiological state of a starter culture is deter-

Lactobacillus lactis

mined by microscopic examination of the dyed cells

Lactobacillus johnsoni

of the culture. Cells of ST grown fresh in milk or

LA1

broth display pairs or long chains of spherical coccal

Lactbacillus fermentum

shape (Figure 12.2). Under stressed condition of nu-

Lactobacillus brevis

trition and age (old cells, cells exposed to excessive

Bifidobacterium longum

Bifidobacterium breve

acid, solid media colonies, inhibitor containing milk),

Bifidobacterium bifidum

the cells appear oblong in straight chains, resembling

Bifidobacterium

somewhat like LB.

adolescentis

The acid producing ability is measured by pH drop

Bifidobacterium animalis

and titratable acidity rise in 12% reconstituted nonfat

Bifidobacterium infantis

dry milk medium (sterilized at 116◦C/18 minutes)

Source: Adapted from: Chandan, 1999, 2004.

incubated at 40◦C for 8 hours. A ratio *of 3 parts of*

ST and 1 part of LB gives a pH of 4.20 and % TA of

1.05 (Chandan and Shahani, 1993) under the above

in protein digestibility, alleviation of lactose intoler-

conditions.

ance, enhancement of mineral absorption, control of

Since starter cultures from culture suppliers are *intestinal health, lowering of serum cholesterol, an-*

added to the pasteurized yogurt mix, it is essen-

tihypertensive effects, anticancer properties, and im-

tial that the commercial starter be contaminant-free.

munity enhancement (Takano and Yamamoto, 2003).

Commercial starter culture suppliers provide mi-

Some yogurt manufacturers

incorporate them after

crobiological specifications in terms of contaminant

yogurt fermentation, whereas others coculture them

tolerances for their products. Accordingly, microbio-

with yogurt organisms.

logical specifications of commercial cultures are out-

Both ST and LB are fairly compatible as well *lined (Sellars, 1989). In general, counts of mesophilic*

as symbiotic for growth in milk medium. However,

lactics, yeasts and molds, coliforms, anaerobic spore-

the optional organisms do not necessarily exhibit

formers, and salt-tolerant micrococci should not

compatibility with LB and ST. Judicious selection

exceed 10 CFU/g. Escherichi coli,

Enterococcus

of strains of LB, ST, and the optional organisms

faecium, and coagulase positive staphylococci should

is necessary to insure survival and growth of all

be < 1 CFU/g. The culture must be free of salmonella,

the component organisms of the starter. Neverthe-

listeria, and other pathogenic contaminants.

less, product characteristics, especially flavor, may

Data relative to various characteristics of bacteria

be significantly altered from traditional yogurt fla-

most commonly used for yogurt processing are pre-

vor, when yogurt culture is cocultured with optional

sented in Table 12.3.

bacteria, especially bifidobacteria. Normally, the yo-

gurt culture, which is composed of LB and ST, is

Factors Influencing Growth

responsible for the characteristic flavor and aroma

of Yogurt Starter

of yogurt through the production of acetaldehyde,

diacetyl, and acetic acid during the fermentation pro-

Yogurt fermentation constitutes the most important *cess. Lactic acid, being a nonvolatile substance, con-*

step in its manufacture. To optimize the parameters

tributes to the acidic and refreshing taste of yogurt,

for yogurt production, an understanding of factors

Table 12.3. *Certain Characteristics of Most Commonly Used Microorganisms in Yogurt Production.*

Streptococcus

Lactobacillus delbrueckii

Characteristic

thermophilus

subsp. bulgaricus

Lactobacillus acidophilus

Cell shape and

Spherical to ovoid,

Rods with round ends,

Rods with round ends, single,

configuration

pairs to chains

single, short chains,

pairs, short chains, no

metachromatic

metachromatic granules

granules

Catalase reaction

–

–

–

Growth temperature, ◦C

Minimum

20

22

20–22

Maximum

50

52

45–48

Optimum

40–45

40–45

37

Incubation temperature, $^{\circ}C$

40–45

42

37

Heat tolerance

++

+

−

(60◦C/30 minutes)

Lactic acid production

0.7–0.8%

1.8%

2.0%

in milk

Lactic acid isomers

L(+)

D(−)

DL

Acetic acid

Trace

Trace

+

Gas (CO2) production

−

−

−

Proteolytic activity

+/−

+

+/−

Lipolytic activity

+/−

+/−

+/−

Citrate fermentation

−

−

−

Fermentation ability for

carbohydrates:

Lactose

+

+

+

Glucose

+

+

+

Galactose

−

−

+

Sucrose

+

+

+

Fructose

+

+

+

Aroma/flavor compounds

++

++

+

Hydrogen peroxide

+/−

+

+

production

Mucopolysaccharide

+

++

–

production

Alcohol production

–

Trace

Trace

Salt tolerance:

2.0

2.0

6.5

% maximum

Source: Compiled from: Chandan and Shahani, 1995; Surono and Hosono, 2003; Nauth, 2004.

involved in the growth of yogurt

bacteria is important

dairy environment from which it can be easily iso-

to manage the uniformity of product quality and cost

lated. ST (Fig. 12.2) is a Gram-positive, anaero-

effectiveness of manufacturing operation.

bic, nonmotile, and catalase negative organism with

spherical/ovoid cells of 0.7–0.9 □m in diameter

(Robinson, 2003b).

Streptococcus thermophilus

ST can survive 60◦C for 30 minutes (Nauth, 2004).

Streptococcus thermophilus (ST) is characterized by

It does not grow at 10◦C. Although the optimum

its typical attributes, which distinguish it from lacto-

growth temperature for ST is 37◦C, it grows well *cocci used in the manufacture of cheese, buttermilk,*

in cooperation with LB at the yogurt incubation

and sour cream. ST originates exclusively from the

temperature of 43◦C. During yogurt fermentation, the

Figure 12.2. *Streptococcus thermophilus*

cells under microscope. 1,000 ×

magnification.

initial need of ST for nitrogen source is fulfilled by

digestive tract following consumption of yogurt by

free amino acids present inherently in milk medium.

lactose intolerant individuals.

As fermentation proceeds, the peptides generated by

When cultured in milk at 43◦C, many strains ap-

LB are hydrolyzed by the peptidases of ST to gener-

pear as spherical occurring in pairs or long chains of

ate free amino acids for its nutritional needs.

10–20 cells. Most cells appear as diplococci. At high

Milk is a good medium for its growth. ST can fer-

acidity levels in milk, if the cells are aged or if the

ment glucose, fructose, mannose, sucrose, and lac-

culture is grown on solid media, ST

may exhibit long

tose. Milk lactose is transported through the cell

chains. When plated on solid media, ST produces

membrane with the help of the enzyme galacto-

pin-point colonies. The display of abnormal shapes

side permease located in the membrane. The lac-

of cells obtained from liquid media are indicators of *tose in the cell is then hydrolyzed by lactase or*

stress conditions on the organism, viz., bacteriophage

ᴺₗ *-galactsidase enzyme. ST produces significant lev-*

attack, and inhibitors (sanitizers, antibiotics, cleaning

els of lactase, which catalyzes the hydrolysis of lac-

compounds, etc.) in the growth medium. ST is very

tose to glucose and galactose. Glucose *is converted*

sensitive to inhibitory substances, especially antibi-

to pyruvate via Embden-Meyerhof pathway (Chap-

otics. It is readily inhibited by 0.005 IU penicillin/ml

ter 6). Pyruvate is metabolized to lactic acid by the

of milk. It should be noted that ST is more often at-

enzyme lactic dehydrogenase. In most strains, glu-

tacked by bacteriophage than LB.

cose is readily utilized in milk medium while lactic

acid and galactose accumulate. Some strains can uti-

Lactobacillus delbrueckii subsp. bulgaricus

lize galactose. These strains display galactokinase ac-

tivity converting galactose to galactose-1-phosphate,

This organism was originally described by Orla *which is further converted to glucose-1-phosphate*

Jensen in 1919 as Thermobacterium bulgaricum. On

or galactose-6-phosphate and further metabolized to

the basis of DNA homology studies, four subspecies

lactic acid (Robinson, 2003b). The lactic acid pro-

of Lb. delbrueckii are classified as bulgaricus, le-

duced by this organism is L (+) lactic *acid. ST is*

ichmannii, lactis, and delbrueckii. LB is a Gram-

inhibited by increasing levels of lactic acid and at ap-

positive, catalase-negative, and nonmotile organism.

proximately 1% concentration (pH 4.3), its growth

(Fig. 12.3).

is arrested and cell numbers reach stability. At this

LB is an anaerobic/aerotolerant homofermentative

stage the fermented mass displays ST counts of log

organism that produces D (−) lactic acid and some

7–8 CFU/g.

hydrogen peroxide. It can produce a large quantity

The lactase activity of ST has a physiological sig-

of lactic acid (up to 1.8%), but for yogurt produc-

nificance in aiding the digestion of lactose in human

tion the strains, which are moderate acid producers

Figure 12.3. *Lactobacillus delbrueckii*

spp .

bulgaricus cells under microscope. 1,000 ×

magnification.

are selected. Like ST, LB produces lactase enzyme

rates of acid and flavor production by yogurt starter

to hydrolyze lactose to glucose and galactose. Glu-

containing both ST and LB are considerably higher *cose is metabolized to lactic acid, while galactose*

than by either of the two organisms grown separately

accumulates in the growth medium.

(Loones, 1989; Robinson, 2003b). Although they can

The cells of LB appear under microscope as slen-

grow independently, they utilize each other's metabo-

der rods with rounded ends. The cells occur singly or *lites to effect remarkable efficiency in acid produc-*

in chains of 3–4 short rods (0.5–0.8 × 2.0–9.0 □m)

tion. In general, LB has significantly more cell-bound

with rounded ends. In a young and vigorous state,

proteolytic enzyme activity, producing stimulatory

the cells occur mainly singly or in pairs. Younger LB

peptides and amino acids (especially,

valine) from

cells under microscopic examination do not show vo-

casein protein for ST. The relatively high amino-

lutin (metachromatic) granules. With increasing age

peptidase and cell-free and cell-bound dipeptidase

(20–24 hours), the cells elongate and the volutin gran-

activity of ST is complementary to strong proteinase *ules become more visible. Nutritional stress leads to*

and a low-peptidase activity of LB. ST in turn pro-

copious granules in the rods. LB has a higher re-

duces formic acid and removes oxygen, which stim-

sistance to antibiotics than ST, but is inhibited by

ulates the growth of LB. In addition, urease activ-

0.3–0.6 IU of penicillin/ml of milk.

ity of ST produces CO_2 which also stimulates LB

The optimum growth temperature of LB is 45◦C,

growth. Concomitant with CO_2 production, urease

but for yogurt production, a temperature of 42–43◦C

liberates ammonia, which acts as a weak buffer. Con-

is used to accommodate the lower optimum growth

sequently, milk cultured by ST alone

exhibits consid-

temperature of ST. LB utilizes lactose, glucose, fruc-

erably low titratable acidity or high pH of coagulated

tose, and in some strains galactose to produce as high

mass. Formic acid formed by ST as well as by heat

as 1.8% D(−) lactic acid. It tolerates low pH much

treatment of milk accelerates LB growth. During the *better than ST. Unlike ST, LB can hydrolyze casein*

early part of incubation, ST grows faster and outnum-

($^{N}{}_{L}$-casein, preferentially) to peptides, using its cell

bers LB by 3–4 to 1. However, in the later stages,

wall bound proteinase (Argyle et al., 1976a, 1976b;

(at pH 5.0), ST growth slows down due to adverse

Chandan et al., 1982). But to convert

the resulting

effect of acid development and the numbers of LB

peptides to free amino acids, LB has to rely on ST,

gradually approach the population of ST. Therefore,

which has active peptidase activity.

acid production is accomplished in the first stage of

incubation predominantly by ST, and in the second *stage, mainly by LB.*

Collaborative Growth of ST and LB

Yogurt organisms are microaerophilic in nature.

Yogurt starter organisms display obligate symbiotic

Heat treatment of milk drives out oxygen. It also de-

relationship during their growth in milk medium. The

stroys competitive flora. Furthermore, heat produced

Figure 12.4. Lactobacillus acidophilus cells

under microscope. 1,000 × magnification.

sulfhdryl compounds tend to generate

reducing con-

of these organisms through the gut and the possibil-

ditions in the medium. Accordingly, rate of acid

ity of obtaining the benefits associated with them.

production in high heat-treated milk is considerably

Such benefits include improvement of gastrointesti-

higher than in raw or pasteurized milk.

nal health and overall prevention of disease. Research

Viability of yogurt culture is an important attribute

studies show that Lb. acidophilus in the formula re-

for consumer acceptance. The number of ST and LB

sults in the improvement of nutritional profile for ba-

cells in a sample of yogurt can be enumerated by stan-

bies and protects them from diarrheal

episodes and

dard International Dairy Federation procedure (IDF,

assists in lactose digestion. Further benefits of con-

2003). Provided the fermentation conditions are opti-

suming the culture include control of intestinal infec-

mal, the manufacturer of yogurt should achieve com-

tions in the very young and very old, cancer preven-

bined yogurt culture level of at least 100 million

tion, and enhanced competence of immune function

CFU/g of the product.

(Chandan, 1999). For efficacy, desirable acidophilus

level in yogurt should exceed one million CFU/g

at consumption stage. Other lactobacilli occasion-

Lactobacillus acidophilus

ally found in yogurt are Lactobacillus reuteri and

Lactobacillus acidophilus is an adjunct culture com-

Lb casei.

monly found in yogurt marketed in the United States

and other countries with highly developed yogurt

Bifidobacteria

markets (Fig. 12.4).

There has been strong interest in the

microflora

Other probiotic cultures frequently found in yogurt

of the mammalian gastrointestinal (GI) tract and its

are species of bifidobacteria (Fig. 12.5).

role in promoting health of the host (Chandan, 1989;

They are a group of Y-shaped anaerobic organisms.

Chandan, 2002; Fernandes et al., 1992; Takano and

Some are tolerant to oxygen and can be successfully

Yamamoto, 2003). Certain strains of this organism

used as adjunct cultures in yogurt. They are character-

can be implanted in the colon after surviving the harsh

ized by the production of 2 moles of L (+) lactic acid

conditions of low pH and surface active bile secre-

and 3 moles of acetic acid from 2 moles *of glucose.*

tions in stomach and small intestine. These strains

Commonly used bifidobacteria are: Bifidobacterium

possess properties required of probiotics and are con-

bifidum, B. infantis, B. adolescentis, and B. breve.

sidered to be desirable dietary adjuncts. Probiotics are

Although the adjunct organisms do not play an es-

defined as live microorganisms, which contribute to

sential role in yogurt manufacturing, the yogurt fer-

the well being of human and animals by improving

mented with these organisms generally tends to taste

their microbial balance in the GI tract. Probiotics are

milder in terms of acidity and flavor. Also, their use

discussed in Chapters 21 and 22.

Consuming yogurt

can be declared on the label and ingredient statement

containing the probiotics allows continuous passage

to provide possible marketing advantage, particularly

Figure 12.5. *Bifidobacteria cells under*

microscope. 1,000 × magnification.

for consumers familiar with the benefits of probiotic

contribute toward the total potential inhibitory effect

bacteria.

on yogurt culture growth.

Phage infections and accompanying

loss in the rate

of acid production by lactic cultures results in flavor

Inhibiting Factors

and texture defects, as well as major product losses

As given in Chapter 6, proper selection of ST and

in fermented dairy products. Serious economic losses

LB strains is necessary to achieve maximum sym-

have been attributed to phage attack. It is known that

biosis between the two organisms. Certain abnor-

specific phages affect ST and LB, and that ST is rel-

mal milks (mastitic cows, hydrolytic rancidity in

atively more susceptible than LB.

milk) are inhibitory to their growth. Seasonal vari-

Yogurt fermentation process is relatively fast *ations in milk composition resulting in lower mi-*

(3–4 hours using bulk starter and 5–6 hours using di-

cronutrients (trace elements, nonprotein nitrogenous

rect set starter cultures). It is improbable that both ST

compounds) may affect starter performance. Natu-

and LB would be simultaneously attacked by phages

ral inhibitors secreted in milk

(lactoperoxidase thio-

specific for the two organisms. In the likelihood of a

cyanate system, agglutinins, lysozyme) are gener-

phage attack on ST, acid production may be carried on

ally destroyed by proper heat treatment and therefore

by LB, causing little or no interruption in production

do not pose a problem. Antibiotics residues in milk *schedule. However, it may affect the flavour charac-*

and entry of sanitation chemicals (quaternary com-

teristic. In fact, lytic phage may lyse ST cells spilling

pounds, iodophors, hypochlorites, hydrogen perox-

cellular contents in the medium, which could con-

ide) have profound inhibitory effect on the growth of

ceivably supply stimulants for LB

growth. Also, the

yogurt starter.

use of mixed strain yogurt starter cultures minimizes

Yogurt mixes designed for manufacture of refriger-

the risk of production failure from a single phage at-

ated or frozen yogurt may contain appreciable quan-

tack. This rationale may explain partially why the yo-

tities of sucrose, high fructose corn syrup, dextrose,

gurt industry has experienced low incidence of phage

and various DE corn syrups. The sweeteners exert os-

problems. Nonetheless, most commercial strains of

motic pressure in the system, leading to progressive

yogurt cultures have been phage typed. Specific

inhibition and decline in the rate of

acid production by

phage sensitivity has been determined to facilitate

the culture. Being a colligative property, the osmotic-

starter rotation procedures as a practical way to avoid

based inhibitory effect would be directly proportional

phage threats in yogurt plants. If the plant begins to

to concentration of the sweetener and inversely re-

experience longer fermentation times, the starter cul-

lated to the molecular weight of the solute. In this

ture can be pulled out of production and replaced with

regard, solutes inherently present in milk solids-not-

a new starter that has different phage sensitivity.

fat part of yogurt mix accruing from starting milk

The ST phage is destroyed by heat

treatment of

and added milk solids and whey products would also

74◦C for 23 seconds. This phage proliferates much

faster at pH 6.0 than at pH 6.5 or pH 7.0. Methods

2. Flavor and aroma production. The best method

used for phage detection include

plaque assay, inhi-

for determining the sensory quality is an

bition of acid production (litmus color change), en-

organoleptic evaluation 24–48 hours after pack-

zyme immunoassay, ATP assay by bioluminescence,

aging and at the end of code. It is also customary

changes in impedance, and conductance measure-

to check the pH/titratable acidity and viscosity of

ment.

the stored samples.

Phage problem in yogurt plants cannot be ignored.

3. Mucopolysaccharide production. There are sev-

Accordingly, adherence to strict sanitation proce-

eral strains producing polysaccharide or slime/

dures and attention to proper air quality would insure

ropiness within both ST and LB. Production of

prevention of phage attack.

some polysaccharide by the culture is sometimes

Commercial production of yogurt relies heavily

desirable to improve the consistency and viscosity

on fermentation ability and characteristics imparted *of yogurt, particularly cup-set yogurt, yogurt with*

by the starter. By controlling the culture strains and

low solids or a "natural" product produced with-

balance, the acidity and flavor development of yogurt

out the use of stabilizers. Excess ropiness should

can be optimized. Traditionally, the ratio between ST

be avoided since it tends to mask flavor *and aroma,*

and LB was maintained between 1:1 and 3:2 in the

and imparts slick mouth-feel and an undesirable

finished yogurt. With current technology and today's

stringy consistency. The intensity of polysaccha-

market toward a more mild yogurt acid and flavor,

ride production can be controlled from none to *the ratio is maintained to favor ST around 80–90%*

heavy. Also, the temperature of incubation affects

of the total yogurt culture.

the degree of polysaccharide production by the

In yogurt, the ratio of yogurt bacteria, production

culture. Low incubation temperature appears to

of lactic acid and aroma compounds, and body char-

induce polysaccharide production.

acteristics can be controlled to some degree by the

4. Proteolysis. Protein hydrolysis favorably affects

following factors:

the digestibility of proteins in yogurt, but is detri-

mental to the consistency and taste. Certain strains

of LB to avoid are those which produce bitter pep-

tides from casein as a result of extensive protein

degradation by proteolysis. ST exhibits very weak

The culture suppliers deliver frozen or freeze dried

proteolysis in milk.

forms of cultures containing one or more types of se-

5. Sugar resistance. Depending on culture strain, the *lected strains which exhibit discreet properties. Sev-*

sensitivity of yogurt culture to sucrose concentra-

eral characteristics should be considered in selecting

tion varies between 5% and 12%. In general, most

the strains which are best suited to meet the marketing

cultures show significant inhibition at 8–10% su-

objectives.

crose concentration. However, there are special-

1. Acid production during fermentation and pH sta-

ized cultures, which can ferment yogurt mixes

bility during shelf life of yogurt. At present, the

containing sucrose levels as high as 10–13% with-

US consumer shows a preference for yogurt with

out a significant slow down in acid

development.

mild acidity (pH 4.2–4.4). A culture with strong

acid production usually leads to overacidification

Ratio of ST and LB in the Culture

during cooling and storage including shelf life.

It is recommended to select a culture with weak

Depending on the type or form of yogurt culture used *to medium acid production ability. The use of*

in yogurt manufacture, the ratio of its constituent bac-

mixed strain cultures with mild acid production

teria may be controlled to enhance flavor, acid level,

is particularly important during the long shelf life

and texture.

(6–7 weeks) of the product. In particular, it as-

sumes even more importance during interruption

Fresh Bulk Starter.

Since bulk starter is produced

in the refrigeration chain starting from product de-

and controlled by the yogurt manufacturer, it is more

livery to grocery market ending with consumer re-

easily subject to variability in the culture-strain ra-

frigerated storage. The ability of acid production

tio. The manufacturer must strive to maintain con-

by the culture can be ascertained by plotting an

sistent fermentation temperature and rate of cooling

acid curve (pH drop versus time).

at the end of fermentation with bulk starter to assure *consistent yogurt production. However, the benefits*

base is incubated at 41–43◦C. When time permits, it

that are obtainable from exact control of the culture-

is possible to use a low temperature (32–37◦C) with

strain ratio are more difficult to accomplish at this

bulk starter for the production of vat incubated Swiss-

level. This is one reason that most yogurt manufac-

style or blended-type yogurt. The lower tempera-

turers use direct set starter cultures.

ture range produces a steady acid development and

a slightly fuller body with fewer tendencies toward

Frozen Concentrated Cultures.

Using direct set

wheying off, grainy texture, and over-

acidification.

frozen concentrated cultures provides more consis-

For the production of cup-set Sundae-style yogurt

tent yogurt production because the culture manufac-

with bulk starter, it is preferable to use a temperature

turer controls the strain ratio. However, there are still

range of 41–43◦C to provide efficient use of incu-

some limitations to frozen mixed strain cultures due

bation room. At temperatures higher than 45◦C, the

to their inability to utilize single-strain culture pro-

finished product can experience more wheying-off

duction. They have limited ability to "customize" cul-

problems, harsher flavors, and a grainy texture due to

tures and control of downward shift in *post fermenta-*

rapid acid development. This is because rapid acidi-

tion pH; also they are unable to alter ratios of ST: LB,

fication leads to a very dense aggregation of the pro-

all of which have desirable effects on the final yogurt.

tein particles with a corresponding decrease of bound

Furthermore, they are sensitive to temperature abuse *water. Also, higher temperature (> 45◦C) favors the*

during shipping and storage.

differential growth of LB resulting in undesirable cul-

ture ratio and flavor. When using direct set cultures,

Freeze-dried or Pelletized cultures.

This newer

most manufacturers recommend a temperature range

technology has greatly enhanced the

functional ben-

of 41–42◦C to achieve the benefits of the specific

efits of these direct set products. The use of direct

culture ratio maintained by the supplier.

set freeze-dried cultures provides the best opportu-

nity to control strain ratios to optimize yogurt quality.

Composition of the mix.

The total solids in the

This process combines defined single-strain culture

mix including sucrose content should be taken into

with the blending of specific freeze dried or pelletized

account for selection of the culture.

strains in precise ratios. The advantages consist of:

r Ability to obtain abnormal ratios of ST: LB (50:1

Amount of bulk starter.

The rate of inoculum

to 100:1) to produce mild yogurt.

changes the ratio of ST: LB in the finished yogurt,

r Exact control of viscosity and mouth feel.

as shown below (Table 12.4).

r Exact control of tartness and flavor intensity.

Addition of too high level of culture may cause a *r Control of post-processing acidification.*

defect in the structure and in the aroma of the finished

r Possibility of developing new value added

yogurt. The optimum amount of bulk starter should

yogurts containing bifidobacteria and

be about 1.0–2.0% and may be increased to 4–5% if

Lactobacillus acidophilus.

sugar content of the mix is high (10–11%).

r Better protection of multiple strains from

Both incubation temperature and inoculation rate

bacteriophage attack.

influence the structure and properties of yogurt gel.

r Provide customized strain blends for specific

In general, the conditions favoring faster acid pro-

functionalities.

duction (higher temperature and higher inoculation

rate) tend to produce weak gel and more whey sepa-

Incubation Time.

In general, the longer the in-

ration. It appears that weak yogurt gel and syneresis

cubation time, the higher the numbers of LB and

more chances of postprocessing

acidification. Ac-

Table 12.4. *Effect of Inoculum Size of Bulk*

cordingly, caution must be exercised so that the LB

Starter on the Ratio of ST and LB.

does not produce too much lactic acid to make yogurt

%Inoculum

Ratio of ST/LB a

bitter and too sour.

0.5

3:1

Incubation Temperature.

The optimum growth

1.0

2:1

temperature for LB is 40–50◦C and for ST, it is 35–

2.0

3:2

40◦C. The incubation temperature for yogurt culture

5.0

2:3

ranges from 31◦C to 45◦C. However, most yogurt

a incubation to 0.85% titratable acidity

206

Part II: Manufacture of Yogurt

are related to rearrangement of casein particles in the *doses have been implicated in toxicity problems in*

gel network and the rate of solubilization of colloidal

small infants.

calcium during fermentation (Lee and Lucey, 2004).

Lactic acid production results in coagulation of

milk beginning at pH 5.2–5.3, at the point where the

casein is first destabilized, and continues until com-

Changes in Milk Constituents

pletion at pH 4.6. During lactic acid production, there

During Yogurt Production

is a gradual removal of phosphorus and calcium that

is bound to the stable casein particle as tricalcium

Biochemical and Microbiological Changes

phosphate. Texture, body, and acid flavor of yogurt

During Fermentation

owe their origin to lactic acid produced during fer-

Conversion of milk base to yogurt is accompanied

mentation.

by intense metabolic activity of the fermenting or-

Small quantities of organoleptic moieties are gen-

ganisms ST and LB. Yogurt is a unique product in *erated through carbohydrate catabolism, via volatile*

that it supplies the consumer vital nutrients of milk,

fatty acids, ethanol, acetoin, acetic acid, butanone, di-

as well as metabolic products of fermentation along

acetyl, and acetaldehyde. (See Chapter 6). Homolac-

with abundant quantities of live and active yogurt

tic fermentation in yogurt yields lactic *acid as 95% of*

cultures. As a result of culture growth, transforma-

the fermentation output. Lactic acid acts as a preser-

tion of chemical, physical, microbiological, sensory,

vative.

nutritional, and physiological attributes in basic milk

medium is noted. Changes during fermentation are

Proteins.

Aggregation of whey proteins in yogurt

profound and many are relevant to the health at-

has been observed (Argyle et al., 1976a,b), which

tributes of yogurt.

contributes to the consistency of yogurt during stor-

age. Hydrolysis of milk proteins is easily measured

Carbohydrate.

Lactose content of yogurt mix is

by liberation of −NH2 groups during fermentation.

generally around 6%. During fermentation lactose is

LB displays appreciable proteolytic activity in milk

the primary carbon source resulting in approximately

(Argyle et al., 1976a,b; Chandan et al., 1982). In

30% reduction. However, a significant level of lac-

his review, Loones (1989) reported that free amino

tose (4.2%) remains unutilized. One mole of lactose

groups double in yogurt after 24 hours. The proteoly-

gives rise to 1 mole of galactose, two moles of lactic

sis continues during the shelf life of yogurt, doubling

acid, and energy for bacterial growth. Some strains of

free amino group again in 21 days

storage at 7◦C. The

ST exhibit both β-galactosidase and phospho β-D-

major amino acids liberated are proline and glycine.

galactosidase activity. Therefore, these strains also

The essential amino acids liberated increase 3.8–3.9

use a phospho-enolypyruvate-phospho transferase

fold during the storage of yogurt, indicating that vari-

system. Lactose is converted to lactose phosphate,

ous proteolytic enzymes and peptidases remain active

which is hydrolyzed by phospho NL *-D-galactosidase*

throughout the shelf life of yogurt. The proteolytic

to galactose-6-phosphate and glucose and that on gly-

activity of the two yogurt bacteria is moderate but is

colysis gives lactic acid (Chapter 6).

Although lac-

quite significant in relation to the symbiotic growth

tose content is in excess in the fermentation medium,

of the culture and production of flavor compounds.

lactic acid build-up beyond 1.5% acts progressively

as an inhibitor for further growth of yogurt bacte-

Lipids.

A weak lipase activity results in the lib-

ria. Normally, the fermentation period is terminated

eration of minor amounts of free fatty acids, par-

by temperature drop to 4◦C. At this temperature, the

ticularly stearic and oleic acids. Individual esterases

culture is alive but its activity is drastically limited to

and lipases of yogurt bacteria appear to be more ac-

allow fairly controlled flavor in marketing channels.

tive toward short-chain fatty acid glycerides than to-

Lactic acid produced by ST is L (+) isomer, which

ward long-chain substrates (DeMoraes and Chandan,

physiologically is more digestible than the D (−) iso-

1982). Since nonfat and low fat yogurts comprise

mer produced by LB. It seems that the

kidneys of

the majority of yogurt marketed in the United States,

small infants are not capable of handling D (−) lac-

lipid hydrolysis contributes little to the product at-

tic acid. Yogurt contains both isomers. The L (+)

tributes.

isomer is normally 50–70% of the total lactic acid.

Normal consumption level of yogurt does not pose

Formation of Yogurt Flavor Compounds.

Lac-

hazard from D (−) lactic acid, but relatively large

tic acid, acetaldehyde, acetone, diacetyl, and other

carbonyl compounds produced by

fermentation con-

commercially available. They are especially appro-

stitute key flavor compounds of yogurt. Acetalde-

priate for stirred yogurt production.

hyde content varies from 4 to 60 ppm in yogurt. Di-

It

is

conceivable

that

some

of

the

exo-

acetyl varies from 0.1 to 0.3 ppm and acetic acid

polysaccharides exert physiological role in human

varies from 50 to 200 ppm. These key compounds *nutrition because of their chemical structure resem-*

are produced by yogurt bacteria. Certain amino acids

bling dietary fiber.

(threonine, methionine) are known precursors of ac-

etaldehyde. For example, threonine in the presence

Other Metabolites.

Bacteriocins and several other

of threonine aldolase yields glycine

and acetalde-

antimicrobial compounds are generated by yogurt or-

hyde. Acetaldehyde can arise from glucose, via acetyl

ganisms. A bacteriocin called bulgarican is elabo-

CoA or from nucleic acids, via thymidine of DNA.

rated by LB that has been shown to possess antago-

Diacetyl and acetoin are metabolic products of car-

nistic property toward the growth of several spoilage

bohydrate metabolism in ST. Acetone and butane-

bacteria (Reddy et al., 1984). Similarly, Lb. aci-

2-one may develop in milk during prefermentation

dophilus produces acidophilin, which is shown to

processing.

exhibit a wide spectrum activity against both Gram-

Several compounds contribute to yogurt aroma

positive and Gram-negative bacteria (Shahani et al.,

(Marsili,

2003).

They

include

acetaldehyde,

1972). Benzoic acid (15–30 ppm) in yogurt has been *dimethyl sulfide, 2,3-butanedione, 2,3-pentanedione,*

detected, which is associated with metabolic activity

2-methylthiophene, 3-methyl-2-butenal, 1-octen-3-

of the culture (Chandan et al., 1977). These metabo-

one, dimethyl trisulfide, 1-nonen-3-one, acetic acid,

lites tend to exert preservative effect by controlling

methional, (cis,cis)-nonenal, 2-methyl *tetrahydro-*

the growth of contaminating spoilage and pathogenic

thiophen-3-one, 2-phenyacetaldehyde, 3-methyl-

organisms gaining postfermentation entry. As a re-

butyric acid, caproic acid, guaiacol, benzothiozole

sult, the product attains extension of shelf life and

and more.

reasonable degree of safety from food borne illness.

Synthesis of Oligosaccharides and Polysaccha-

Cell Mass.

As a consequence of fermentation, yo-

rids.

Both ST and LB are documented in the lit-

gurt organisms multiply to a count of 108 to 1010

erature to elaborate different

oligosaccharides in the

CFU g−1. Yogurt bacteria occupy some 1% of vol-

yogurt-mix medium. As much as 0.2% (by weight) of

ume or mass of yogurt. These cells contain cell walls,

mucopolysaccharides has been observed in 10 days

enzymes, nucleic acids, cellular proteins, lipids, and

of storage period. In stirred yogurt, drinking yo-

carbohydrates. Lactase or N L -

galactosidase has been

gurt, and reduced-fat yogurt, potential contribution

shown to contribute a major health-related property to

of exo-polysaccharides to impart smooth texture,

yogurt. Clinical studies have concluded that live and

higher viscosity, lower synerisis, and better mechan-

active culture containing yogurt can be consumed by *ical handling is possible. Excessive shear during*

several millions of lactose-deficient individuals with-

pumping destroys much of the textural advantage be-

out developing gastrointestinal distress or diarrhea.

cause the viscosity-imparting function of the muco-

polysaccharides is not shear resistant. Most of the

Minerals.

Yogurt is an excellent dietary source of

polysaccharides elaborated in yogurt contain glu-

calcium, phosphorus, magnesium, and zinc in human

cose, galactose along with minor quantities of fruc-

nutrition. Research has shown that bioavailability of

tose, mannose, rhamnose, xylose, arabinose, or N-

the minerals from yogurt is essentially equal to that *acetylgalactosamine, individually or in combination.*

from milk. Since yogurt is a low-pH product com-

Molecular weight is of the order of 0.5–1 million

pared to milk, most of calcium and magnesium oc-

Daltons. Intrinsic viscosity range of 1.5–4.7 dl g^{-1}

curs in ionic form.

has been reported for exo-polysaccharides of ST and

The complete conversion from colloidal form in

LB (Zourari et al., 1992). The polysaccharides form a

milk to ionic form in yogurt may have some bearing

network of filaments visible under the scanning elec-

on the physiological efficiency of utilization of the

tron microscope. The bacterial cells are covered by

minerals.

part of the polysaccharide and the filaments bind the

cells and milk proteins. Upon shear treatment, the fil-

Vitamins.

Yogurt bacteria during and after fer-

aments rupture off from the cells, but maintain links

mentation affect the B-vitamin content of yogurt.

with casein micelles. Ropy strains of ST and LB are

The processing parameters and subsequent storage

conditions influence the vitamin content at the time

REFERENCES

of consumption of the products. Incubation temper-

ature and fermentation time exert significant balance

Argyle P, Jones N, Chandan RC,

Gordon JF. 1976a.

Aggregation of whey proteins during storage of

between vitamin synthesis and utilization by the cul-

acidified milks. J. Dairy Research, 43:45–51.

ture. In general, there is a decrease of vitamin B12,

Argyle P, Mathison GE, Chandan RC. 1976b.

biotin, and pantothenic acid and an increase of folic

Production of cell-bound proteinase by

acid during yogurt production. Nevertheless, yogurt

Lactobacillus bulgaricus and its location in the

is still an excellent source of vitamins inherent to

bacterial cell. J. App. Bact. 41:175–184.

milk.

Chandan RC (Ed). 1989. Yogurt: Nutritional and

Health Properties. National Yogurt Association,

Postfermentation Changes

McLean, VA.

Chandan RC. 1997. Dairy-Based Ingredients. Eagan

These changes refer to the shelf life period of yogurt

Press, St. Paul, Minnesota, MN.

following manufacture.

Chandan RC. 1999. Enhancing market value of milk

by adding cultures. J. Dairy Sci. 82:2245–2256.

Refrigerated Yogurt and Drinkables.

The chain

Chandan RC. 2002. Symposium: Benefits of live

comprised of distribution, marketing, and retail lead-

fermented milks: Present diversity of products. In:

ing to eventual consumption of product by the

Proceedings of International Dairy Congress, Paris,

consumer may require 4–7 weeks of shelf life. Nu-

France [Available in CD Rom].

tritional quality is reasonably preserved by tempera-

Chandan RC. 2004. Dairy: Yogurt. In: JS Smith, YH

tures of 4–6°C in this chain. Maintenance of product

Hui (Eds), Food Processing: Principles and

integrity by appropriate packaging is achieved. How-

Applications. Blackwell Publishing, Ames, IA.

ever, a slight increase in acidity (of the order of 0.2%)

pp. 297–328.

is noticeable during this period. Viability of the yo-

Chandan RC, Argyle PJ, Mathison GE. 1982. Action

gurt culture is also slightly reduced by one log cycle.

of Lactobacillus bulgaricus protease preparations on

These changes are relatively minor compared to the

milk proteins. J.Dairy Sci. 65:1408–1413.

changes observed during fermentation.

Chandan RC, Gordon JF, Morrison A. 1977. Natural

benzoate content of dairy products.

Soft Serve Mix and Soft Serve Yogurt.

Soft serve

Milchwissenschaft 32(9):534–527.

mix may be marketed refrigerated or frozen until dis-

Chandan RC, Shahani KM. 1993. Yogurt. In: YH Hui

pensed as soft serve frozen yogurt by the operator.

(Ed), Dairy Science and Technology Handbook, Vol.

If marketed refrigerated, changes similar to those in

2. VCH Publishers, New York, pp. 1–56.

refrigerated yogurt are projected in the mix until ex-

Chandan RC, Shahani KM. 1995. Other fermented

trusion through the soft serve freezer. If marketed

dairy products. In: G Reed, TW Nagodawithana

(Ed), Biotechnology, 2nd ed., Vol. 9, VCH

frozen, the mix has to be thawed prior to extrusion.

Publishers, Weinheim, Germany, pp.

386–418.

A loss of 1–2 log cycles in viable cell counts of yo-

DeMoraes J, Chandan RC. 1982. Factors influencing

gurt culture may be noticed by the freeze-thaw cycle.

the production and activity of Sterptococcus

Furthermore, destruction of cell viability is possible

thermophilus lipase. J. Food Sci. 47:1579–1583.

during the freezing process through the soft serve

Fernandes CF, Chandan RC, Shahani KM. 1992.

freezer. Other than viable cell counts, no significant

Fermented dairy products and health. In: BJB Wood

changes are known.

(Ed), The Lactic Acid Bacteria, Vol. 1. Elsevier,

New York, pp. 279–339.

Hard Pack Frozen Yogurt.

Shelf-life require-

International Dairy Federation. 2003. Yogurt:

ments of 6–12 months are normal for this type of

Enumeration of Characteristic Organisms-Colony

yogurt. A loss of 1–2 log cycles in viable counts of

Count Technique at 37 C. IDF Standard No. 117A, *yogurt bacteria may be attributed to the freezing pro-*

Brussels, Belgium.

cess of the mix. During the shelf-life storage con-

Lee WJ, Lucey JA. 2004. Structure and physical

ditions, especially fluctuation in temperatures could

properties of yogurt gels: Effect of inoculation rate

have a deleterious effect on the viability and activity *and incubation temperature. J. Dairy Sci.*

of yogurt cultures. The formation of crystals during

87:3153–3164.

frozen state conceivably may rupture bacterial cells,

Loones A. 1989. Transformation of milk components

reducing live cell counts progressively.

during yogurt fermentation. In: RC Chandan (Ed),

Yogurt: Nutritional and Health Properties. National

Properties. National Yogurt Association, McLean,

Yogurt Association, McLean, VA, pp.95–114.

VA, pp. 115–144.

Marsili R. 2003. Flavors and off-flavors in dairy

Shah N. 2003. Yogurt: The product and

manufacture.

products. In: H Roginski, JW Fuquay, PF Fox (Eds),

In: B Caballero, L Truco, PM Finglas (Eds),

Encyclopedia of Dairy Sciences,. Vol. 2. Academic

Encyclopedia of Food Sciences and Nutrition,

Press, New York, pp. 1069–1081.

Vol. 10, 2nd ed. Academic Press, New York,

Nauth KR. 2004. Yogurt. In: YH Hui, L

pp. 6252–6259.

Meunier-Goddik, AS Hansen, J Josephsen, W-K

Shahani KM, Vakil JR, Chandan RC. September 5,

Nip, PS Stanfield, F Toldra (Eds), Handbook of

1972. Antibiotic acidophilin and process for

Food and Beverage Fermentation Technology.

preparing the same. United States Patent 3,689,

Marcell Decker, New York, pp. 125–145.

640.

Reddy G, Shahani KM, Friend BA, Chandan RC.

Surono I, Hosono A. 2003. Starter cultures.

1984. Natural antibiotic activity of Lactobacillus

In: H Roginski, JW Fuquay, PF Fox (Eds), *acidophilus and bulgaricus III. Production and*

Encyclopedia of Dairy Sciences, Vol. 2. Academic

Partial Purification of Bulgarican from Lactobacillus

Press, New York, pp. 101023–101028.

bulgaricus. Cultured Dairy Prod. J. 19(5):7–11.

Takano T, Yamamoto N. 2003. Health aspects of

Robinson RK. 2003a. Yogurt types and manufacture.

fermented milks. In: H Roginski, JW Fuquay,

In: H Roginski, JW Fuquay, PF Fox (Eds),

PF Fox (Eds), Encyclopedia of Dairy Sciences,

Encyclopedia of Dairy Sciences, Vol. 2. Academic

Vol. 2. Academic Press, New York, pp. 1063–

Press, New York, pp. 1055–1058.

1069.

Robinson RK. 2003b. Yogurt, role of yogurt cultures.

Vedamuthu ER. 1991. The yogurt story —past, present

In: H Roginski, JW Fuquay, PF Fox (Eds),

and future. Dairy, Food Environ. Sanit. 11:202–203,

Encyclopedia of Dairy Sciences, Vol. 2. Academic

265–276, 371–374, 513–514.

Press, New York, pp. 1059–101063.

Zourari A, Accolas J-P, Desmazeaud MJ. 1992.

Sellars RL. 1989. Health properties of yogurt. In: RC

Metabolism and biochemical characteristics of

Chandan (Ed), Yogurt: Nutritional and Health

yogurt bacteria: A review. Le Lait. 72(1):1–34.

13

Manufacture of Various Types of Yogurt

Ramesh C. Chandan and Kevin R. O'Rell

Introduction

"natural" foods gave rise to entirely specialized

General Procedures Applicable to All Categories

groups of products. These products will be discussed

Packaging Equipment and Materials

in this chapter.

Production of Yogurt Starters

The topics included in this chapter will be dis-

Yogurt Styles and Definitions

cussed under the following headings: (a) General

Market Statistics on Yogurt Trade

manufacturing procedures applicable to all cate-

Manufacturing Processes for Major Types of Yogurt

gories, (b) yogurt types, styles, subcategories, and

General Manufacturing Procedures

definitions, (c) market statistics on yogurt trade,

Plain Yogurt

Fruit-Flavored Yogurt

and (d) manufacturing process for

major yogurt

Vanilla-Flavored Yogurt

categories.

Natural Yogurt

Organic Yogurt

GENERAL PROCEDURES

Yogurt Drink/Smoothies

APPLICABLE TO ALL

Yogurt Whips/Mousse

CATEGORIES

Concentrated/Greek-Style/Strained Yogurt

Frozen Yogurt

As discussed in Chapter 3, in the United States, a yo-

Postculturing Heat Treatment

gurt plant must be a Grade A milk processing facility.

Acknowledgment

All the equipment must conform to Grade A regula-

References

tions for processing (FDA, 1999). The equipment for

Bibliography

transportation, handling, and storage must be made

of nontoxic, smooth, nonabsorbent, and corrosion-

INTRODUCTION

resistant materials. The construction of the process-

The yogurt market is highly sophisticated, complex, *ing equipment such as tanks, pumps, valves, heat ex-*

and diverse. The evolution of the yogurt market

changers, piping, and others must be designed for

has been dictated by market forces and consumer

cleaning in place (CIP) and sterilization. Grade A

demands. Different types or styles or categories

milk and cream must be stored at 4◦C

in vertical/silo

(and subgroups) of yogurt have entered the market-

tanks for a period not to exceed 72 hours. The stor-

place in response to consumer preference, changing

age vessels must be equipped with agitators for slow

lifestyles, and dietary adjustments. The first major

agitation to prevent the separation of cream. One *change in the yogurt market was the entry of "flavored*

more legal requirement is the provision for accurate

yogurts." Under this category different styles were

temperature-indicating thermometers and an appro-

introduced. This was followed by subcategories that

priate recording system with charts.

offered dietary choices, for example, full-fat, low-

fat, and fat-free types. Changing lifestyles gave rise

to liquid yogurts and "snacking types" and "on-the-

Most plants attempt to synchronize the packaging

go tubular types." The emphasis on "healthy" and

lines with the termination of the incubation period.

Generally, textural defects in yogurt products are

the squeezable tubes add convenience, portability,

caused by excessive shear during pumping or agi-

and play value to children. In addition, yogurt in tubes

tation. Therefore, positive drive pumps are preferred *is freeze–thaw stable, which adds another dimension*

over centrifugal pumps for moving the product after

of convenience and versatility of its use.

culturing or ripening. For adding fruit to the product,

it is advantageous to use a fruit feeder system. Vari-

Production of Yogurt Starters

ous packaging machines of suitable speeds (up to 400 *cups/minute) are available to package various kinds*

The first step in the manufacture of yogurt is the

and sizes of yogurt products. More details of pack-

preparation of starter. The same procedures for starter

aging materials and containers for yogurt are given

preparation are used regardless of the type or style of

in Chapter 8.

yogurt being produced in the plant.

Yogurt is generally packaged in plastic containers

The starter is a crucial component in the produc-

varying in size from 4 to 32 oz. Yogurt packaged in

tion of high quality yogurt delivering consistent qual-

tubes weighs even less per tube (2 to 3 oz). The ma-

ity attributes desired by consumers. The movement *chines involve volumetric piston filling. The product*

of personnel assigned to starter room and traffic be-

is sold by weight and the machines delivering vol-

tween the starter room and the rest of production area

umetric measure are standardized accordingly. The

should be strictly restricted. An effective sanitation

pumping step of fermented and flavored *yogurt base*

program including filtered air and positive pressure in

exerts some shear on the body of yogurt. In some

the culture and fermentation area should significantly

cases, specific shape of the cup characterizes certain

control airborne contamination. The result would be

product branding. Some plants use preformed cups.

controlled fermentation time and consistently high-

The cup may be formed by injection molding—a

quality product (Chandan, 2004; Chandan and Sha-

process in which beads of plastic are injected into

hani, 1993).

a mold at high temperature and pressure. In this type

As discussed in Chapters 6 and 11, yogurt cultures *of packaging, a die-cut foil lid is heat sealed on to*

are available from various culture suppliers as frozen

the cups. Foil lids are cut into circles and procured

concentrates or freeze-dried concentrates for direct

by the plants from a supplier along with preformed

inoculation into fermentation tanks. These offer con-

cups. A plastic over-cap may be used.

In some cases,

venience of use and reliability of performance and

partially formed cups are procured and assembled at

functionality of the culture. However, for economic

the plant. Some other plants use roll stock, which is

reasons, large manufacturers of yogurt may prefer to

used in form–fill–seal system of packaging. In this *make their own bulk starters.*

case, cups are fabricated in the plant by a process

The characterizing culture for yogurt manufac-

called thermoforming. This involves ramming a plug

ture consists of Lactobacillus delbrueckii subsp. bul-

into a sheet of heated plastic. Multipacks of yogurt

garicus (LB) and Streptococcus thermophilus (ST).

are produced by this process. Following the forma-

Frozen/freeze-dried culture concentrates available

tion of cups, these are filled with appropriate volume

from commercial culture suppliers can be used for

of yogurt and are heat-sealed with foil lid. These are

direct inoculation into yogurt mix or making bulk

then placed in cases and transferred to *a refrigerated*

starters. Reasons for their use include convenience,

room for cooling and distribution. For breakfast yo-

ease of handling, dependable quality, and reliable ac-

gurt, a mixture of granola, nuts, chocolate bits, dry

tivity. The frozen concentrates are shipped frozen in

fruits, and cereal is packaged in a small cup and sealed *dry ice and stored at the plant in special freezers at*

with a foil. Subsequently, the cereal cup in inverted

$-40^{\circ}C$ or below for a limited period of time specified

and sealed on the top of yogurt cup. This package is

by the culture supplier. Presently, the freeze-dried

designed to keep the ingredients isolated from yogurt

concentrates are preferred by many

yogurt manufac-

until the time of consumption. This system helps to

turers because these can be stored in a refrigerator

maintain crispness in cereals and nuts, which oth-

(freezer) and do not require dry ice for shipping.

erwise would become soggy or interact adversely

The starter area is segregated in most yogurt plants *if mixed with yogurt at the plant level, i.e., during*

for maintaining a sanitary environment. It should

packaging.

have positive pressure and HEPA-filtered (capturing

Some interesting innovations in yogurt packaging

particles larger than 0.3 μm) air supply to prevent

include spoon-in-the-cup lid and squeezable tubes.

possible contamination from airborne bacteria and

The former adds convenience in eating yogurt, while

bacteriophages.

Dry milk

Funnel

Water

Figure 13.1. *Equipment set up for*

reconstitution of nonfat dry milk (NFDM)

using a "powder cone"/funnel/hopper.

The vat on the right contains measured

VAT

volume of water. The weighed NFDM is

deposited in the cone and the valve on

the vat is opened. The pump on the left

Valve

circulates the reconstituted milk until all

Pump

the dry milk is dispersed.

For making bulk starter, Grade A skim milk is used.

facilitates the denaturation of the milk proteins and

In most yogurt plants, it is Grade A, antibiotic-free,

expulsion of dissolved oxygen. The medium is then *low-heat nonfat dry milk (NFDM). The dry milk is*

cooled in the tank to the inoculation temperature,

reconstituted in water and contains 9–12% solids.

42–43◦C. During cooling, the air drawn into the vat

Mainly, two types of equipment are used for recon-

should be free of airborne contaminants (phages, bac-

stitution. One is cone/funnel/hopper

type of set up

teria, and yeast and mold spores). Accordingly, use

(see Fig. 13.1). The other type of equipment is a high

of proper filters (e.g. HEPA) on the tanks to filter-

shear blender in which all the ingredients are weighed

sterilize incoming air is desirable.

in and blended together (Fig. 13.2).

The next step is inoculation of frozen

or

The practice of using fresh skim milk or pretested

lyophilized (freeze-dried) culture concentrate (Fig.

reconstituted NFDM reduces the risk of off-flavors

13.4). Instruction for handling the culture concentrate

being transferred to the finished yogurt from untested

as prescribed by the supplier should be followed care-

or held-over milk used for making starter. Pretesting

fully. When using the frozen culture concentrate, the

for the absence of inhibitory principles (antibiotics,

can is thawed by placing it in cold or lukewarm water

sanitizers) is also advisable to insure desirable growth

containing a low level of sanitizer, preferably chlorine

of the starter in the medium. Another

quality attribute

(quaternary ammonium compounds have a residual

preferred with the NFDM for starter preparation is

effect), until the contents are partially thawed. The

low-heat powder with not less than 6.0 mg of whey

culture cans are emptied into the starter vat as asepti-

protein nitrogen/g of powder (Chapters 10 and 11).

cally as possible and bulk starter medium is agitated

The starter medium is never fortified with growth

sufficiently to facilitate mixing and achieving uni-

activators like yeast extract, beef extract, or protein

form dispersion of the culture. For freeze-dried cul-

hydrolysates because they tend to impart undesirable

ture, the contents of the container are *emptied into*

flavor to the starter, which would be carried over to

the medium taking due precautions not to introduce

yogurt. Additionally, kosher requirements would pre-

contamination from improper handling, followed by

clude the use of such ingredients. Bulk starter is usu-

sufficient agitation time, usually 20–30 minutes, as-

ally made in specially designed aseptic tanks.

suring proper dispersion of the culture.

Figure 13.3 outlines the process for making bulk

Incubation period for yogurt bulk starter ranges

starters. Following addition of fresh skim milk or

from 4 to 6 hours and the proper temperature of 42–

reconstitution of NFDM in water in the tank, the

43◦C is maintained by holding hot water in the jacket

medium is heated to 90–95◦C and held for 30–

of the tank. The fermentation must be quiescent

60 minutes. Such a heat treatment improves the

(i.e., lack of agitation and vibrations) to avoid phase

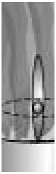
growth properties of the medium by destroying

separation in the starter following

incubation. The

original microorganisms and bacteriophages, and

progress of fermentation is monitored by titratable



smear (stained with methylene blue dye) is helpful in

determining the physiological condition of the starter

bacteria by observing the cell morphology as well as

the ST/LB ratio. In the earlier literature, a ratio of 1:1

was considered desirable, but more recent trend is in

favor of ST predomination (66–80%). An organolep-

tic examination is also helpful to detect *any unwanted*

flavors in the starter.

YOGURT STYLES AND

DEFINITIONS

To assist in the understanding of various types of yo-

gurt available in the market, Fig. 13.5 shows classifi-

cation of the yogurt category. We will discuss their

manufacture later. All types of yogurts may be label-

ed nonfat, low fat, or full fat, depending on the milk fat

content of yogurt mix. Further, they may be prepared

for consumption by toddlers, children, or adults.

Table 13.1 lists various types of yogurt found in

the market in North America and Europe.

MARKET STATISTICS ON

YOGURT TRADE

In the United States, the sale of refrigerated yo-

gurt category in 2004 is $2.7 billion and is grow-

ing. Its sales are up by 6% compared to that in 2003.

Blended/Swiss style and single-serve product forms

are the primary product types. The blended style

constitutes 74% of the category, while fruit-on-the-

bottom (FOB) style has shrunk to 8%.

Drinkable yo-

gurts form 12% of the market, whereas plain and

yogurt with toppings constitute 5% and 1%, respec-

tively. Compared to the previous year, the blended

yogurt, plain, and drinkables grew by 1%, 5.7%, and

***Figure 13.2.** High shear mixer for blending dry milk*

97.1%, respectively. The category decline was 13.6%

and water. Courtesy: Tetra Pak.

in FOB and 3.9% in yogurt with toppings, respec-

tively. The yogurt market is dominated by flavored

varieties and plain yogurt is only a fraction of the

yogurt sold. Among the flavored varieties, 10 flavors

acidity/pH measurements at regular intervals. When

account for 70% of the category volume.

the titratable acidity is 0.85–0.90% (or the pH is

Organic/natural yogurt experienced dramatic

4.4–4.5), the fermentation is terminated by turning

growth accounting for 22% sales increase in yogurt

the agitators on and replacing warm water in the

sold in regular grocery stores and 17% increase in

jacket with chilled water. If the culture *is going to*

natural yogurt sold in natural food grocery stores. In

be used within next 4–6 hours, circulating chilled

the refrigerated yogurt category based on packaging,

water is used to drop the temperature of the starter

the single serve package accounts for 62% with 2.8%

to 10–12°C. If the starter will not be used within *growth over previous year. Multipacks are gaining in*

next 6 hours, it is advisable to drop the temperature

popularity and have 20% share of the market with a

to 4–5◦C. The starter is now ready to use. Occa-

growth of 21.3% over the previous year. Large multi-

sionally, a microscopic examination of the culture

serve packs have 10% of the market

and have grown

Frozen/lyophlized

Yogurt culture

(add post pasteurization)

Grade A low-heat

NFDM

Batch tank

Reconstitute and standardize to 10–12%

solids non-fat. Batch pasteurize at 90˚C

for 30-60 Minutes, Cool to 43˚C and

add yogurt culture. Incubate to pH 4.4–

4.5. Agitate and cool to 4–5˚C

Pumped to pasteurized uncultured

standardized yogurt base tanks

***Figure 13.3.** Preparation of bulk starter in yogurt plant.*

7% over the previous year. Multipack tube market is

8% and its share has declined 1.8% as compared to

previous year.

The total U.S. market for yogurt may be divided

into three categories based on the fat content: non-

fat, low fat, and full fat. All types of yogurt (Table

13.1) are divided into one of these categories based *on milk fat content and the code of federal regulations*

standard of identity Title 21, Parts 131.200–131.206

(FDA, 2003). In the year 2004, the estimated sales of

all types of full fat yogurt were $262.1 million (in-

crease of 1.7% as compared to 2003), the low fat yo-

gurt sales were $1,506.2 million (increase of 3.9%),

and the fat-free/nonfat sales were

$901.3 million (in-

crease of 10.9%) (see Table 13.2).

Nonfat yogurt is available as plain, sugar sweet-

ened with vanilla or with fruit preparations or with

fruit flavor only. A significant share of nonfat yogurt

is light yogurt, which is sweetened with aspartame

and/or other high-intensity sweeteners.

The market share of full fat, low fat, *and nonfat*

in all styles of yogurt is illustrated in Fig. 13.6. Full

fat yogurt has declined from 30% in 1985 to 10% in

2004, whereas in the same period, low fat yogurt de-

clined from 66% to 56% and nonfat yogurt increased

from 4% to 34%.

Figure 13.7 shows recent trend in full fat, low fat, *and nonfat yogurt with respect to plain, blended, and*

FOB styles. At present, the blended/Swiss-style yo-

***Figure 13.4.** Inoculation of freeze-dried*

gurt in the market consists of 11% full fat, 56% low

culture concentrate during starter preparation.

fat, and 33% fat-free. The corresponding data for

Courtesy: Tetra Pak.

FOB yogurt type is 2% full fat, 86% low fat, and

Yogurt

Fruit

flavored

Blended/

Fruit on-

Stirred

the-bottom

Traditional

Western

Swiss

French

cup

style

Custard

Vanilla

Natural

Organic

Drinks/

Smoothies

Whips/

Mousse

Concentrated

***Figure 13.5.** Classification of*

Frozen

various types of yogurt.

12% fat-free; while for plain yogurt it *is 19% full fat,*

market are whipped yogurts, which are full fat yo-

31% low fat, and 50% is fat-free.

gurts with a mild and sweet flavor and a foamy/fluffy

Lately, an extra-creamy yogurt has been intro-

texture. Several yogurts are designed for children.

duced in the market. It contains fat content of the

The attributes preferred by children (darker colors,

order of 4.0–4.5%, but would still be characterized

enhanced sweetness, fruit purees without fruit in-

as full fat yogurt by US Federal standards and mar-

tegrity, thicker custard-like consistency) are built into

ket data tracking. This type of yogurt is characterized

such products. Yogurt drinks and

smoothies are gain-

by its mild and creamy taste. Also available in the

ing market growth (Fig. 13.8).

Table 13.1. *Major Styles of Commercial Yogurts and Their Definition*

Style of Yogurt

Definition

Plain

Unflavored yogurt may be cultured in individual cups or cultured in a *vat and dispensed into cups. No sugar is added to the formulation.*

Fruit flavored

This type of yogurt is cultured in a vat or bulk and then flavored with a

fruit preparation. Styles consist of blended/stirred and fruit-on-the

bottom.

Blended/stirred

In this style, fermented base containing sugar is blended with fruit

preparation to disperse the fruit

throughout the body of the yogurt.

This style is further subdivided into Swiss- and French-style

blended yogurt.

Swiss/blended

The fermented base is blended with fruit preparation to disperse the

fruit throughout and packaged. On cooling, the product thickens and

viscous custard-like texture is formed. The product contains

stabilizers to assist in texture

formation.

French/blended

Similar to Swiss style, but is characterized by a distinctly less viscous

texture. Generally contains no stabilizers other than milk solids.

Light

Nonfat yogurt in which no sugar is added to yogurt base and high

intensity sweeteners are used, resulting in significant reduction in *calories.*

Lo carb

Nonfat yogurt in which high intensity sweeteners are used in place of

sugar. Fruit preparations are replaced with fruit flavors. Lactose

content of nonfat milk is reduced by membrane processing. Milk

protein concentrate and whey protein isolate are used to reduce the

lactose content further.

Custard

Designed for children. It has a very viscous body resembling custard.

Only fruit puree/juice is used for fruit flavoring. Usually, fermented

in the cup.

Sundae/fruit-on-the-bottom

The fruit is deposited on the bottom of the cup, followed by a top layer

of unfermented or fermented yogurt. Before consumption it requires

blending to mix the fruit preparation.

Cup-incubated traditional sundae

The fruit is layered in the bottom of the cup and unfermented

(inoculated) yogurt mix is deposited on the top. The cups are

incubated individually to desired pH and cooled quickly to control

further acid production.

Vat-incubated sundae

The fruit is layered in the bottom of the cup and white fermented

yogurt base is deposited on the top. On cooling, the texture of the *top layer is developed.*

Western sundae

The fruit is layered on the bottom of the cup, and yogurt base

fermented in vat is deposited on the top. It is characterized by

special formulation of yogurt base in that corresponding color and

flavor of the fruit-on-the-bottom is included in the top layer.

Vanilla flavored

The yogurt may be cup- or vat-

incubated. Following fermentation,

yogurt base is mixed with vanilla flavor.

“Natural”

Contains natural ingredients only. Generally, it does not contain

stabilizers, artificial colors, or flavors.

Organic

Contains only ingredients certified as organic.

Yogurt drink/smoothie

Drinkable yogurt is fluid enough to drink. May be sweet and fruit

flavored. Smoothies are drinking yogurt, often fortified with

minerals and vitamins, prebiotics and probiotics. Some may be

designed as a meal replacement.

Continued

***Table 13.1.** (Continued)*

Style of Yogurt

Definition

Whips/mousse

This yogurt contains up to 50% (by volume) of inert gas/air to create a

fluffy/light texture.

Yogurt with topping

Sweetened fermented base is packaged separately in a cup and sealed.

Topping consisting of cereals, nuts, or fruits and is packaged in a

smaller cup and sealed. Then the smaller cup is inverted and placed *on the larger yogurt cup. The two cups are tied together by plastic*

wrap. The consumer mixes the toppings prior to consumption.

Concentrated/Greek/strained

It is relatively high in milk fat and milk solids-not-fat. It has a creamy

texture and mild flavor as a result of whey removal by

centrifugal/membrane separation or by straining through cloth.

Frozen

The fermented yogurt is blended with low fat/nonfat ice cream to

obtain pH of 6.0. The yogurt mix is then extruded through a soft

serve machine at 50% overrun and garnished with nuts and other

foods to get soft serve frozen yogurt. If the extruded frozen yogurt is

hardened like ice cream, it is called hard frozen yogurt.

***Table 13.2.** Estimated Sales of Full Fat, Low Fat, and Nonfat Yogurts in the Overall United States Refrigerated Yogurt Market During 2004*

Type of Yogurt

Full Fat

Low Fat

Fat-Free

Sales a

262.1

1,506.2

901.3

Change b

+1.7%

+3.9%

+10.9%

a Million dollars.

b Against year 2003.

80%

72%

70%

66%

60%

56%

51%

52%

arket *50%*

50%

Full fat yogurt

f m

44%

o *40%*

40%

Low fat yogurt

36%

are

34%

h

Nonfat yogurt

30%

30%

S

***%** 20%*

18%

13%

10%

10%

10%

10%

4%

4%

0%

1980

1985

1990

1995

2000

2005

Year

Figure 13.6. *Recent trends in the U.S. market for full fat, low fat, and nonfat yogurts.*

218

100

90

86

80

70

57

60

50

Full fat

50

Low fat

Nonfat

40

31

32

% Market share

30

19

20

11

12

10

2

0

Plain

Blended

FOB

Style of yogurt

Figure 13.7. *Current market share of major styles of full fat, low fat, and nonfat yogurts with respect to plain, blended, and fruit-on-the-bottom varieties in the United States.*

268.7

250

on $ 200

150

131.2

es, milli 100

96.5

Sal

63.3

50

17.8

0

1998

1999

2000

2001

2002

2003

2004

Year

Figure 13.8. *Recent trend in the sales of yogurt drinks.*

MANUFACTURING PROCESSES

(c) Minimize air incorporation.

FOR MAJOR TYPES OF YOGURT

(d) Perform prepasteurization tests to conform to

chemical composition standards of

butterfat

The sequence of stages for yogurt manufacture is

and solids.

summarized in the previous Chapter 12 in Table 12.1.

(e) Restandardize, if necessary.

The formulation of yogurt varies considerably, de-

2. Pasteurization and Heat Treatment: Generally,

pending on the style that is being

produced. Never-

pasteurization of milk is carried out with the pur-

theless, the first step in the manufacture of yogurt is

pose of killing all the pathogenic microorganisms,

basically the same regardless of the style made. The

and significantly reducing the majority of other

starting step is to make yogurt mix by blending var-

organisms present and inactivating the inherent

ious ingredients. In this step, the formulation for a

enzymes of milk. In the U.S. yogurt processing

particular yogurt production is calculated in terms of

industry, the FDA regulations require the plant op-

the weight/volume of each ingredient for the batch

erators to install legal pasteurization *equipment,*

size desired. At the time of manufacture, the liquid

although the heat treatment of yogurt mix uses

dairy ingredients like condensed milk, cream, whole

higher temperatures with a longer holding time

milk, low fat milk, or skim milk are pumped into a

than legal milk pasteurization. Accordingly, there *processing vat. Next, NFDM solids may be added*

are two sets of heat treatments: first one is to com-

with the aid of powder blender equipment consisting

ply with the legal requirements and the second

of a funnel and a circulating pump (Fig. 13.1) or a

one in tandem is more intense in temperature and

high shear type blender (Fig. 13.2).

holding time. The main purpose of this additional

The product is then pasteurized and then subjected

heat treatment is to denature whey proteins and to

to high heat treatment to facilitate the growth of yo-

create optimum conditions for the growth of yo-

gurt culture and to denature the milk protein aiding in

gurt culture. Proper denaturation of

whey proteins

the formation of desirable body and texture in the yo-

(80–85%) increases their water binding capacity,

gurt. The mix is homogenized, cooled to incubation

which improves the consistency and viscosity of

temperature, and inoculated with the culture. From

yogurt and helps to prevent free whey separa-

this point, the process varies with the style of yogurt

tion (syneresis). The level of desired denaturation

that is being produced. The yogurt mix is either left

depends on the type of yogurt being processed.

in the fermentation vat for incubation or pumped into

The manufacture of a "natural" yogurt, which has

individual cups and placed in the

incubation room.

no stabilizers, requires a greater denaturation of

The flavoring system used will also vary according

serum or whey proteins. Studies have shown that

to the style.

heating the mix at 85◦C for 20 minutes is opti-

The following are the critical physical, chemical, *mum for maximum water binding capacity of milk*

and biological steps in yogurt technology.

proteins. This treatment gives minimum amount

1. Blending: In the mix preparation, it is necessary to

of drainage of whey from coagulated product

homogeneously disperse and dissolve the dry in-

when compared to lower or higher

treatments of

gredients in the liquid phase obtaining a uniform

the milk. Other equivalent time–temperature heat

mixture. The following are important considera-

treatments that are equally effective are given in

tions during this step:

Table 13.3.

(a) Sufficient agitation in the mix tank.

Heat treatment exceeding the above-mentioned

(b) Incorporate dry ingredients using a pump and

guidelines adversely affects the consistency of yo-

funnel set-up or preferably a special high

gurt because of too much serum protein denaturation,

shear blending equipment.

***Table 13.3.** Denaturation of Whey Proteins as a Function of Heat*

Treatment

Temperature (◦C)

Holding Period (min)

Denaturation of Whey Proteins (%)

85

20–30

85–90

85.0-90.6

30

85–90

90.6

15

85–90

90.6–93.3

2

70–75

95.

8–10

90–95

13 Manufacture of Various Types of

Figure 13.9. *Principle of a homogenizer. Milk stream is forced from the right through a narrow orifice where fat globules are split and homogenized milk exits from the left. Courtesy: Tetra Pak.*

which results in yogurt that is weak set with signifi-

Greek-style yogurts and natural whole milk

cant syneresis.

yogurts, no homogenization is done because a

Other kinds of yogurt containing increased milk

cream layer on the top is desired.

solids content and stabilizers technically require

(b) Improvement of the consistency and viscosity

lower serum protein denaturation, since these de-

of the yogurt because of uniform distribution *pend on the higher solids and stabilizer to impart*

of finely divided fat globules within the coag-

the desired consistency and prevention of whey sep-

ulum structure.

aration. For these products, high-temperature–short-

(c) Greater stability of the coagulum against whey

time systems can be used, provided that a tempera-

separation. In addition it has been shown that

ture of 90.6–93.3◦C can be obtained and the holding

a high temperature–pressure homogenization

period is at least 30 seconds. If this holding period

breaks up the casein micelles altering the hy-

can be extended using a special tube with a hold-

drogen bonds of the casein, increasing *its hy-*

ing period of 1–5 minutes, better consistency and in-

drophilic ability and denaturing serum pro-

creased protection from whey separation are usually

teins, both of which result in a more stabilized

observed.

protein complex and increased whey retention.

This procedure can be used in the production

3. Homogenization: This process of mechanically

of all "natural" yogurts with minimum or no

breaking milk fat globules to smaller size also

stabilizer use.

helps in more uniform dispersion of stabilizers in

yogurt mix (Fig. 13.9). The homogenization of

Studies have shown that homogenization after pas-

yogurt mix with fat content greater than 1.5% has

teurization favors better consistency in the final prod-

the following advantages:

uct. The optimum range for homogenization has been

(a) No rising of cream during incubation, which is

found to be 50–60◦C, with 35◦C as the minimum ef-

the main purpose of homogenization. In some

fective temperature.

In the manufacture of "natural" yogurt with mini-

acidic range and coagulation is observed at pH 4.6–

mum stabilization (MSNF 11–13%), a high pressure

4.7. During heat processing, a major

whey protein,

of homogenization of approximately 23–28 MPa/

□-lactoglobulin, interacts with □-casein and during

6MPa (2000–2500/500 psi), double stage or 23–

coagulation this complex is coprecipitated as well.

28 MPa (2000–2500 psi), single stage is used in order

Thus, the coagulated proteins in the yogurt are a co-

to improve consistency and help prevent whey sepa-

precipitate of casein and denatured whey proteins

ration.

with entrapped fat globules.

Yogurt with higher total solids content and/or sta-

5. Cooling: The objective of cooling fermented

bilizers can use lower homogenization pressures of *mass is to restrict the growth of yogurt culture*

the order of 6–17 MPa (500–1500 psi). Improving the

and its enzyme activity as quickly as possible

consistency, viscosity, and prevention of whey sep-

and maintain the desired pH, body, and texture.

aration using homogenization is less important with

Under practical conditions, the

introduction of

this type of yogurt because of the increased solids

cooling yogurt mass after completed incubation

content and the effect of the stabilizer.

depends on

If the stabilizer that is being used contains a mod-

(a) manufacturing conditions such as tempera-

ified starch, which is not resistant to *shear, a mini-*

ture of incubation or intensity of acidifica-

mum homogenization pressure should be considered

tion.

to prevent destruction of the starch structure resulting

(b) processing facilities available for cooling,

from severe shearing from the homogenizer. In this *such as cooling tunnel or cells, tube cooler, vat*

case, a homogenization pressure of 3–4 MPa (250–

with agitator, plate cooler, or scraped surface

300 psi) single stage is recommended. Since homog-

cooler.

enization follows heat treatment, the need for utmost

(c) type of yogurt produced, i.e., cup set, fruit fla-

care in cleaning and sanitation of the homogenizer is

vored, vat set, and plain (natural).

emphasized.

(d) the desired organoleptic properties, such as fi-

4. Coagulation: The protein content of yogurt milk

nal acidity and aroma production.

consists of casein, (comprising of 80% of the to-

Generally, cooling in yogurt plants

should take

tal protein) and serum/whey proteins. Casein is

place at a pH of 4.5–4.65. Cooling with agitation

present in milk in the form of micelles composed

at pH 4.7 or above can result in a grainy body and

of a calcium–caseinate complex (Chapter 2).

undesirable texture in the finished yogurt. The rate of

These casein particles are very stable in fresh milk

cooling should be steady but not too fast. Cooling too

of normal composition partly because of their elec-

rapidly can bring unfavorable changes in the struc-

trical charge. The charged particles repel each other

ture of the coagulum contributing to whey separation

and stay in suspension. This stability is *affected by*

in the finished yogurt. It is thought that this defect

changes in milk composition relating to ionic balance

is probably due to the very rapid contractions of the

and salt concentration, by processing treatments, es-

protein filaments and their disturbed hydration. The

pecially by changes of the hydrogen ion concentra-

method of cooling depends on the style of yogurt that

tion.

is being produced. It is desirable to reach a tempera-

During yogurt fermentation, lactic acid is produced

ture of 18–20◦C within 1 hour to quickly stop further

as a result of bacterial growth. As the pH is lowered

culture growth. Cup-incubated yogurt is cooled in the *due to acid production, there is a gradual removal*

retail containers using a blast of cold circulated air in

of calcium and phosphorus (bound to casein as tri-

a cooling chamber/cell or a blast cold tunnel. High-

calcium phosphate) from the casein particles. At the

velocity air creates simulated wind-chill conditions.

pH of 5.2–5.3, the caseinate particles *are destabi-*

Vat-incubated yogurt is cooled using a special plate

lized, initiating precipitation. Complete precipitation

cooler, a multitube cooler, or in some cases in a pro-

occurs at a pH of 4.6–4.7, which represents the iso-

cessing vat with the circulation of refrigeration water

electric point of casein. At this point casein is free of *in its jacket wall and agitation of the coagulum in the*

bound calcium phosphate and the particles have no

vat. When cooling in the vat, it is better to use a narrow

charge to keep them repelled from each other leading

high tank with swept surface agitation for quick cool-

to their precipitation.

ing of the gel. Wide and high processing tanks with

As mentioned earlier, denaturation of the serum

a propeller-type agitator are unfavorable for cool-

proteins results in their decreased solubility in the

ing. Many plants pump their cooled fermented base

through a back-pressure valve, a perforated stainless *manufacture of frozen yogurt. The steps involved in*

steel disk, a stainless steel mesh screen, or a "sour

the manufacturing of set-type and stirred-type plain

cream" cone in the line to insure a smooth texture in

yogurts are shown in Fig. 13.10.

the fermented mass.

Plain yogurt normally contains no added sugar or

In the vat-incubated yogurt, the temperature of

flavors in order to offer the consumer natural yogurt

filling varies according to the type of stabilizers

flavor for consumption or as an option of flavoring

used. Generally, it is desirable to cool the yogurt to

with other food materials of the consumer's choice.

7–13◦C.

In addition, it may be used for cooking or for salad

preparation with fresh fruits or grated vegetables. In

6. Stirring: Stirring should not be too rigorous or too

most recipes, plain yogurt is a substitute for sour

long. This is especially important in the manu-

cream providing a lower fat/calories alternative. For

facture of natural yogurts; however, it *should also*

these reasons it is common to find plain yogurt pack-

be considered in stabilized yogurt since excessive

aged in larger multiserve containers.

stirring may break down some of the stabiliza-

tion and change the level of stabilizer needed to

obtain desirable body. In order to obtain a homo-

Fruit-Flavored Yogurt

geneous gel, it is preferable to use a higher rate

For the production of blended/Swiss style, the fer-

of stirring initially, reducing the rate of agitation

mented yogurt base is mixed with various fruit prepa-

as the temperature drops below 30◦C. Stirring at

rations. The fruit incorporation is conveniently done *pH above 4.70 gives a partially formed gel result-*

using a fruit feeder or metering pump at a 10–20%

ing in a grainy texture; therefore, stirring should

level followed by a static in-line mixer to assure ho-

commence at pH 4.65 or below.

mogenous blending of the fruit with the yogurt base.

7. Pumping: Pumps are needed to transport stirred

Prior to flavoring, the texture of stirred-yogurt can

yogurt from fermentation tanks through pipes and

be made smoother by pumping it through a back-

possibly a plate cooler to the filling machine. They

pressure valve or a stainless steel screen.

operate with different pressures, depending on the

The second class of fruit-flavored

yogurt is FOB.

design. However, for this application only positive

In this case the fruit is dispensed on the bottom of

drive pumps should be used. This insures a posi-

the cup and the top layer is that of fermented yogurt

tive displacement of the gel without impairing its

or cultured yogurt mix. In the latter case, individual *structure. Centrifugal pumps should not be used*

cups are incubated, and then cooled. We will now

because the high centrifugal force produced by

discuss all the types of fruit-flavored yogurts.

the rotary propeller forces the product to leave the

pump with high speed and high pressure, which

damages the gel consistency resulting

in a weaker

Blended or Swiss-Style Yogurt

body.

This type of yogurt is the most popular and com-

mands more share of the market than the other va-

GENERAL MANUFACTURING

rieties. Its volume has grown consistently over the

PROCEDURES

years. There are two contributing factors for its

growth: First is the reformulation of the stabiliza-

We will now discuss general processes for major

tion system that results in a smoother body and less

types of yogurt.

gel-like texture. Second is the incorporation of "mild"

yogurt cultures, which produces a more pleasing mild *taste and very little or no acidification (lowering of*

Plain Yogurt

pH) during the entire shelf life. These yogurt at-

Plain yogurt is gaining share of the refrigerated yo-

tributes have gained broad consumer acceptance in

gurt category. Its market share is currently around 5%

the market.

of the total refrigerated yogurt category in the United

Swiss or blended yogurt is a homogeneous blend

States. Plain yogurt is made either by cup-incubation

of fruit and/or fruit-flavored syrup with fermented yo-

or by vat-incubation. It can be found in the market

gurt base. This product is made using vat-incubation

as full fat, low fat, or nonfat yogurt.

Formulations

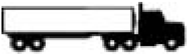
and almost always requires the use of stabilizers. The

vary widely and the total solids range from 12.50%

stabilizers and their level can be varied to obtain the

to 14.0%. Plain yogurt is an integral component of the

desired product. The sugar solids vary, depending on



Standardize mix to:

0–2% fat, 10.5%

MSNF,

Standardizing tank

NFDM, and

Stabilizer

^{o}C)

^{o}C.

(60

Cooling

^{o}C/10 min.)

Pre-Heat

(Cool to 45

(97

Heat Exchanger

Homogenizer

1500 psi (17MPa))

Holding Tube

TK

Balance

Yogurt Starter

Milk/Skim Storage

Mix Tank

(45ºC, Don't set)

Casing / Palletizing

Incubator

Filler

(45ºC, 4.5 pH)

Blast

Cold

Plain Yogurt (Cup-set)

Cooler

Storage

(Cool to 5º C)

Refrigerated Distribution

Figure 13.10. *Flow sheet for the*

manufacture of cup-set plain yogurt.

the sugar content of fruit preparation and flavoring.

Bloom (0.25–0.40%). It produces a creamy, firm yo-

The fat content varies according to the desired prod-

gurt, which is resistant to wheying-off and comes out

uct category, namely, full fat, low fat, or nonfat yogurt

smooth and free of lumps. If a “natural” approach *(see Table 13.4 for variations in the formulation).*

is desired, a gelatin–pectin stabilizer or agar–pectin

One of the most common stabilizer blends used for

stabilizer can be used. Again, other stabilizer com-

blended yogurt consists of a combination of modi-

binations can be used to meet specific marketing or

fied food starch (0.6–1.5%) and gelatin *of 225–250*

manufacturing needs.

Table 13.4. *Typical Formulation of Blended/Swiss-Style Yogurt Base*

Composition

Nonfat Yogurt (%)

Low Fat Yogurt (%)

Full Fat Yogurt (%)

Milk fat

0.3–0.5

1.0–2.0 (> 0.5– < 2)

3.25–3.50

Milk solids-not-fat

11.0–12.0

10.5–12.0

10.5–11.0

Sugar solids

0–6.0

0–6.0

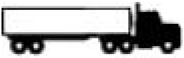
0–6.0

Stabilizer

0.4–1.6

0.3–1.4

0.3–1.2



13 Manufacture of Various Types of Yogurt

225

Standardize mix to:

0 - 3.25% fat, 9 -

12% MSNF, 0.6%

Standardizing Tank

stabilizer, 8% sugar

NFDM, Stabilizer

and Sugar

ºC)

ºC,

Pre-Heat

(60

ºC/10 min.)

Cooling

Heat Exchanger

(97

(Cool to 45

Homogenizer

1500 psi (17MPa))

Holding Tube

TK

Balance

Yogurt Starter

Milk/Skim Storage

Fruit Preparation

Base Storage

Fermentation Tank

Tank

(45ºC, 4.5pH cut)

(4ºC)

Filler

In-Line Fruit

Addition

Blast

Cold

Cooler

Blended Style Yogurt

Storage

(optional)

(Cool to 5ºC)

Casing / Palletizing

Refrigerated Distribution

Figure 13.11. *Flow sheet for stirred/blended/Swiss style yogurt.*

Over-stabilized yogurt possesses a solid-like con-

(b) Flavored syrup or flavored concentrate and/or

sistency and lacks a refreshing character. Blended or

fruit juice

Swiss-style yogurt should be spoonable *and should*

r no visible fruit

not be of flowing kind or have the consistency

r lower calorie versus fruited yogurt

of a drink. The steps involved in the manufac-

r 8–9% sugar versus 10–12%

ture of blended/Swiss-style yogurt are illustrated in

Fig. 13.11. A typical in-line fruit mixing is illustrated

in Fig. 13.12.

Typical flavorings for stirred style yogurt are as

follows:

(a) Fruit preparations used at 10–18% level

r degree Brix (◦Bx): 45–64

r % fruit: 15–35

r

***Figure 13.12.** Fruit mixer built into the pipe. Courtesy:*

sweetener: sugar and/or corn sweeteners

Tetra Pak.

r stabilizer: pectin/modified food starch

(c) Combination of fruit preparation and flavored

Table 13.5. *Composition for a Low Fat*

syrup or flavored concentrate

French-Style Yogurt

r economy version

r

Ingredients

%

6–10% fruit (40–50◦Bx)

r 2–4% flavoring.

Milk fat

1.5–2.00

Milk solids-not-fat

8.62–8.66

Details of the fruit preparation are given in Chap-

Added nonfat dry milk

3.85–5.00

ter 9.

Sugar solids

3.00–3.60

Stabilizer a

As needed

Light Yogurt

Total solids

17.00–20.00

a Gelatin–pectin (0.35–0.45%), modified starch–gelatin

This is made without the addition of sugar. High-

(0.60–0.90%), pectin, low methoxy (0.10–0.12%), agar–

intensity sweeteners are used to replace the sugar in

pectin (0.50–0.65), or whey protein

concentrate (0.5–0.9%).

the formulation. The synthetic sweetener is added ei-

ther in the fruit preparation or flavoring or directly to

the yogurt base. Light yogurts are stirred-style prod-

There are other typical processing methods used

ucts that use a special fruit preparation characterized

in the manufacture of European and other special yo-

by 10–12◦Bx, 30–60% fruit content, and is designed

gurts. Two of these processes for concentrating solids

for use at 10–18% level.

and increasing protein concentration are reverse os-

mosis and ultrafiltration.

Custard Style

Reverse osmosis (RO) is a pressure filtration

This fruit-flavored yogurt is a reduced *fat product*

process that utilizes a semipermeable membrane

containing enough starch to create custard-like con-

made of cellulose acetate, vinyl, ceramic, or certain

sistency. Furthermore, it contains no fruit chunks

high-polymer materials. The membrane is charac-

and is preferred mostly by children. It is a cup-

terized by the molecular weight and the size of

fermented product. Other children-directed yogurts

molecules that are retained by it. With RO, water

contain bright colors and are sweeter than regular

molecules pass through the membrane while prac-

yogurt. Some are packaged in a cup in such a manner

tically all the dry matter is retained.

RO is a high-

so as to produce multiple colored vertically deposited

pressure process and can concentrate skim milk into

layers during packaging. Other yogurts for children

a concentrate containing 5.4% protein, 7.2% lactose,

are packaged in plastic tubes.

and 1.1% ash. The concentrate is standardized with *cream, homogenized, heat treated, and cultured.*

Ultrafiltration is a similar kind of membrane fil-

French-Style Yogurt

tration process that works at much lower pressures

This style of yogurt is more common in Europe. In

than RO process. It utilizes a specific semipermeable

the United States, it has been popular in the past, but *membrane that is more porous than the membrane*

now its market is virtually nonexistent. It is a blended

used in the RO process. With ultrafitration membrane,

yogurt similar to Swiss style in that it has fruit dis-

water molecules, lactose, and minerals pass through

persed throughout the body of yogurt, but it is char-

the membrane while proteins and fats

are retained.

acterized by distinctly weak set and creamy texture.

Skim milk is concentrated to 6.8% protein, 4.9% lac-

The relatively runny body (low viscosity) style has

tose, and 1.0% ash. This concentrate (retentate) is

lost popularity in the United States and has given way

then blended with cream, homogenized, pasteurized, *to viscous pudding-like body and texture of Swiss*

and cultured. The ultrafiltration concentrate can be

style. It is a vat-incubated product and depends on the

used in various mixtures to increase the protein con-

technology of the stabilization system (hydrocolloids

centration at different levels in the final product.

or protein preparations) to develop its

characteristic

soft body and texture. In some cases, it also employs

Sundae Style or Fruit-on-the-Bottom

the use of selective culture strains, which produce a

(FOB-)Style Yogurt

"ropy" body and/or special processing methods such

as evaporation, ultrafiltration, or reverse osmosis to

The popularity of this variety has

significantly de-

concentrate milk solids. Table 13.5 gives the typical

clined in recent years and has a market share of only

composition for a low fat French-style yogurt.

8% of the total refrigerated yogurt category in the

Table 13.6. *Formulation for a Traditional*

the bottom, a stabilizer must be added to the

Sundae-Style Low Fat Yogurt Base That Is

yogurt base. Table 13.7 gives the formulation

Cup-Incubated

for sundae-style yogurt that is vat-incubated.

(c) Western style sundae type yogurt: One specific

Ingredients

%

kind of sundae-type yogurt is called "Western

Milk fat

1.00

style." It is made with flavored sweetened yo-

Milk solids-not-fat

8.64

gurt on the top. The top layer may

consist of

Added nonfat dry milk

4.00

yogurt mix containing stabilizers, sweeteners,

Stabilizers (optional) a

0.07−0.15

and the flavor and color indicative of the fruit

Total solids

13.64+

on the bottom. The flavored yogurt on the top

a Usually pectin, agar, or gelatin.

can be made with or without color. The bot-

tom layer consists of fruit. This yogurt can be

either incubated in the cup or the vat, but a

United States. There are two types of sundae-style yo-

stabilizer is used regardless of the method of *gurt. First is the traditional style and the second is the*

incubation. The sugar solids in the yogurt base

Western style. The traditional sundae style constitutes

vary, depending on the Brix of fruit prepara-

the majority of sundae-style yogurt. The traditional-

tion and top phase flavoring. Table 13.8 gives

style product is made using plain

yogurt on the top

formulation for a typical low fat formulation.

and fruit preparation on the bottom. The yogurt top

phase can be produced by either incubation in the

container or adding vat-incubated yogurt.

Typical Flavorings for Sundae-Style Yogurt

(a) Cup-incubated traditional sundae-style yo-

(a) Fruit Preparations to be used at 18–23% level.

gurt: The largest percentage of sundae-style

r ◦Bx: 40–64

yogurt is produced by incubation in the cup

r % fruit: 35–45

and can be formulated without a stabilizer by

r sweetener: sugar and corn sweeteners

relying on added nonfat milk solids,

proper

r stabilizer: modified food starch or pectin or

heat treatment of the mix, and proper fer-

pectin–locust bean gum

mentation to obtain a semifirm body without

(b) Combination of flavored syrup or flavor con-

wheying-off. However, with current trend to-

centrate and fruit preparation

ward increased code dates, warehouse distri-

r Western style

bution, and handling, the addition of a small

r 1–4% top phase flavoring

amount of pectin, agar, or gelatin to the yo-

r 12–14% FOB

gurt will help maintain product consistency

throughout the product's shelf-life.
Table 13.6

Vanilla-Flavored Yogurt

gives formulation for a traditional sundae-

style low fat yogurt base that is cup-incubated.

Vanilla is the second largest selling flavor in the U.S.

market with the sales of $240 million for 2004. Chap-

In a typical traditional 8 oz cup of sundae-style *ter 11 details the sourcing and manufacture of vanilla*

yogurt, 59 ml (2 oz) of special fruit preparation is

and its various forms used in the production of vanilla

layered at the bottom followed by 177 ml (6 oz) of

yogurt. As discussed in Chapter 11, it is most com-

inoculated yogurt mix on the top. After the containers

mon to use vanilla extract added in

yogurt production

are sealed, incubation and setting of the yogurt takes

after fermentation for blended yogurts or added prior

place in the individual cup. When a desirable pH of

to fermentation for cup-set yogurt. When using pure

4.3–4.4 is attained, the cups are placed in refriger-

vanilla extract the usage rate will vary depending on *ated rooms, or blast cooling tunnels or cells for rapid*

the fold or concentration of the extract, the source

cooling. For consumption, the consumer mixes the

of the vanilla beans, and the desired flavor profile in

fruit and yogurt layers. Flow sheet for the manufac-

the finished yogurt. In yogurt production it is most

ture of traditional sundae-style yogurt *is illustrated*

typical to use vanilla extracts from 1× (1-fold) to

in Fig. 13.13.

3× (3-fold). The higher the fold or concentration of

(b) Vat-incubated sundae-style yogurt: If the yo-

the vanilla extract, the lower the usage rate in the

gurt is first incubated in the vat and then *yogurt. For a 2× vanilla extract a typical usage rate*

pumped into the cup with fruit preparation on

is 0.45–0.60%. The vanilla extract supplier should

Standardize mix to:

0 - 3.25% fat, 9 -

12% MSNF, 0.6%

stabilizer, 8% sugar

Standardizing Tank

NFDM, Stabilizer

ºC)

and Sugar

ºC.

(60

ºC/10 min.)

Pre-Heat

Cooling

(97

(Cool to 45

Heat Exchanger

Homogenizer

1500 psi (17MPa))

Holding Tube

TK

Balance

Yogurt Starter

Fruit placed in bottom

Milk/Skim Storage

of cup and yogurt

Mix Tank

layered on top

(45ºC, Don't set)

Casing / Palletizing

Incubator

Filler

(45ºC, 4.5 pH)

Blast

Cold

Cooler

FOB Style Yogurt

Storage

(Cool to 5ºC)

Refrigerated Distribution

Figure 13.13. *Flow sheet for the manufacture of fruit-on-the-bottom yogurt.*

Table 13.7. *Formulation for Sundae-*

Style

Table 13.8. *Formulation for a Western Style*

Yogurt That Is Vat-Incubated

Sundae Type Yogurt

Ingredients

%

Ingredients

%

Milk fat

1.00

Milk fat

1.00

Milk solids-not-fat

8.64

Milk solids-not-fat

8.64

Added nonfat dry milk

2.00 (2.0−4.0)

Added nonfat dry milk

3.00 (2.00−4.00)

Stabilizer

1.00 (0.45−1.40)

Sugar solids

4.00 (3.0−6.0)

Total solids

12.64 +

*Stabilizer**

1.20 (0.45−1.80)

Total solids

17.64 +/−

** Typical gelatin or gelatin-modified starch combination.*

be consulted to provide recommended starting usages

represented by its annual growth of 17.1% in the nat-

for the various extracts. For economic *reasons some*

ural market and 21.9% in grocery. The birth of the

manufacturers might choose to blend a vanilla fla-

organic regulations occurred when Congress passed

vor or vanillin with pure vanilla extract to lower the

the Organic Foods Production Act (OFPA) in 1990.

cost. This would also impact the product label. Some

The OFPA required the USDA to develop national

manufacturers prefer to obtain vanilla in processed

standards for organically produced agricultural prod-

syrup (vanilla extract in liquid sugar syrup) from a

ucts to assure consumers that the organic foods that

typical fruit preparation supplier. With this syrup, it

they purchase are produced, processed, *and certified*

is possible to produce both vanilla and fruited yo-

to one consistent national organic standard. This was

gurts using one plain yogurt base. Whether vanilla

accomplished by the implementation of the National

yogurt is produced from pure vanilla extract or in a

Organic Program (NOP); Final Rule on October 21, *50–60◦Br syrup, the finished yogurt usually targets*

2002. Yogurt that is sold, labeled, or represented as

a finished sugar content of 7–9%. This sugar level

organic will have to be produced and processed in ac-

gives the balance of sweetness and acidity in most

cordance with the NOP standards as defined in 7 CFR

yogurts to deliver a well-rounded

vanilla flavor for

Part 205 (FDA, 2003).

the consumer.

Under the NOP standards, food products meeting

the requirements for "100% organic" and "organic"

may display these terms and may use the USDA or-

Natural Yogurt

ganic seal. Products labeled as "100% organic" must *contain (by weight, excluding water and salt) only*

In the United States there is no definition for "natural"

100% organically produced ingredients, including

in food regulations. Since there is no legal definition,

any processing aids. This product category is primar-

so called natural yogurts are defined by the consumer.

ily found in produce, meat, or

minimally processed

In formulating yogurts for this market segment there

foods. Manufacturers of multiingredient foods, such

are certain guidelines that yogurt manufacturers have

as yogurt, strive to achieve the organic label. Yogurt,

come to use:

as well as all products labeled "organic," must con-

r Natural or WONF (with other natural flavors)

sist of at least 95% organically produced ingredients

flavorings.

(by weight, excluding and salt), and any remaining

r No added preservatives.

product ingredients must be organic compliant, that

r No high-intensity sweeteners or corn sweeteners;

is, consist of nonagricultural substances approved on

preferred carbohydrate sources include sucrose,

the National List (FDA, 7 CFR 205.605) or non-

fructose, fruit juice concentrates, or honey.

organically produced agricultural products that are

r No stabilizers or the minimum use of acceptable

not commercially available in organic

form (7 CFR

gums like pectin, agar, or locust bean gum.

205.606). Any yogurt, or other product, labeled as

r No artificial colors; if colors are needed, it is

organic must identify each organically produced in-

preferable to use extracts derived from vegetable

gredient in the ingredient statement on the informa-

or fruit sources (i.e., grapes, beet, annatto,

tion panel. The regulations also prohibit the use of

blackberry).

genetic engineering, ionizing radiation, and sewage

sludge in organic production and handling.

In the processing of blended or cup-set natural yo-

A yogurt manufacturer interested in producing *gurts, as discussed earlier, the heat treatment to ob-*

organic products must be certified. Certification

tain 80–90% protein denaturation is important to help

standards under the NOP regulations establish the

control syneresis, since either no or minimal use of

requirements that organic production (crops and live-

stabilizers is preferred.

stock) and handling (processing) operations must

meet the standards necessary to be certified by

a USDA-accredited certifying agent. The informa-

Organic Yogurt

tion that an applicant must submit to the certifying

The total sales for organic yogurt are approximately

agent includes the applicant's organic system plan.

$179 million, representing 6.5% of the total refrig-

The organic system plan describes (among other

erated yogurt category for the 52-week period end-

things) practices and substances used in process-

ing in May 2004. The popularity of this category is

ing, record keeping procedures, practices to prevent

Table 13.9. *Organic Ingredients for yogurt manufacture (as defined by 7 CFR 205) Organic Ingredients (as defined by 7 CFR 205)*

Organic milk and cream

Organic Nonfat dry milk

Organic sugar or organic evaporated cane juice

Organic agave

Organic tapioca, rice, or corn starch

Organic fruits, fruit puree, and fruit *juice/concentrate*

Organic Compliant Ingredients (as defined by 7 CFR 205)

Agar-agar: allowed 205.605 (a)

Colors: allowed 205.605 (a) (5)—nonsynthetic sources only

Dairy cultures: allowed 205.605 (a) (6)

Flavors: allowed 205.605 (a) (9)—nonsynthetic sources only and must not be produced using synthetic solvents and carrier systems or any artificial preservatives

Ascorbic acid: allowed 205.605 (b) (4)

Nutrient vitamins and minerals: allowed 205.605 (b) (19)—in accordance with 21 CFR 104.20, Nutritional Quality Guidelines for Foods

LM pectin: allowed 205.605 (b) (21)

Gelatin: approved by the National Organic Standards Board, pending listing in the Federal Register commingling of organic and nonorganic products,

yogurt at all. If the product contains descriptors such

and on-site inspections.

as "a blend of yogurt and fruit juice," it automatically

There are many available organic ingredients that

requires that the product use yogurt in its preparation.

can be used in the production of a certified organic

A descriptor "a blend of juice and milk" allows the

yogurt, low fat yogurt, or nonfat yogurt. Table 13.9

use of directly acidified milk (Roberts,

2004).

lists some of these agricultural organic ingredients

Typically, commercial drinkable yogurt is a low fat

as well as some ingredients that can be found on the

(< 2.0% fat) drink containing 8.0–9.5% milk solids-

National List and be used for the other 5% portion of

not-fat and 8–12% sugar. Its pH varies from 4.0 to *the formulation.*

4.5. Low-calorie drinks are made with high-intensity

sweeteners replacing all the sugar. Yogurt drinks gen-

erally contain fruit juices or purees, although in some

Yogurt Drink/Smoothies

markets they may contain only sugar, with or with-

Yogurt drinks have registered a significant growth *out fruit flavors. The fruit content is generally in the*

(Berry, 2004) in the current yogurt market (Fig. 13.9).

range of 8–15%. In some markets the fruit juice range

This product is designed to be consumed as a drink

may be as high as 30–49%.

or shake. It consists of (a) refreshing low-milk-solids

Yogurt drinkables and smoothies are of two *drink or (b) a health-promoting yogurt drink sup-*

types: regular and those fortified with prebiotics,

plemented with prebiotics, probiotics, vitamins, and

probiotics, minerals, and vitamins. The prebiotic

minerals. In order to be labeled as yogurt drink, the

fructo-oligosaccharides (FOS) or inulin, along with

white mass (yogurt component) of the

drink/beverage

synergistic probiotic cultures of Lactobacillus casei,

must conform to the FDA standard of identity that

Lactobacillus reuteri, and bifidobacteria are present

calls for > 8.25% milk solids-not-fat and fat level

in addition to yogurt culture. The type and level of

to satisfy nonfat yogurt (< 0.5%), low fat yogurt *stabilizer chosen is designed to keep the product from*

(2.00%), or yogurt (> 3.25%) label (Chandan, 1997),

settling into two phases during its shelf life. The sta-

prior to the addition of other ingredients. After the

bilizers prevent the milk protein from aggregation

addition of fruit and flavors, it does not have to meet

and subsequent separation of clear

layer on the top.

these standards. If a yogurt-based beverage is pro-

The stabilizers also help in appropriate viscosity of

duced that does not conform to these standards, it

the drink. A mixture of hydrocolloids in the range

can still be marketed given a fanciful name other

of 0.01–0.5% is usually employed. High-methoxy *than "yogurt" drink. Similarly, smoothies are not*

pectin is especially functional in imparting the re-

necessarily standardized and some may not contain

quired viscosity and protein interaction to prevent

separation. Another important processing step is low-

Table 13.10. *Formulation for the Manufacture*

pressure homogenization (6 MPa (500 psi)) of fer-

of a Long-Life Sweetened Yogurt Drink

mented base to create small casein particles, which

(Lassi)

interact with pectin to stop aggregation of the protein

Ingredients

%

and creating thereby a stable suspension.

The production method for drinkables is simi-

Milk fat

0.5–3.5

lar to that of blended/Swiss-style yogurt. The mix

Milk solids-not-fat

9.00

contains milk solids, sugar, stabilizers, and optional

Sugar

10–11

ingredients consisting of mineral–vitamin supple-

Sodium dihydrogen phosphate

0.5

ment, fructo-oligosaccharide. This blended mix is

High-methoxy pectin

0.5

heat-treated at 85∘C for 30 minutes or *at 95◦C for*

10 minutes to create conditions favorable for culture

growth and for viscosity generation. The mix is then

cooled to 39–41◦C, inoculated with 1–2% of yogurt

UHT processing after fermentation and aseptic pack-

starter and optional probiotic cultures, and incubated

aging. Wheying-off is controlled by using a suitable *in quiescent state until a pH of 4.3–4.4 is achieved.*

stabilizer and proper processing conditions. The pro-

The curd is broken while cooling to 18–19◦C. The

cess has been patented for the manufacture of long-

next step is distinctly different for yogurt drinks. Cer-

life sweetened drink, which maintains phase stability

tain processes require addition of

pasteurized solu-

and does not separate over extended storage in asep-

tion of high-methoxy pectin to achieve 0.3% pectin

tic packs. Standardized low fat milk (9–10% SNF

level in the yogurt drink. The cooled fermented mass

and 0.5–1.0% milk fat) is heated to 85◦C for 30 min-

is homogenized at low pressure (6 MPa (500 psi), *utes or to 91◦C for 2.5–5 minutes and cultured with*

single stage) to convert casein to low particle size

yogurt culture. It is then fermented to lower the pH

and facilitate interaction with pectin to obtain desired

to 4.5. The set curd is broken with the help of stir-

low viscosity and to render stable suspension. At this

rer while pasteurized sugar solution

(30% in water)

point, fruit puree and flavoring or syrup may be in-

is added so as to give 8–12% sugar concentration in

corporated. Typical flavorings for yogurt smoothies

the blend. The blend is then homogenized at 23 MPa

consist of flavored syrups or flavor concentrate and/or

(2000 psi) and UHT processed at 135–145◦C for 1–5

fruit juices. After proper blending, the drink is ready

seconds and packaged aseptically employing stan-

for packaging in paper cartons or bottles. Individual

dard equipment. A flow sheet for the production of

serving bottles are commonly used for yogurt drink-

sweetened yogurt drink is shown in Fig. 13.14. The

ables. When the yogurt drink is en

route to the bottle

figure shows procedure for making drink with live

filler, it is desirable to cool it to 5◦C by passing it

cultures as well as for heat-treated and aseptically

through a plate cooler. Prior to filling, the bottles are

packaged (extended-life) drink.

unscrambled and air-blown to remove any dust or *foreign material. These are then turned upside down,*

Yogurt Whips/Mousse

rinsed, sterilized, and filled with required weight, fol-

lowed by sealing with aluminum foil and application

Whipped yogurt has unique eating quality in that it is

of a cap. The finished product is checked for pH, vis-

fluffy and light textured and has a good mouth feel.

cosity, and color at regular intervals. After coding and

It adds variety and new taste sensation to the prod-

shrink-wrapping, the bottles are packed in cases and

uct portfolio. The foam formation of the mix takes

mechanically moved to cold room. These are then

place during processing. Compared to stirred-type

placed on pellets, shrink-wrapped, and *transferred to*

yogurt, the mix for whipped yogurt contains more

the cooler before being shipped out of the plant (Clark

sugar and stabilizers. Gelatin is an essential ingredi-

and Plotka, 2004).

ent of whipped yogurt. Low to regular fat mix whips

Aneja et al. (2002) and Chandan (2002) have given *better than the nonfat mix. The stability of the foam is*

details for the manufacture of a long-life sweetened

facilitated by the use of suitable emulsifiers and stabi-

yogurt drink (lassi). Table 13.10 gives the formula-

lizers in the mix. An emulsifier aids in foam formation

tion for lassi.

while stabilizer is responsible for viscosity, mouth

The process used in the manufacture of this yogurt

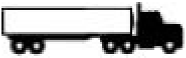
feel, and stability of the foam and emulsion struc-

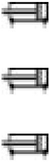
drink includes pasteurization, homogenization, and

ture. The bubbles formed are prevented from col-

culturing systems. The shelf life can be extended by

lapsing by the action of stabilizer–emulsifier during





From Yogurt Drink

Batching

Casing / Palletizing

Hold Tank

Cold

Bottle Filling

(Mix well, stand

Yogurt Drink

(Non Aseptic)

1 hr.,5° C)

Storage

Shear Pump

Refrigerated Distribution

)

Steam

ºC)

Aseptic

Shear Pump

ºC)

Injector

ºC)

Hold Tank

ºC/4 sec.

(80

(80

Pre-Heat

Cooling

Vacuum

Chamber

(Cool to 40

Holding Tube

Heat Exchanger

TK

(No pressure)

(110-120

Balance

Homogenizer

Carton Filling

Ambient

Aseptic Yogurt Drink

(Aseptic)

Storage

Casing / Palletizing

Ambient Distribution

Figure 13.14. *Flow sheet of the manufacturing procedure for refrigerated and long-life sweetened yogurt drink.*

the shelf life of the product. High altitude can affect

foam matrix consisting of fat globules, gas bubbles,

the stability of the foam as well. Generally, a sta-

and aqueous phase containing soluble and insoluble

bilizer system includes starch, gelatin, carageenan, *components of the mix is formed at low whipping*

guar gum, xanthan gum, and locust bean gum. The

temperature.

emulsifiers include mono- and diglycerides, espe-

cially the lactylated type. The stabilizer–emulsifier

Concentrated/Greek-Style/Strained

blend is incorporated directly in the yogurt mix prior *to the heat treatment. After fermentation, the mix*

is whipped using inert gas like nitrogen to increase

This type of yogurt is more common in the United

the volume of the mix by 50%. Thus, the whipped

Kingdom and some other countries. The base for

yogurt has an overrun of 50%. Thus, a 6-oz cup *this type of yogurt is whole milk, supplemented with*

will hold 4 oz of yogurt whip. During whipping, the

cream to standardize the fat level to 7%. In tradi-

high turbulence in the equipment results in fine gas

tional process, after fermentation is complete, the

bubbles dispersed in the aqueous phase. The mixing

yogurt is concentrated by straining

through cheese

head of the aeration machine disintegrates large gas

cloth at 4◦C overnight. Because of the drainage of

bubbles into finer bubbles forming desirable foam

whey, the total solids increase from 14% to 21–

structure. The emulsifiers are surface-active agents.

23% (Tamime and Robinson, 1999; Robinson, 2003).

By reducing surface tension, they facilitate bubble

The concentration step results in a remarkably thick

formation, while the stabilizers enhance viscosity

viscous body. The fat content of this type of yo-

and form a coating around the bubbles to give them

gurt rises to approximately 10%. The high fat con-

strength and capacity to resist from

collapse. The

tent imparts very creamy flavor and moderates the

acid flavor. The fermented protein also concentrates

frozen yogurt mix obtained by blending yogurt and

and contributes to smooth texture. The traditional *low fat/nonfat ice cream has a pH of 6.0 or titratable*

method is labor intensive and lacks sanitation con-

acidity of 0.30%. Thus, the industry standards require

ditions for obtaining desirable shelf life of the prod-

minimum titratable acidity of 0.30%, with a contri-

uct. Accordingly, modern processing procedures for

bution of approximately 0.15% as a

consequence of

whey removal are employed. Drainage of the whey

fermentation by yogurt bacteria. Most manufacturers

is accomplished by ultrafiltration or is done when

use 10% of yogurt in their formulations. As a con-

the fermented milk passes through Quarg/centrifugal

sequence, frozen yogurt tastes very similar to low *separators. The resulting concentrated yogurt is sub-*

fat/nonfat ice cream, with a hint of yogurt flavor at

sequently packaged.

the end. This flavor attribute is preferred by the con-

Alternatively, Greek yogurt can also be found in

sumer because the perceived health attributes of yo-

the UK market that does not involve the concentration *gurt bacteria are available along with the popular taste*

step. Such Greek yogurt is formulated with high fat

of low fat/nonfat ice cream. Frozen yogurt is labeled

content of 7–10% and SNF content of 10–12%.

according to the fat content of standard serving size

(4 fl oz) used in the ice cream industry. Accordingly,

the product containing > 3 g of fat per

4 fl oz is labeled

Frozen Yogurt

as frozen yogurt, the product containing 0.5–3.0 g per

The sale of frozen yogurt category in the United

4 fl oz is low fat frozen yogurt, and the product with

States has been on the decline in recent years. For the

< 0.5 g fat is labeled nonfat frozen yogurt.

52-week period ending on May 16, 2004, this cate-

A typical formulation of low fat frozen yogurt is

gory has shown a decline of 7.8% but still represents

given in Table 13.11. The table shows a mix com-

$195 million in sales. It remains a viable business

posed of 10% nonfat sweetened plain yogurt and 90%

perhaps because of its low fat and

nonfat attribute

*low fat ice cream mix. If a lower pH (<
6.0) is desired*

*and the health image of yogurt. The
frozen yogurt*

*in the finished product, the proportion
of plain yogurt*

*base mix may be manufactured in a
cultured dairy*

*can be increased to > 10% and vice
versa.*

*plant and shipped to a soft-serve
operator or an ice*

Some manufacturers may pasteurize the soft

cream plant. Alternatively, the mix may be prepared

frozen yogurt mix, which is a low acid food, to en-

and frozen in an ice cream plant. (For details, see

hance its shelf life. Pasteurization also assures safety

Marshall and Arbuckle, 1996.)

of the food by destruction of possible contaminat-

Currently, no Federal standards have been ap-

ing pathogens, including Listeria and Campylobac-

proved for frozen yogurt. The product may be de-

ter. However, the label of the heat-treated product

fined as a food prepared by freezing while stirring a

must display the phrase "heat treated after culturing"

blend of pasteurized nonfat or low fat *ice cream mix*

on the package panel.

and yogurt (Marshall and Arbuckle, 1996). Yogurt

Figure 13.15 illustrates the typical process for

used for blending with ice milk mix must comply

making frozen yogurt. Like ice cream, frozen yo-

with the Federal and State compositional standards *gurt is flavored and extruded from ice cream freezer*

for yogurt. It must be cultured with LB and ST to

at −8◦C to obtain soft serve frozen yogurt for imme-

titratable acidity of minimum of 0.85%. In general,

diate consumption.

Table 13.11. *Formulation for Low Fat Frozen Yogurt*

Component

Yogurt 10%

Ice Milk 90%

Frozen Yogurt Mix

Milk fat

0.07

2.39

2.16

Milk solids-not-fat

10.96

10.02

10.11

Whey protein concentrate 34 (97% solids)

0.0

2.7

2.4

Sucrose, (100% solids)

4.0

13.5

12.6

Corn syrup solids, 36 or 42 DE (95% solids)

0.0

6.0

5.4

Maltodextrin 10DE (96% solids)

0.0

4.0

3.6

Stabilizer (90% solids)

0.0

0.7

0.6

Total solids,%

15.03

36.04

33.94

Titratable acidity,%

0.85

0.15

0.30

pH

4.6

6.7

6.0

234

Part II: Manufacture of Yogurt

Standardizing Tank

NFDM, Stabilizer,

WPC-34, Sugar, 10

DE Maltodextrins,

°C)

and CSS 36 DE

°C

[60

Pre-Heat

°C/25 sec.)

Cooling

Homogenizer

(Cool to 5

Heat Exchanger

(80

1500 pel (17MPa)]

Holding Tube

TK

Baance

Standardize mix box 2.4%

Plain Yogurt

Flavor / Color

Milk / Skim/Condensed

fat, 10% MSNF, 13.5%

(11% MSNF,

Storage

sugar, 0.7% stabilizer,

4% sugar)

Mix Tank

maltodextrin, 2.7% WPC

(10% yogurt,

6.0 pH)

Palletizing

Cold

Bag in

Soft Serve Mix

Storage

Box Filler

Refrigerated Distribution

Fruit/Nut

36 DE Corn Syrup Solids

Blast

Carton

Freezer

Filler

(−40° C)

In-Line

(Extrude -6° C)

Addition

Ice Cream Freezer

Frozen

Frozen Yogurt

Storage

Palletizing

Frozen Distribution

***Figure 13.15.** Flow diagram for the manufacture of soft serve mix and hard frozen yogurt.*

Soft serve frozen yogurt may be garnished with

weight of the mix. Using the same cup, the frozen

nuts and other food materials to enhance its eating ex-

yogurt is packed and its net weight is determined.

perience. The extruded frozen yogurt may be packed

The overrun is calculated as follows:

in suitable containers and hardened at $-25^{\circ}C$ *to ob-*

tain hard pack frozen yogurt. The ice cream freezer

% Overrun = (Density of mix − Density of frozen yogurt) × 100

is a scraped surface freezing barrel (heat exchanger)

Density of frozen yogurt

(Fig. 13.16). As the liquid mix is pumped through the

= 100 × (Net weight of mix − Net weight of frozen yogurt)

Net weight of frozen yogurt

barrel, removal of the sensible and latent heat leads to

formation of frozen mass. The dasher scrapes the in-

Assuming the mix weighs 9 lb/gallon, and the

ner surface of the barrel while the frozen mass moves *frozen yogurt has 50% overrun, a gallon of frozen*

toward the exit point. Simultaneously, air cells are

yogurt would weigh 6 lb. Accordingly, one serving

formed as a result of whipping action of the dasher

of one-half cup (or 4 fl oz) would weigh 85 g.

and the volume of the mix increases. Eventually, the

semifrozen yogurt mass exits from the

barrel as foam

with a specific controllable degree of aeration. The

POSTCULTURING HEAT

overrun or the degree of air incorporated in the foam

TREATMENT

is around 50%. It implies that the original volume of

the mix is increased by 50% in the finished frozen

The shelf life of yogurt may be

extended by heating

yogurt.

yogurt after culturing to inactivate the culture and the

The calculation of overrun involves weighing a cup

constituent enzymes. Heating to 60–65◦C stabilizes

of the mix before freezing and determining the net

the product so the yogurt shelf life will be 8–12 weeks *et al., 1992; Mistry, 2001; Tamime and Robinson, 1999; Nauth, 2004). Indeed, the scientific evidence has been compelling that the health properties of yogurt are mostly lost by heat treatment (Chapters 21 and 22). This issue has been debated around the* *world. The Codex standard for yogurt does call for*

live and active status to be labeled as yogurt. Further-

more, if the product is heat-treated after culturing, it

has to be labeled as "heat-treated fermented milk."

A similar standard, which is awaiting clearance, has

been proposed by National Yogurt Association to US

FDA. The standard would also require

a minimum

yogurt culture count of 10 million CFU/g in refriger-

ated yogurt at the time of consumption to insure the

live and active status of the product.

ACKNOWLEDGMENT

We appreciate the contribution of Brent Cannell for

preparing flow sheet diagrams for this chapter.

REFERENCES

Aneja RP, Mathur BN, Chandan RC, Banerjee AK.

2002. Technology of Indian Milk Products. Dairy

India Yearbook, New Delhi, India, pp. 158–182.

Berry, D. 2004. Cultured dairy foods: A world of

opportunity. Dairy Foods, April 2004.

Figure 13.16. *An ice cream freezer used for*

Chandan RC (Ed). 1989. Yogurt: Nutritional and

manufacturing frozen yogurt. Courtesy: Tetra Pak.

Health Properties. National Yogurt Assoc, McLean,

VA.

Chandan RC. 1997. Dairy-Based Ingredients. Eagan

Press, St. Paul, MN.

at 12◦C. However, this treatment destroys the “live”

Chandan RC. 1999. Enhancing market value of milk

nature of yogurt, which may be a desirable consumer

by adding cultures. J. Dairy Sci. 82:2245–2256.

attribute to retain (Chandan and Shahani, 1993; Shah,

Chandan RC. 2002. Benefits of live fermented milks:

2003). Federal Standards of Identity for refrigerated

Present diversity of products. In: Proceedings of

International Dairy Congress, Paris,

France.

yogurt permit the thermal destruction of viable or-

[Available in CD-ROM.]

ganisms with the objective of shelf life extension,

Chandan RC. 2004. Dairy: Yogurt. In: JS Smith, YH

but the phrase "heat treated after culturing" must be

Hui (Ed), Food Processing: Principles and *displayed on the principle display panel of the pack-*

Applications. Blackwell, Ames, IA, Ch 16.

age. The postripening heat treatment may be designed

Chandan RC, Shahani KM. 1993. Yogurt. In: YH Hui

to (1) ensure destruction of starter bacteria, contami-

(Ed), Dairy Science and Technology Handbook, Vol.

nating organisms, and enzymes and (2)

redevelop the

2. VCH Publ., New York, pp. 1–56.

texture and body of the yogurt by appropriate stabi-

Clarke S, Plotka VC. 2004. Yogurt and sour cream:

lizer and homogenization processes.

Operational procedures and processing equipment.

The heat-treated yogurt possibility is quite contro-

In: YH Hui, L Munier-Goddik, AS

Hansen, J

versial in the United States. Although legal, the major

Josephson, W-K Nip, PS Stannfield, F. Toldra (Ed),

players in the yogurt industry believe that such prod-

Handbook of Food and Beverage Fermentation

uct will not deliver live and active yogurt expectation

Technology. Marcel Dekker, New York,

of the consumers (Chandan, 1989, 1999; Fernandes

pp. 159–182.

Fernandes CF, Chandan RC, Shahani KM. 1992.

Stanfield, F Toldra (Eds). Handbook of Food and

Fermented dairy products and health. In: BJB Wood

Beverage Fermentation Technology.

Marcel Dekker,

(Ed), The Lactic Acid Bacteria, Vol. 1. Elsevier,

New York, Ch 7, pp. 125–145.

New York, pp. 279–339.

Roberts B. 2004. Dairy Foods, June 2004, pp. 56.

Food and Drug Administration (FDA). 2003. United

Robinson RK. 2003. Yogurt types and manufacture.

States Department of Health and

Human Services,

In: H Roginski, JW Fuquay, PF Fox (Eds),

Public Health Services. 2002. Code of Federal

Encyclopedia of Dairy Sciences, Vol. 2. Academic

Regulations. Title 21. Section 131. US Government

Press, New York, pp. 1055–1058.

Publishing Office, Washington, DC.

Shah N. 2003. Yogurt: The product and

manufacture.

Food and Drug Administration (FDA). 1999. United

In: B Caballero, L Truco, PM Finglas (Eds),

States Department of Health and Human Services,

Encyclopedia of Food Sciences and Nutrition,

Public Health Services. Grade "A" Pasteurized Milk

Vol. 10, 2nd ed. Academic Press, New York, *Ordinance. 1999 Revision. Publication No. 229. US*

pp. 6252–6259.

Government Publishing Office, Washington, DC.

Tamime AY, Robinson RK. 1999. Yogurt Science &

Marshall RT, Arbuckle WS. 1996. Ice Cream, 5th ed.

Technology, 2nd ed. Woodhead Publ. Cambridge,

Chapman and Hall, New York, pp. 317–318.

England, and CRC Press, Boca Raton, FL.

Mistry VV. 2001. Fermented milks and cream. In: EH

Marth, JL Steele (Eds), Applied Dairy

BIBLIOGRAPHY

Microbiology, 2nd ed. . Marcel Dekker, New York,

Ch 9, pp. 301–325.

Dairy Management, Inc. (DMI). 2003. Concentrated

Nauth KR. 2004. Yogurt. In: YH Hui, L

Meunier-

and Dry Milk Ingredients. Dairy Ingredient Applica-

Goddik, AS Hansen, J Josephsen, W-K Nip, PS

tion Guide. DMI, Chicago, IL.

Plant Cleaning and Sanitizing

Dennis Bogart

Cleaning

approximately 75 million people in the United States

Normal Soils

have food poisoning every year. That is roughly 25%

Special Soils

of the population every year. Also CDC estimates that

Manual Cleaning

over 5,000 people every year die from food poison-

Foam Cleaning

ing in the United States. This is a true tragedy and in

COP Cleaning

many cases could be prevented if the food-processing

CIP Cleaning

plants use good GMPs and sanitation. Simple things

Sanitizing

such as washing hands for 20 seconds with soap, and

Bacteriophage (Phage) Control

Phage Control

cleaning and sanitizing the plant can go a long way

A Final Thought

toward preserving a good company name.

In cleaning and sanitizing yogurt plants there are *a few ideas that need to be dismissed right away:*

The concepts of cleaning and sanitizing in a yogurt

r Yogurt is a "safe product because the product's

processing plant are fairly simple and basic. First

acidity takes care of any 'bad bugs'"—FALSE

clean the soil from the surface, and then sanitize

r Sanitizers kill everything—FALSE

the surface. Simple to look at, read about and talk

r Phage will not attack yogurt as in other products

about; however, very difficult to accomplish on a

like buttermilk—FALSE

regular basis. In fact, millions of dollars worth of

r Cleaning removes all the bacteria and phage from

yogurt and other cultured dairy products have been *a surface—FALSE*

lost due to poor sanitation and it would be almost im-

r The external environment is not

possible to calculate the number of good customers

important—FALSE

lost due to poor sanitation. There are a lot of compa-

r Sanitizer rotation is important because we

nies today that I call "used-to-bees."

Some of these

develop "resistant" bacteria—FALSE

companies, at one time, were major players in the

r Quat sanitizers are too dangerous to use—FALSE

dairy industry and some were small independent op-

erations. They all have one thing in common. They

no longer exist. They are gone, a part of history and

CLEANING

we can think of many dairy companies that are "used-

to-bees." Some are "used-to-bees" because of the fi-

Cleaning is simply the removal of soil from a sur-

nancial burden of business; however, far too many

face (notice that this says nothing about killing

because of poor quality product.

microorganisms—that is for later). There are no gra-

The issues with the product not only involve top-

dients of clean. The surface is either clean or it is

ics such as shelf life, flavor, appearance, and other

dirty. If all the soils are removed, the surface is clean.

quality issues but also product safety. The Center for

If the soil is not completely removed, it *is still dirty.*

Disease Control and Prevention (CDC) estimates that

There are several types of soil with which we have

237

238

Part II: Manufacture of Yogurt

to be concerned. Some of these are called normal,

sugars such as lactose, sucrose, and fructose are eas-

whereas others can be called special.

ily rinsed out with the prerinse. That is assuming that

they are not all complexed within the other four soils.

This will happen frequently and thus compounds the

Normal Soils

issues with the complex carbohydrates. Also there

Fat–

is a very dangerous situation that

develops inside

tanks, silos, and other enclosed spaces. When lac-

All yogurts and other cutured dairy foods contain fat.

tose is mixed with caustics, carbon monoxide (CO)

Even nonfat products may contain up to 0.5% butter-

may be formed. There have been several incidences

fat, while others may contain 4% butterfat or more.

where personnel have entered a tank after cleaning

The fat will coat the surfaces with a greasy film that

and succumbed to the colorless and odorless gas.

over time becomes rancid, attracts other soils, resists

rinsing and, as all other soils, protects microorgan-

isms from the action of sanitizers. Oil (fat) and wa-

Complex Carbohydrates

ter do not mix. This is one reason we need to use a

good detergent or soap (surfactants). A surfactant is

Complex carbohydrates are actually a matrix of all

simply a chemical that has two functional ends on

the soils together attached to the surface. Most of the

its molecule. One end is hydrophilic and "likes wa-

time this happens when the yogurt mix

is pasteurized

ter." The other end is hydrophobic and "likes fats and

and the soil is simply referred to as "burn-on." The

oils." When the surfactant is in a solution of water

second circumstance where this complex soil forms

and gets close to fat, it attaches itself to the water and

is on equipment that has not been properly cleaned *on the other end to the oil. Thus the fat or oil mixes*

and the soil keeps building upon itself. The addition

with the water. If the cleaning procedures are prop-

of stabilizers and emulsifiers compound the soiling

erly followed, the cleaner will remove the fat from

issue. The more ingredients added, the more likely

the surface. There is also a very special *circumstance,*

a soil will form. As with butterfat, strong alkaline

where it is very good that there is a little fat on the

cleaners are needed to clean this tough soil from the

surface, when the cleaning operation starts. This is es-

surface.

pecially true for clean-out-of-place (COP), clean-in-

place (CIP), and pasteurizer cleaning. The cleaning

chemicals normally used for these applications usu-

Proteins

ally do not contain any surfactants. This is especially

Milk is an excellent source of protein and most cul-

true for the chlorinated CIP cleaners used in COP and

tured dairy products have added proteins and other

CIP. Also caustic cleaners used to clean pasteurizers

milk solids. Protein is the last and the hardest to re-

frequently do not have surfactants in their formulas.

move organic soil that we normally encounter. They

So how is the fat removed? Chemically all of these

are relatively easy to see on a surface because of

cleaners contain strong alkalis such as *caustic soda*

their typical blue film. However, if the cleaning has

(NaOH) or caustic potash (KOH). When these alka-

been neglected or the protein film has been allowed

lis are mixed with fats or oils in normal cleaning,

to thicken, it will change from a blue haze to an "ap-

the fat or oil will undergo a chemical process known *plesauce" appearance. Further development will lead*

as saponification. In other words it makes good old-

to a serious white film that may be confused with a

fashioned soap, a natural surfactant. This is a very

mineral film. There are four common ways to re-

desirable reaction and greatly boosts the cleaning ac-

move protein films and to keep them

from building

tion of the cleaner. It is extremely important to have

up. The first is in cleaning a pasteurizer. Extremely

a vigorous prerinse to remove excess butterfat from

strong (1–3%) caustic circulated hot ($> 170^\circ F$) for

tanks and lines and an even more vigorous postrinse

more than 30 minutes will usually control the pro-

to thoroughly rinse the now dissolved or suspended

tein film. The issue is that the protein is an extremely

soils from the system.

long and complex molecule that is not soluble in wa-

ter. The caustic acts to break this long molecule up

into shorter chains that are soluble in water and re-

Sugars

moved in the postrinse. As this treatment with caus-

The various sugars in yogurt are relatively easy to

tic is neither feasible nor recommended in COP, CIP,

clean. Water will usually do the trick. Most of the

foam, or manual cleaning, other ways need to be used *to break the protein molecule. The most common in*

Bacteriophage–

North America is to add chlorine to the cleaner. Chlo-

In many ways, bacteriophage, the virus that attacks

rine, at typical concentrations between 75 and 300

the bacterial culture can be considered a soil. In a

ppm, will quickly remove protein soils. Other alter-

culture plant, phage (as it is more commonly known)

natives including enzymes, hydrogen peroxide, and

is frequently associated with dirty equipment, air, or

selected acids will also act to remove protein films.

the environmental surfaces. Controlling phage is a

Protein films are especially important for they may

constant battle for any cultured

products plant and

harbor phage that will destroy the yogurt during the

especially a yogurt operation. To control phage, good

culturing phase of production. One issue to be very

sanitation, adherence to GMPs, and culture rotation

aware of is if chlorinated cleaners are being used,

are needed.

they will clean protein films, boost general cleaning,

As stated previously cleaning is the removal of soil

and deodorize. One thing that they will not do is to

from a surface and if any soil is left on the surface, the

kill sufficient microorganisms to achieve sanitizing.

surface will be dirty. There are three main principles

The pH is too high for the chlorine to *be active as*

that must be remembered when cleaning in a yogurt

a sanitizer. This is critical because you must always

plant:

clean prior to sanitizing.

1. The prerinse is the most important step in the entire

cleaning process.

Minerals–

2. The surface is either clean or it is dirty.

3. You cannot sanitize a dirty surface.

Mineral films are formed in many ways. A common

industry name for mineral films is "stone." These

The cleaning process is fairly simple. First, pre-

stones are further referred to by their common ori-

rinse to remove all the gross soil; second, wash with *gin such as milkstone, beetstone, beerstone, water-*

an appropriate cleaner; and third, rinse off or remove

stone, and soapstone. In the cultured dairy-products

the soil. These steps sound simple, but there are nu-

industry the three most common stones are milkstone,

merous ways to foul up the process in the four main

soapstone, and waterstone. All of these *hard to clean*

cleaning methods: manual, foam, COP, and CIP.

stones have one thing in common, they generally need

to be cleaned with an acid. The food grade acids such

Manual Cleaning

as phosphoric, nitric, sulfuric, and sulfamic are most

commonly used. Normally the surface is cleaned with

Manual cleaning is normally accomplished with a

an alkaline detergent to remove all the organic soils,

bucket of suds and a brush or pad. It is a very common

rinsed thoroughly with water, and then the acid is

method of cleaning and has been used in the dairy in-

applied.

dustry for literally hundreds of years. Although man-

ual cleaning is very common, there are issues that

occur frequently:

Special Soils

r Failure to use the right detergent or cleaner.

Manual cleaners are specifically designed to be

Biofilms–

active at moderately hot temperatures

Biofilms are formed by many bacteria when they at-

(100–120°F), to produce copious amounts of

tach to a surface. They secrete a very viscous polysac-

stable foam and to be relatively mild to skin. Other

charide slime to cover for protection. This slime is a

types of cleaners, such as CIP or foam cleaners,

complex carbohydrate film and can be cleaned with

may function quite differently and

produce poor

an alkaline cleaner. It is not easy to clean biofilms, as

results, possible corrosion of the surfaces, or be

vigorous agitation may be needed. The significance

too harsh to use even with gloves. Always follow

of these films is that they protect the bacteria from the

the manufacturer's recommendations as to what *action of the sanitizer, thus the bacteria will survive*

product to use for manual cleaning.

sanitizing. To further emphasize the significance of

r Failure to use the correct amount. If a little bit is

biofilms, Listeria and Pseudomonas form biofilms.

good, more is better. This idea has caused

The first is a psychrotrophic pathogen and the sec-

numerous problems in plants. It will cause poor

ond spoils probably more dairy products than any

rinsing, too strong a solution for operator's skin,

other bacteria.

heavy streaking, and possibly corrosion issues.

240

Part II: Manufacture of Yogurt

Many times an operator will put far too *much*

most importantly, gross soils are rinsed from the sur-

detergent in a bucket and just keeps adding water

faces. After a thorough prerinse, a thin layer of foam

to the bucket. Most powdered manual cleaners

cleaner is applied to the surface. After waiting 5 to

will have directions to use approximately one

10 minutes, the foam and soils are rinsed off the sur-

ounce per gallon of water. Using more than that

face. As with manual cleaning, there are several is-

level will not clean better but will waste

sues that need to be addressed when you foam clean:

considerable money and will have all the other

consequences listed above.

r Failure to use the proper detergent. Because foam

r Failure to use the right type of manual cleaner.

cleaners are used with minimal scrubbing, they

The best type of manual cleaner for a yogurt

are approximately 5–10 times stronger than a

operation is a chlorinated alkaline cleaner. These

manual cleaner. The best type of foam

cleaner in a

types of cleaners come in powdered and liquid

yogurt operation for general cleaning is

form and will do a very good job. They are

liquid-chlorinated alkaline foam cleaner. This

especially good at removing the protein films that

type of cleaner removes all the organic soils and *frequently form on the product contact surfaces.*

leaves the surface ready to sanitize. Occasionally,

The proper cleaning solutions will have a mild

depending on water hardness and other

alkali and high foaming surfactants to remove any

conditions, acid foam cleaner may also be used.

butterfat and carbohydrate soils. The chlorine will

This acid foam cleaning removes mineral films

be present at between 60 and 200 ppm and will

and leave the surface shinny. Take special note

break up and help remove the very tough protein

that when you acid foam clean, it is always best to

films.

use it after an alkaline foam cleaner and be very *r Failure to use clean, fresh solutions. If the*

careful to avoid mixing the two cleaners in any

solutions become too dirty or are more than

way.

30 minutes old, they loose their chlorine and

r Failure to use the proper amount of cleaner.

temperature and become very poor cleaners.

Always follow the manufacture's directions for

Streaks, films, and poor rinsing will result.

the amount of product to use. If the directions are

r Failure to use the proper tools. Good brushes and

too vague, always ask your supplier to clarify

pads are essential to good manual cleaning. The

what is the right amount. Typical

usages are

brushes need to be of the proper size and color

between 2 and 4 oz/gallon; however, some

(follow color coding system) and in good

products are recommended outside of this range.

condition. Wood-handled brushes must never be

r Allowing the foam to dry. This is a primary failure *used. Many operations use what are termed*

in foam cleaning. If the foam dries on the surface,

"green pads." I strongly recommend against their

all the soils that the cleaner has removed will be

use. Although they do clean well, they will

redeposited on the surface. This redeposited soil

severely scratch stainless steel and

their green

is frequently referred to as "redep." "Redep" is

color makes it very hard to tell when they need to

extremely hard to remove and will make it

be replaced. I recommend that these "green pads"

impossible to sanitize the surface. Frequently an

be replaced with "white pads." These pads will *operator will either foam too much equipment*

not scratch stainless steel as the green ones do and

and surfaces or will go on break after foaming.

you can tell when they need to be replaced.

The worst situation is if the equipment is warm or

r Failure to scrub. Manual cleaners are the mildest

hot, it quickly dries the foam. All of *these*

of all the commonly used cleaners. Because of

situations must be avoided when foam cleaning.

this, they need heavy scrubbing and a little time to

Only let the foam stay on a cool surface for

do their job. These cleaners will never "soak"

5–10 minutes and rinse thoroughly.

clean a surface and therefore should never be used

r Failure to use the proper temperatures. Prerinsing

in any other type of cleaning such as CIP or COP.

and postrinsing with too hot water will "cook" the

soils on the surface and cause, at a minimum,

streaking. For good cleaning, rinse waters should

Foam Cleaning

be between 70◦F and 110◦F. This temperature

Foam cleaning is a quick and effective method for

will remove the soil and help eliminate streaking.

cleaning surfaces that have a light or moderate soil

The temperature of the water to generate the foam

load on them. The process is quite simple. First, and

is also very important. Always use cool *or cold*

water for this purpose. If hot water is used, the

r Failure to properly prerinse. All the parts that are

product may not foam properly and may quickly

to be cleaned in a COP vat must be thoroughly

dry and cause "redep."

rinsed prior to placing into the vat. Failure to

r Too wet or dry foam. The amount of water trapped

properly rinse might overload the detergent with

in the foam determines if the foam is too dry or

soil and may cause excess foaming. This is a

too wet. All foamers currently sold by reputable

major reason that can cause COP

cleaning to be

companies will have a method for adjusting the

ineffective. Ensure that the prerinse is with cool

foam. This is usually by adjusting the water

or lukewarm (< 120◦F) water or else there is a risk

and/or air pressure or the air/solution mixture. If

of "cooking" the soils onto the surface.

the foam is too dry, there will not be enough water

r Overloading the COP vat. This is the number two

in the foam for it to act as a good cleaner; and if

reason for failure. Always leave some room in the

the foam is too wet, it will be very heavy or soupy

vat for the water to properly circulate. COP

and fall from the equipment very fast.

Good foam

cleaning depends upon temperature, time,

is similar to a wet shaving cream and will hang on

chemical strength, and vigorous water circulation.

a vertical surface for at least 5 minutes.

If the vat is overloaded, there will be poor

r Poor foaming technique. Here is the second *circulation and the process will probably fail.*

reason for foam cleaning to fail. If good foaming

Another situation I have frequently seen is an

technique is not used, the operator will miss large

operator trying to clean an 8-foot pipe in a 6-foot

areas of the surfaces being cleaned. Always foam

COP vat. Half of the pipe will stick out *of the vat*

from the bottom up. Never foam from the top

and never get cleaned. In fact, none of the pipes

down, and always have a plan as to how the foam

will be cleaned because there is absolutely no

will be applied to the equipment.

circulation of the cleaner in the pipe. Taking the *r Failure to scrub difficult soils. Even as good as*

pipe out and turning it around surely will not help.

foam cleaning is, it may not clean all the soil from

Long pipes need to be cleaned in a CIP system,

a surface. There will be areas that need to have

pipe wash vat, or manually scrubbed with pipe

some scrubbing to remove all the soil.

brushes.

r Postrinse failure. In a COP vat when the cleaning

time is finished, the supply pump is turned off and

COP Cleaning

the tank is drained. Frequently, the soil that has

been removed off the equipment's surface floats

Clean-Out-of-Place (COP) cleaning is a wonderful *when the circulation of the cleaner ceases. This*

method to clean small parts, pipes, and other miscel-

floating soil redeposits onto the surfaces if the vat

laneous items. The parts are rinsed and placed into a

is simply drained at this time. Always add cool to

specially designed tank that will circulate a cleaning

warm water to the vat and overflow the *floating*

solution around and through all the parts. Again, as

soil. When doing so be very careful not to get any

with all types of cleaning, there are issues to address:

of the cleaning chemicals on yourself or others.

r Failure to use the proper detergent. COP tanks

When the soil has overflowed, drain the tank and *are not designed to tolerate foam. Foam in these*

thoroughly rinse parts with either a cold water

tanks causes the pump to cavitate, thus greatly

hose or by refilling the vat with cold water.

reducing the flow rate of the wash water. For this

r Failure to Disassemble. The number one reason

reason only a cleaner designed to be a

CIP cleaner

for cleaning failures in a COP vat is not

is to be used. I strongly recommend a chlorinated

completely disassembling all the parts to be

CIP cleaner for good soil removal. Remember to

cleaned. Any equipment that is not completely

always follow the manufacturer's directions as to *disassembled will not clean and will be dirty.*

the proper concentration.

There is no exception to this rule. All gaskets,

r Improper cleaning temperature. If the cleaning

joints, and other assemblies must be taken apart.

temperature is too cold the equipment will be

Small and/or delicate pieces should be placed into *dirty; and if it is too hot the equipment might be*

a COP basket to facilitate cleaning and to protect

damaged and it could be dangerous to the

them. As stated, I have found this to be the

operator. COP tanks are not "boil-out" tanks.

number one cause for failure and I frequently

Keeping the cleaning temperature at

145–160°F

recommend that sanitation leaders and

will help in cleaning and saving energy.

supervisors not walk by a COP vat without

looking into it to verify that all the parts are

the minimum flow to the spray device in the tank *disassembled and that the vat is not overloaded.*

will be 80 gal/min. This amount of water will

cause a turbulent flow down the side of the tank.

r The wrong detergent. I recommend chlorinated

CIP Cleaning

CIP cleaners for most CIP cleaning in a cultured

plant. This will clean and leave the surfaces ready

Generally prior to the mid 1940s, all equipment in a

to be sanitized. If nonchlorinated cleaners are

dairy plant was completely taken down and manually

used, the equipment needs to be periodically

cleaned every day. It was usually left overnight to dry

inspected for a protein buildup. When using a

and reassembled the next workday.

This worked rea-

chlorinated cleaner, you not only have to measure

sonably well in small dedicated operations; however,

the concentration of the cleaner but also the

this would be virtually impossible in today's mas-

concentration of the chlorine. Both have to be at

sive processing plants where silos and tanks holding *optimal concentration. Always follow the*

60,000 gallons or more are common and have miles

supplier's recommendations for the cleaner and

of welded processing pipes and lines. A way of clean-

keep the chlorine between 70 and 250 ppm. If a

ing this type of equipment had to be developed prior

reclaim system is used, extra chlorine *may have to*

to the introduction of modern processing plants. That

be added.

breakthrough came in the mid 1940s and 1950s with

r Too low or high a cleaning temperature. For most

the advent of CIP cleaning. Today, CIP cleaning sys-

cleaning of a processing plant, a temperature of *tems range from simple manually operated systems*

140–170◦F should work well. If excess

to huge systems completely run by powerful comput-

temperature is used, the equipment may be

ers. There are two fundamental CIP systems used in

damaged and poor cleaning may result. Too low a

modern cultured dairy product plants:

temperature could leave the equipment dirty.

1. Reclaim CIP. The heart of a reclaim system is a

r System out of "balance." "Balance" is a term used

large tank used to reclaim the CIP cleaning so-

to describe the CIP system's hydraulics. A well

lution for the next cycle. These systems can save

running system will have all the rinse *and wash*

energy and possibly water; however, the systems,

water following correct flow/time patterns. A

by their very nature, will wash over and over with

system out of balance will loose water,

the same wash water. This may cause contamina-

contaminate solutions, mix chemicals, poorly *tion to be spread throughout the plant if the system*

clean, and waste money. "Balance" is extremely

is not running at top efficiency.

important and must be addressed. As a hint if the

2. Single use CIP. A single-use CIP system always

CIP supply pump has an air eliminator, the CIP

uses fresh-wash water to wash each system. Mod-

system may be out of balance. Normally there is

ern single use systems will not use excess water

no need for an air eliminator on the CIP supply

or energy and can be an asset to the production of

pump.

high-quality products.

r Poor prerinse. The most important step in the CIP *cleaning process is the prerinse. The CIP system*

CIP systems offer an excellent way to clean if they

must be programmed to thoroughly remove all the

are properly designed and running well. They do, as

gross soils from the equipment. If the gross soils

with other methods of cleaning, have a number of

are not removed, the cleaning solutions *will be*

issues that are critical to cleaning:

overloaded with soil and the equipment will

r Low flow rate. CIP cleaning totally depends upon

probably be dirty.

the flow of the cleaning solution for mechanical

action. The flow rate through a pipe must be at a

Cleaning in a cultured plant is vital to *the safe pro-*

minimum of 5 ft/sec for the water to have enough

duction of high-quality products. There is still the

turbulence to clean. Any flow under this rate

simple truth that the surfaces are either clean or dirty.

results in the flow being too easy (laminar) to

If the cleaning operations listed above are properly *clean. Also tanks and silos must have proper flow*

performed, the surfaces will be clean and ready to

down the walls to clean. There is a simple

sanitize. I am frequently asked, "Why do we need

formula used to calculate the minimum

to sanitize when we clean all the bacteria from the

flow—two times the circumference measured in *surface?" This is a good question and the best way*

feet. As an example, if the circumference is 40 ft,

to address it is that effective cleaning will remove

between 90% and 99% of the bacteria from the equip-

r Store all sanitizers out of direct sunlight in a cool, *ment's surface. This is a very good reduction but not*

dry room with good ventilation.

enough. Not enough to protect public health and to

There are numerous ways to sanitize cultured dairy

assure high-quality cultured products.

plants. Various chemicals and heat have been used

over the years and I offer the following recommen-

dations specifically designed for culture operations.

SANITIZING

r For sanitizing in CIP systems and HTST units a

para acetic acid sanitizer (PAA) is normally

Sanitizing is the treatment of a cleaned surface with a

recommended. All reputable suppliers of cleaners

chemical or physical agent to destroy pathogenic mi-

and sanitizers will be able to supply an

croorganisms and to reduce the total microbial vege-

appropriate PAA sanitizer. Most PAA sanitizers

tative cell population to a safe level. Always note that

have a fairly wide concentration range approved

"sanitizing" is not "sterilizing" and not all microor-

for food contact surfaces. It is recommended that *ganisms are killed. Typically, sanitizing of a surface*

the PAA sanitizer be used at maximum strength to

will reduce the microbial population by three logs.

help control yeast, mold, and bacteriophage. For

That is another 99.9% beyond what is accomplished

CIP systems, always use the products in cool

by cleaning. What is left on the surface *is a matter*

water and handle carefully. When used in HTST

of numbers. If there are a large number of microbes

units, the heat of forward flow may cause gasket

on a surface and the population is reduced by 99.9%,

damage and I recommend that Viton gaskets be

there could still be a substantial population of mi-

used. They are more expensive than other gaskets

crobes left. Vigorous cleaning and good sanitizing

but will tolerate the PAA well. Because PAA

will leave a surface with very few bacteria and other

sanitizers are not strong acids, the normal

microbes. It is an accepted criterion that, after sani-

cleaning regimen may need to have an

acid

tizing, there should be fewer than two microbes per

cleaning cycle. Always consult with your

square centimeter of surface area. If the cleaning or

chemical supplier regarding acid cleaning.

sanitizing steps fail, there may be massive numbers

r COP vats are excellent vats in which to sanitize *left on the surface and product quality will be com-*

previously cleaned equipment. There are two

promised.

good sanitizers for use in a COP tank. The first

There are a number of general rules for sanitizing:

choice is an iodine sanitizer. When using an

r Only use sanitizers that are approved by the *iodine sanitizer, always make sure that the*

Federal EPA for use on food contact surfaces.

concentration is set at 25 ppm and that the use

r Always follow label directions for use on food

solution has a pH < 4.5. Do not use an iodine

contact surfaces. It is a violation of Federal law if

sanitizer if the pH is over 5.5. A good

iodine

these directions are not followed.

sanitizer is very effective on bacteria, yeast,

r Pick the best sanitizers for your plant and then let

and mold and is color-coded. The second choice

them do their job. Put 95% of your effort into

is to use a PAA sanitizer. I recommend that *properly cleaning the surface.*

the strength be set at mid-range of the use

r Pick sanitizers based upon how they are to be

concentrations. Note: Only use iodine for soaking

used and the individual plant circumstances.

gaskets and other rubber parts to avoid excessive

r In a cultured plant, never rinse the sanitizer from *corrosion.*

r

food contact surfaces with water.

The best sanitizer for manual sanitizing of pieces

r Constantly check the sanitizer concentrations.

and parts either by using a central sanitizer unit or

r Rotation of sanitizers because of "resistant bugs"

in a bucket is iodine. Use a

concentration of

is not necessary. If there are problems, it is almost

25 ppm and be sure the pH is acceptable. Iodine is

always a cleaning issue.

well accepted by operators. Its color makes it easy

r There is no sanitizer that can make up for poor

to judge the concentration and it does not have a *cleaning.*

harsh odor. I have heard that iodine will stain

r Sanitize open surfaces within 30 minutes of use

stainless steel. Under proper use, that does not

and closed tanks within 3 hours of use.

happen. What an iodine sanitizer will stain is soil,

r All sanitizers have broad-spectrum activity except *especially protein films. A second choice is to use*

quaternary ammonium compounds (Quats).

PAA. It is a good sanitizer; however, it does have

a mildly offensive odor and is not tolerated well

What is a virus and how do they multiply? Are they *by many operators.*

really alive, dead, or somewhere in-between? These

r Now the topic comes up about what product to

are really good questions. First of all a virus is the

use for sanitizing environmental surfaces such as

smallest "living" thing that we know of, being much

floors, walls, drains, and doorway entrances. I *smaller than bacteria. The question, as to if they are*

recommend that the best product for most of these

alive, arises from the fact that a virus cannot multiply

applications is a Quat sanitizer, especially an acid

or duplicate itself. To replicate, a virus will attack a

Quat sanitizer. I am very well aware that there are

very specific host cell. During this

attack, the virus

many people in the cultured products industry

will inject its DNA into the host cell and catastroph-

who are very much against this type of sanitizer

ically change the complete function of the cell from

because it could kill the culture. There is some

whatever it was doing into becoming a virus man-

truth that Quats, even small amounts like 5 ppm,

ufacturing plant. After the host cell makes around

are very effective against the Gram-positive

30–200 new virus cells, the cell ruptures, thus releas-

bacteria that make up culture. For this reason, I

ing the viruses (lysing) and the process starts all over.

recommend Quats only for the

environment. If the

As discussed above, phage is a virus that specifically

Quat that is on the floor ends up in the culture, the

attacks bacteria, such as culture. Because of the rapid

plant has a problem far worse than a dead culture.

and massive multiplication of the phage in the culture,

Quat sanitizers are excellent products for *the phage will rapidly kill all the culture bacteria and*

controlling yeast, mold, and pathogenic bacteria

ruin the production. For example, a typical scenario

on environmental surfaces. They have low

would be that after the culture is added to the main

corrosion and no offensive odor. I recommend

product, the pH starts to drop from

approximately 6.8

using a disinfecting strength of 500–1,000 ppm

toward the desired finished pH. However, about half

for nonfood contact surfaces. Apply the Quat to a

way to the desired pH, further acid production just

clean surface and do not rinse it off and it will

stops and without quick intervention the production *form a residual effect that will help control*

is lost. The phage have completely taken over and

unwanted microbes. The most effective method

killed all the "good" bacteria.

for applying to the floor and building microbial

barriers at doorways is to use "door foamers."

They deposit sanitizing foam at the door for

Phage Control

sanitizing shoes and fork lift wheels. This

There are four specific issues in controlling phage

approach is far superior to trying to use a footbath,

that must be addressed:

which frequently becomes very dirty or dry.

r Culture and culture rotation

To sum up the recommendations for

sanitizers:

r Sanitation

1. PAA for CIP

r Emergency recovery

2. Iodine for central sanitizer systems and manual

r Plant design and condition

sanitizing

3. Acid Quats for environmental sanitizing

Environmental Sanitation.

First of all, the envi-

ronmental areas such as the HVAC, floors, walls, ceil-

BACTERIOPHAGE (PHAGE)

ings, drains, and doors need to be in good repair and

CONTROL

of sanitary design. If these areas are neglected, it will

be very difficult to control phage. Install a floor san-

In a dairy plant producing cultured

dairy products,

itizing foam system on each doorway or entryway.

the term "phage" will cause even the most seasoned

The sanitizer of choice for these floor foamers is Quat

employee to become immediately concerned for their

at 800–1000 ppm. PAA may also be used following

product. Phage (or phage particles) is a very special *label directions. For cleaning the environmental sur-*

type of virus that only attacks bacteria. In the cultured

faces, foam cleaning with chlorinated foam cleaner at

plant, the phage can attack and destroy all the culture

3–4% concentration is recommended. If the plant has

needed to make the product. Many vats of almost

a phage problem, add one quart of

chlorine sanitizer

cheese and tanks of almost yogurt or buttermilk have

to 15 gallons prediluted chlorinated foam solution in a

found their way to the drain or as other forms of waste

tank foamer and foam onto the surfaces. Let stand for

because of phage.

15 minutes and thoroughly rinse. Foaming with the *added chlorine once a week will further help control*

concentration. Following a thorough rinse, acid-wash

phage. Clean the drains every day with chlorinated

with a surfactated CIP acid cleaner and rinse again.

cleaner. After cleaning and thoroughly rinsing, san-

Sanitize prior to production with PAA following

itize all the surfaces with chlorine at 200 ppm. Fog

manufacturer's recommendations.

sanitizing is of little use for phage control and we

Always remember that a surface must be abso-

do not recommend its use. If the HVAC is clean and

lutely clean prior to sanitizing and that most micro-

properly filtered, positive pressure maintained, and

biological issues, including phage, are cleaning is-

environmental surfaces cleaned and sanitized, phage

sues not sanitizing issues. With thorough care and

will not have anywhere to “hide.”

adherence to procedures, phage problems will be a

problem of the past.

Open Cheese Vats.

Clean the vats every day with

a chlorinated cleaner using both foaming and hand

scrubbing. Thoroughly rinse the chlorinated cleaner

A FINAL THOUGHT

and reclean with a manual acid cleaner and rinse

again. Prior to production, sanitize the vats with

The one factor that will make or break *the sanitation*

50–75 ppm chlorine sanitizer. Be very sure to also

program in a plant is people. For many years the

completely clean and sanitize the vat superstructure,

cleanup crew has been made up of the newest, least

paddles, and knives.

trained, least supervised, and lowest paid employees.

Yet these are the employees that totally control the

Loose pieces and parts.

Take every effort to han-

future of the company. If this seems like a disconnect,

dle these pieces and parts in a sanitary manner. This

it is. These employees need to be well trained and

especially includes gaskets, scoops, pipe joints, lu-

given all the tools they need to do their job. This

bricant tubes, and other small items. After thorough

includes proper incentives to do a good jogg and to

cleaning, store these items in sanitizer solutions, not

keep good employees on the job. Many companies

laid out or hung all over the plant. The best sanitizer

today have recognized the absolute

importance of

for long-term storage is iodine at 25 ppm. It will kill

their cleanup crews and have addressed the issues in

phage and minimize any possible corrosion and is

several ways. There are companies that have moved

"kinder" on gaskets than other sanitizers. Change the

sanitation from third shift to first shift. Others pay *solution at least once a day.*

premiums for sanitation or build in bonuses for good

performance. There are other ways like shift rotation

CIP of Closed Vats, Tanks and Silos.

After deter-

and other incentives that can make a difference. It is

mining that the CIP system is properly functioning,

fair to say that if a company relegates *sanitation to*

CIP all systems every day using a "built" chlorinated

a third class operation, it is losing unrealized profit

CIP cleaner following manufacturing directions for

and will probably be a "USED-TO-BEE."

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

15

Yogurt Plant: Quality Assurance

Ramesh C. Chandan and Kevin R. O'Rell

Regulatory Obligations

packaging, and other product issues are included.

Food & Drug Administration (FDA)

In addition, other departments of the FDA are in-

Standard of Identity

volved in product standards and labeling in general

Food Labeling in the United States

under the Fair Packaging and Labeling Act, and mat-

Analytical Tests

ters related to overall compliance. Milk specialists

Quality Control Programs

represent Milk Safety Branch's regional offices and

National Yogurt Association Criteria for Live and Active

work with the state regulatory agencies by provid-

Culture Yogurt

ing scientific, technical, and inspection assistance. In

Refrigerated Yogurt

Frozen Yogurt

this manner, compliance with regulatory policies and

Specification Program

procedures is assured. Besides liaison with the FDA,

Defects and Trouble Shooting

the State Department of Agriculture (Dairy Division

References

or Health Department) is also involved in regulating

milk production and manufacturing in a particular

The quality assurance program for yogurt plant en-

state. To assist States and municipalities in initiating

compasses various functions to assure the quality of

and maintaining effective programs for the preven-

the products produced. It also is designed to insure

tion of milk borne disease, the Public health service,

that manufacturing plant meets all the state and fed-

in 1924, developed a model regulation, *known as the*

eral regulatory obligations in regard to package la-

Standard Milk Ordinance for voluntary adoption by

beling, proper ingredient usage, safety, and shelf life

State and local milk control agencies. To provide for

requirements.

the uniform interpretation of this Ordinance, an ac-

companying code was published in 1927 that pro-

vided administrative and technical details as to satis-

REGULATORY OBLIGATIONS

factory compliance. This model regulation now titled

Milk production, processing, marketing, and manu-

the Grade A Pasteurized Milk Ordinance (PMO)—

facture of dairy products are all regulated by federal, *Recommendations of the United States Public Health*

state, and local authorities. The regulatory compo-

Service/Food and Drug Administration. The PMO is

sition for the manufacture of yogurt in the United

recommended for legal adoption by States, counties,

States is discussed below. Chapter 3 includes detailed

and municipalities, to encourage a

greater uniformity

discussion of regulatory requirements for milk pro-

and a higher level of excellence of milk sanitation

duction, transportation, and processing.

practice in the United States. An important purpose

of this recommended standard is to facilitate the ship-

ment and acceptance of high quality milk and milk

Food & Drug Administration (FDA)

products in interstate and intrastate commerce.

Production, transportation, and processing of Grade

The Pasteurized Milk Ordinance describes the re-

A dairy products are regulated by the Milk Safety

quirements for product safety, milk hauling, sani-

Branch of the FDA. Product safety, labeling, *tation, equipment, and labeling. The PMO is very*

extensive and covers milk production at the farm

Table 15.1. *Code of Federal Regulations*

to the manufacturing facility. The requirements for

(21 CFR): Standard of Identity for

Dairy Foods

chemical, physical, bacteriological, and temperature

CFR Part:

standards are given in Table 3.3 in Chapter 3. Some

salient features include the following:

Dairy food

r

General, definitions

130

Must contain the word Grade A on the container

r

Milk and cream, definitions

131.3

Must contain the identity of the plant

r

Milk

131.110

Product standards of identity must be met

r

Acidified milk

131.111

Temperature—cooled to 7◦C (45◦F) or less and

Cultured milk

131.112

maintained there at

r

Concentrated Milk

131.115

Bacterial limits not to exceed 300,000 CFU/ml in

Sweetened–condensed milk

131.120

commingled raw milk and 20,000 CFU/ml in

Sweetened–condensed skimmed

131.122

pasteurized milk

r

milk

Coliforms—not to exceed 10 CFU/ml

r

Low fat dry milk

131.123

Phosphatase test—less than 350 milliunits/liter

Nonfat dry milk

131.125

for pastcurized fluid products by the Fluorometer

Nonfat dry milk fortified with

131.127

or Charm ALP or equivalent. The test represents

vitamins A and D

detection of 0.075% raw milk or less

Evaporated milk

131.130

r Drugs—no positive results on drug residue testing

Evaporated skimmed milk

131.132

by approved procedures

Low-fat milk

131.135

Acidified low-fat milk

131.136

National Conference of Interstate Milk Shippers

Cultured low-fat milk

131.138

(NCIMS) plays a key role in setting standards and

Skim milk

131.143

regulations related to the PMO, methods of mak-

Acidified skim milk

131.144

ing sanitation ratings of milk supplies, and sanitation

Cultured skim milk

131.146

requirements for Grade A condensed and dry milk

Dry whole milk

131.147

products, including condensed and dry whey. Fur-

Dry cream

131.149

thermore, NCIMS is involved in regulations pertain-

Light cream

131.155

ing to the fabrication of single service containers, and

Light whipping cream

131.160

closures for milk and milk products, and in the eval-

Sour cream

131.157

uation of milk laboratories. The

purpose of NCIMS

Acidified sour cream

131.162

is to promote the best possible milk supply for all

Eggnog

131.170

the people and to provide for unrestricted availabil-

Half-and-half

131.180

ity of milk and milk products in interstate shipment.

Sour half-and-half

131.185

The NCIMS operates to establish uniformity of prod-

Acidified sour half-and-half

131.187

uct standards from state to state. Both producers and

Yogurt

131.200

Low-fat yogurt

131.203

processors of milk are represented in NCIMS. They

Nonfat yogurt

131.206

address issues related to laws and regulations gov-

erning Grade A milk sanitation (storage, handling), *Frozen desserts*

reciprocity between regulatory jurisdictions and vio-

Definitions

135.3

lations of reciprocity.

Ice cream and frozen custard

135.110

Goat's milk ice cream

135.115

Mellorine

135.130

Standard of Identity

Sherbet

135.140

Water ices

135.160

All dairy products with standard of identity defini-

tion must conform to the FDA standard and the reg-

Food labeling

ulations published in Code of Federal Regulations

Food labeling

Part 101

Nutritional quality guidelines for

Part 104

(USDHHS FDA, 2003) (Table 15.1). Chapter 4 con-

food

tains more information on this topic.

Current Good Manufacturing

Part 110

A few dairy products (e.g., butter and nonfat dry

Practice in manufacturing,

milk) are regulated by USDA grading and inspec-

packaging holding human food

tion programs. The FDA has the authority to estab-

Source: Adapted from USDHHS, FDA Revised April 1, 2003.

lish standards of identity for foods whenever doing

http://www.cfsan.fda.gov/~1rd/FCF131.

so will promote honesty and fair dealing in the in-

Certain claims on foods have also been defined for

terest of consumers. Standards generally specify the

inclusion in the label. Table 15.3 lists *these product*

types of ingredients the food must contain (manda-

definitions in terms of low fat, nonfat, and other terms.

tory ingredients), as well as those it may contain

The percentage value for a food label is calculated

(optional ingredients). Standards also may set mini-

as percent of the values shown in Nutritional label *mum and maximum content requirements for valu-*

for yogurt (Fig. 15.1).

able constituents as well as for fillers. FDA has es-

The calorie calculation is based on 4, 4, and 9 cal/g

tablished standards for staple food items, including

of carbohydrate, protein, and fat, respectively. All the

milk, peanut butter, jams and jellies, and milk choco-

calculated numbers are rounded to the nearest whole

late. The USDA's Food Safety and Inspection Service

number.

(USDA/FSIS) also has standards for foods regulated

The FDA regulations also address health claims as

by that agency.

shown below:

r Calcium and osteoporosis: Product

must be high

in calcium content

Food Labeling in the United States

r Sodium and hypertension: Product must be low

sodium

Detailed discussion for food labeling regulations is

r Food high in potassium and high blood pressure

described in Chapter 4.

r Fat and cancer: Product must be low fat

Under the Nutrition Labeling and Education Act of

r Fat and heart disease: Product must be low fat,

1990, the FDA promulgated new labeling regulations

low saturated fat, and low cholesterol

that became effective on May 8, 1994. Actual label

r Soluble fiber from whole oats and coronary heart *values depend on a particular formulation and actual*

disease

nutrient analysis relative to the food being labeled.

r Soluble fiber from psyllium seed husk and

All the nutrients designated in dairy foods label are

coronary heart disease

declared in relation to a standard reference amount *r Whole grain foods and coronary heart disease*

(serving size) of the food. The label must declare the

r Fiber-containing grain products, fruits, and

amounts per serving for calories, calories from fat,

vegetables and cancer

total fat, saturated fat, cholesterol, sodium, total car-

r Fruits and vegetables (High in vitamins A and C) *bohydrates, sugars, dietary fiber, and protein. Also,*

and cancer

percentage Daily Reference Values must be shown

r Fruits, vegetables, and grain products that contain

to a 2,000-calorie and 2,500-calories/day diets for

fiber, particularly soluble fiber and coronary heart

the above nutrients, as well as for vitamins A and C, *disease*

and calcium and iron to make the label consumer-

r Folate and neural tube defects

friendly and useful. Effective January 1, 2006, food

r Soy protein and risk of coronary heart disease

labels will also be required to declare the content of

fat containing trans fatty acids.

In addition, when making any health

claims, the

Daily reference value (DRV) relative to various

product must contain (before fortification) at least

dairy foods is based on an evaluation of scientific

10% of one of the nutrients: Vitamin A, Vitamin C,

data. For example, scientific data indicate that car-

calcium, iron, protein, or fiber.

bohydrates should compose 60% of the daily calorie

Under the current standards, Vitamin A fortifica-

allowance. Therefore, the DRV for carbohydrates is

tion to 2000 International Units (IU) (which is 500

300 grams, providing 1,200 calories. This amount of

IU or 10 per cent of the daily value (DV) per 8 ounce

carbohydrate would furnish

approximately 60% of

serving) is optional for yogurt. When Vitamin D is

reference caloric intake for 2,000 calories per day.

added, its level must be 400 IU per quart (100 IU or

Accordingly, if a food serving contains 30 g of car-

25% of the DV per serving). Because vitamins A and

bohydrates, the DV percentage will be 10%.

D are fat soluble, they get removed in the process of

Daily Reference Values used for calculations for

fat removal from milk. As a result, nonfat and low-

Nutritional Labeling are shown in Table 15.2. The

fat yogurt would be low in vitamins A and D content

DRV for macronutrients is based on the daily diet of

as compared to full-fat yogurt.

Therefore, addition

2,000 calories, except fats, carbohydrates, and fiber,

of Vitamins A and D to low fat and nonfat yogurt is

which are based on 2,500-calorie diet. The reference

practiced by some yogurt manufacturers.

daily intakes (RDI) relates to micronutrients (vita-

The general standard also provides that, under cer-

mins and minerals) regardless of caloric intake.

tain circumstances, safe and suitable ingredients that

***Table 15.2.** Daily Reference Values and Reference Daily Intakes for Nutrition Labeling (based on a 2000 calorie intake; for adults and children 4 or more years of age) in the United States Macronutrient*

Daily Reference Values (DRV)

Total fat a, maximum

65 g

Saturated fatty acids a, maximum

20 g

Cholesterol a, maximum

300 mg

Sodium a, maximum

2.4 g

Potassium a

3.5 g

Total carbohydrate a

300 g

Fiber a

25 g

Protein a

50 g

Micronutrient

Reference Daily Intakes (RDI)

Vitamin A a

5000 IU

Vitamin C a

60 mg

Calcium a

1 g

Iron a

18 mg

Vitamin D

400 IU

Vitamin E

30 IU

Vitamin K

80 □g

Thiamin

1.5 mg

Riboflavin

1.7 mg

Niacin

20 mg

Vitamin B6

2 mg

Folate

400 □g

Vitamin B12

6 □g

Biotin

300 □g

Pantothenic acid

10 mg

Phosphorus

1 g

Iodine

150 □g

Magnesium

400 mg

Zinc

15 mg

Selenium

70 □g

Copper

2 mg

Manganese

2 mg

Chromium

120 □g

Molybdenum

75 □g

Chloride

3.4 g

a FDA regulations require these nutrients be listed in the Nutrition Facts panel. Labeling of other *nutrients is optional.*

Source: Adapted from: http://www.cfsan.fda.gov/~dms/flg-7a.html REV. Jan 30, 1998.

perform a technical effect (for example, thickeners

a. Nuts & Heart Disease

and stabilizers) may be added to the modified foods

b. Walnuts & Heart Disease

to maintain performance characteristics similar to the *c. Omega-3 Fatty Acids & Coronary Heart Dis-*

traditional food.

ease

In addition, the FDA permits certain qualified

d. B Vitamins & Vascular Disease

health claims. The following summarizes them:

3. Qualified Claims About Cognitive Function

a. Phosphatidylserine & Cognitive

Dysfunction

1. Qualified Claims About Cancer Risk

and Dementia

a. Selenium & Cancer

4. Qualified Claims About Neural Tube Birth De-

b. Antioxidant Vitamins & Cancer

fects

2. Qualified Claims About Cardiovascular Disease

a. 0.8 mg Folic Acid & Neural Tube

Birth Defects

Risk

w

If

fat

can

of

“Lo

40

40

which

more

for

the

fat,

r

claims

amount

product

declare

or

product

are

o

fat

are

of

reduced

calories

Free"

g

fat

Continued

be

claims

amount.

amount

from

or

claims

dish

serving

at

that

must

m2

reference

total

that

more

indicate

the

“F

the

are

per

if

to

at”

per

of

or

must

50%

reference

main

Calorie”

be

Calorie

reference

F

calorie

g

saturated

fat

w

and

w

claims,

3

reference

per

or

the

meets

products

more

products

50%

least

must

serving

n

serving

fat,

if

r

calories

“Lo

calories

“Lo

fat

o

If

per

at

1/3

f

labeled

e

for

tha

for

of

meal

is

per

g

per

when

40

OK

v

Free”)

for

food

cholesterol

amount;

from

met

at

50%

least

of

0.5

and

abo

is

less

F

less

than

made

more

made

“Lite”:

are

50%

reduced

at

“Lite”

supplements:

made

supplements:

supplements:

Free”:

Free:

saturated

be

or

if

(or

be

or

or

least

or

definition

than

be

meal

be

at

at

all

fat

at

F

F

to

amount

reference

at”

dietary

greater

dietary

dietary

calories

by

less

must

reduced

meets

F

definition

r

only

is

%

requirements

r

cannot

calories

xt

the

per

total

amount

“Saturated

r

cannot

calories

o

o

o

Comments

“Light”

“Light”

F

“

100%

“Light”—see

F

Ne

F

fat

at”

wer

may

an

may

F

per

may

fe

wer”

“Less”

at”

amount

food

w

less

food

w

less

fat

amount

food

w

F

per

appropriate

food

“Fe

than

food

appropriate

food

25%

“Lo

than

“Lo

“Lo

an

25%

25%

be

an

term

reference

be

be

least

calories

reference

than

reference

not

Calorie”

rather

least

per

amount

appropriate

reference

not

least

saturated

reference

than

reference

not

Saturated

Reduced/Less

At

Reference

Uses

At

Reference

At

Reference

or

of

of

if

if

less

not

fat

less

less

g

r

r

per

g

cal

g

less

amount

and

30%

and

of

50

amount

amount

amount

amount

fat

fat

main

or

100

per

50

main

g

from

per

from

main

g

from

less

120

:3go

than

:1go

or

per

and

per

less

per

and

100

less

15%

and

100

10%

small)

r

small)

r

w

cal

o

o

reference

(and

reference

is

dishes:

less

g

reference

(and

reference

is

dishes

per

more

calories

g

reference

and

calories

saturated

dishes

per

than

calories

saturated

Lo

40

Meals

3

Meals

1

Meals

Claims

for

g

and

fat

(or

less

and

except

and

0.5

main

fatty

fat

fatty

fat

Content

or

amount

understood

reference

than

serving)

labeled

reference

labeled

serving

dishes,

is

ient

meals

trans

trans

a

per

per

per

less

meals

saturated

g

g

w

g

per

for

serving)

g

that

main

saturated

saturated

Nutr

cal

for

0.5

reference

0.5

labeled

belo

5

and

0.5

and

(or

0.5

labeled

g

of

dishes,

per

and

per

than

per

0.5

than

than

than

labeled

defined

than

contain

noted

ingredient

amount

serving

amount

serving

main

per

dishes

less

acids

and

meals

than

less

acids

to

as

Free

Less

Less

Not

Less

No

Definitions

15.3.

at

CFR

F

CFR

CFR

le

t

ba

21

101.60(b)

21

101.62(b)

Fa

21

101.62(c)

otal

T

Nutrient

Calories

T

Saturated

251

is

for

w"

to

g

per

and

by

in

and

food

t

g

40

if

main

size

13

g

in

“Lo

ex

Entire

g

n

serving

26

claims

at”

per

amount

are

F

used

w

per

19.5

or

if

meals

when

and

for

fat

w

100

fat

g

r

g

that

50%

reduced

be

“Lo

less

o

serving

exceeds

“Lo

is

=

50

F

per

wed

products):

amount.

or

meals

labeled

100

total

fat

dishes

least

must

prominence.

exceeds

per

allo

of

cholesterol

and

less

for

reference

mg

claims

and

at

&

saturated

per

if

fat

meals

small).

or

or

labeled

main

products

serving

sodium

35

or

reduced

by

(and

is

only

when

if

reference

for

less

the

for

for

per

color

mg

r

amount

food

Sodium”

amount

f

Calorie"

o

per

in

35

claims

the

claim

less

w

size,

claims

amount;

g

when

made

reduced

supplements:

sodium

amount

amount

Sodium

Sodium”:

s2go

50

or

serving

be

or

“Lo

is

Sodium”:

50%

in

w

products—per

products

(for

is

“Light

type,

dishes:

“Free”

“Reduced/Less”

in

declare

reference

per

Lo

dietary

least

contain

reference

dish

for

and

cholesterol

per

(or

small),

labeled

meal

r

cannot

calories

food

sodium

at

term

same

Light

Sodium”

ery

reference

reference

main

o

Comments

Cholesterol

Must

F

“Light”

“Light

“V

may

may

less

per

amount

food

w

less

amount

food

w

appropriate

food

per

appropriate

food

25%

“Lo

“Lo

an

25%

be

an

be

least

cholesterol

reference

than

reference

not

Cholesterol"

least

sodium

reference

than

reference

not

Sodium"

Reduced/Less

At

Reference

At

Reference

f

or

o

per

or

than

food

per

if

per

g

g

of

must

et)

g

g

mg

g

amount

small)

mg

50

by

fat

and

amount

amount

13

main

less

50

main

less

reference

is

processing

serving,

share

mark

20

100

140

100

(25%)

or

or

per

if

total

significant

et

per

amount

reference

of

and

per

and

per

“Substantially

a

mg

small)

w

mg

reference

(and

food

amount

qualifies

special

and

exceeds

reference

labeled

the

cholesterol

be

Less”

in

with

mark

(5%

dishes:

less

reference

(and

reference

is

dishes:

less

Lo

20

If

Meals

140

Meals

g

et

g

m

Less"

m

and

2

noted

5

fat

and

serving,

mark

as

reference

et)

sodium

reference

than

than

noted

labeled

contains

reference

reference

is

meals

reference

labeled

per

total

cholesterol

meals

as

per

a

contain

less

g

per

mark

per

less

g

per

for

serving)

that

except

labeled

per

m

special

and

g

of

in

that

of

g

for

serving

generally

to

m

significant

2

m

or

2

and

(or

by

13

and

“Substantially

and

than

5

(or

except

)

dishes,

a

be

(5%

dishes,

a

w

than

with

w

than

labeled

amount

than

labeled

ued

ingredient

ingredient

amount

serving

main

per

cholesterol

belo

less

amount

processing

exceeds

amount

the

must

(25%)

food

share

amount

serving

main

per

chloride

understood

sodium

belo

Free

Less

No

If

Less

No

(Contin

15.3.

CFR

CFR

leba

21

101.62(d)

21

101.61

T

Nutrient

Cholesterol

Sodium

252

the

per

if

or

foods

Based

“This

sugar

w”

“Sodium

than

and

are

els).

must

“Sodium

Added

on

or

during

“Lo

statements

amount,

amounts,

v

for

on

le

food

declare

not

not

caries

dehydrated

is

ithout

sugar

Added

ood”

sodium

added

is

terms

factual

(for

reference

must

F

labeled

“W

no

is

reference

criterion

food

if

as

dental

alcohols

prescribed

“Unsalted”

less

so

food

The

“No

less

per

and

reference

Free

if

and

if

or

ts

the

to

and

small

meet

and

50%

wed

claims

sugar

use

panel

panel

allo

remain

with

of

ingredient

State

nutrien

Calorie"

reducing

exceed

must

Sodium

added

Sodium”,

Sugars”

are

health

all

Added”

A

Salted”:

w

include

tablespoons

of

foods

that

about

2

for

Free”

“Lo

Salt

Not

Added

not

or

,or

Free”

conditions

is

information

Free"

normally

not

information

Sugars"

containing

processing.

“Reduced

“Unsweetened”

Sweeteners”

implied

fat”).

less

“Salt

“No

“Lightly

“No

Claims

Does

of

ro

nutrient(s)

g

101.9(f)(1),

serving

30

with

CFR

in

amount

of

21

labeled

vial

in

of

filled

tri

per

less

amount

amount

food

this

a

dietary

and

blank

per

appropriate

defined

25%

use

on

adds

an

a

the

“

as

amount,

not

reference

least

with

sugars

reference

than

reference

claim

supplements

vitamins

minerals

=

(e.g.,

At

May

amount,

reference

per

content"

footnote

Amount"

to

for

insignificant

Sodium

No

refers

Reference

an

mg

that

for

information

e

480

“Small

Defined.

and

basis

recommended

intak

asterisk

containing

Not

an

nutrition

has

consumed;

diluent

“See

a

or

Cholesterol,

g

or

(e.g.,

mg

(or

ater

0.5

as

statement

w

food).

60

amount

to

claim

dishes,

sugar

customarily

the

labeled

a

at,F of

than

with

of

serving

is

main

per

except

profile

part

ingredient

amount

Less

g

a

Calorie”)

form

as

reference

that

and

0.5

understood

w

w

the

Saturated

rehydrated

g

per

labeled

sugars

in

calorie

“Lo

4

Free”:

belo

,

per

prepared

required

dms/flg-6a.html

meals

than

reference

listed

at

= when

F

is

~

ingredient

the

v/

sugars

and

for

less

serving)

generally

contain

noted

(e.g.,

g

to

“Sugar

No

Disclose

13

ingredient

Amount”

consumed

refers

statement

the

exceed:

.cfsan.fda.go

if

elsv

typically

criterion

le

CFR

disclosure

“Reference

g

:

a

are

21

101.60(c)

Except

50

g,

http://www

•

a

When

Sugars

Note

that

per

• 50 on

253

254

Part II: Manufacture of Yogurt

Nonfat Light Yogurt

Yogurt With Aspartame and

Low Fat

other Sweetener.

1% Milk fat

Vitamins A & D Added

Vitamins A & D added

Nutrition Facts

Nutrition Facts

Serving Size 1 Container (170g)

Serving Size 1 Container (170g)

Amount Per Serving

Amount Per Serving

Calories 100

Calories 170

Calories from Fat 0

Calories from Fat 15

% Daily Value

% Daily Value

***Total Fat** 0g.*

0%

***Total Fat** 1.5g.*

3%

Saturated Fat 0g

0%

Saturated Fat 1g

8%

Trans Fat 0g

Trans fat 0g

Cholesterol

***Cholesterol** 10mg*

3%

Less than 5mg

1%

Sodium *80mg*

3%

Sodium *85mg*

4%

Potassium *260mg*

7%

Potassium *250mg*

7%

Total Carbohyrdrate *33g*

11%

***Total Carbohyrdrate** 19g*

6%

Sugars 27g

Sugars 14g

***Protein** 5g*

10%

***Protein** 5g*

11%

Vitamin A

15%

Vitamin A

15%

Vitamin D

20%

Vitamin D

20%

Calcium

20%

Calcium

20%

Phosphorus

15%

Phosphorus

15%

Not a significant source of

Not a significant source of

Iron, Vitamin C and dietary

Iron, Vitamin C and dietary

fiber.

fiber.

** Percent Daily Values are*

** Percent Daily Values are*

based on a 2,000 calorie

based on a 2,000 calorie

diet.

diet.

Figure 15.1. *Typical nutrition facts label for light nonfat yogurt and low-fat yogurt. The format is shown in Chapter 4, page 67.*

Analytical Tests

and sensory characteristics. Analytical tests for milk

To conform to the regulatory standard of identity

composition are for fat, total solids, protein, lactose,

and company standards of quality, safety and cost,

ash, vitamins, and minerals. Basic quality of milk

various analytical tests are performed in the in-

is assessed by tests such as titratable acidity, added

dustry (Chandan and Shahani, 1993, 1995; Chris-

water, foreign materials, antibiotics, sanitizers, afla-

ten, 1993; Tamime and Robinson, 1999). Chapter 7

toxins, pesticides, and other environmental contami-

deals with the laboratory analysis of yogurt and fer-

nants. Abnormal milk tests include

Wisconsin and

mented milks. In general, quality tests for milk and

California somatic cell counts (SCC) for mastitis.

dairy products include analysis for chemical com-

SCC is a measure for white blood cells in the milk

position, physical attributes, microbiological quality,

and is used as an indicator of herd health. Among the *microbiological tests for raw and pasteurized milk,*

program, it is imperative to enforce a strict sanita-

total aerobic plate count gives a measure of total bac-

tion program along with good manufacturing prac-

teria present and is a good indicator of the overall milk *tices. Shelf-life expectations from commercial yogurt*

quality. Coliform count is a marker of sanitary qual-

vary but generally approximate 30–55 days from the

ity of milk. Yeast and mold count is an indicator of

date of manufacture provided the temperature during

the spoilage tendency of low pH products like yogurt,

distribution and retail marketing

channels does not

sour cream, and buttermilk. Pathogenic bacteria may

exceed 10◦C (45◦F). Because lactic acid and some

gain entry in commercial dairy products as postpas-

other metabolites produced in the fermentation pro-

teurization contaminants or by cross contamination

cess protect yogurt from most Gram-negative psy-

with raw milk. Dairy testing in the industry is typi-

chotrophic organisms, most quality issues in yogurt

cally directed toward the incoming milk, cream, con-

are not related to proliferation of spoilage bacteria.

densed, and dry dairy ingredients to determine their

Most problems related to yogurt spoilage are asso-

suitability for use in the plant

operations. Incoming

ciated with yeast and molds, which are highly tolerant

tanker loads of raw milk are generally laboratory-

to low pH and can grow under refrigeration temper-

pasteurized and subjected to organoleptic assess-

atures.

ment (odor, flavor, and mouth-feel). Various tests

The control of yeast contamination is done by

on raw milk include temperature check, sediment,

aggressive sanitation procedures related to equip-

fat content, moisture, total solids content, freezing

ment, ingredients, and plant environment. Clean-in-

point determination to detect adulteration with wa-

place chemical solutions should be

used with special

ter and antibiotic tests. Freshly pasteurized milk and

attention to their strength and proper temperature.

product mixes are tested for coliform count (violet

Hypochlorites and iodophors are effective sanitizing

red bile agar) as an overall index of sanitary qual-

compounds for fungal control on the contact surfaces *ity. Pathogenic organisms receiving attention include*

and in combating the environmental contamination.

Salmonella spp., Staphylococcus aureus, Yersenia

Hypochlorites at high concentrations are corrosive.

enterocolytica, E.coli 0157: H7, and Aeromonas hy-

Iodophors are preferred for their noncorrosive prop-

drophillia due to profound impact

associated with

erty as they are effective at relatively low concen-

their recent outbreaks of food-borne illness.

trations. For detailed discussion of sanitizing proce-

With a view to expedite the results of microbio-

dures, see Chapter 14.

logical analyses and to implement corrective actions

Yeast and mold contamination may also arise

in a timely manner, various rapid methods are be-

from starter, fruit preparations, packaging materials,

ing developed. Accuracy, speed, simplicity, cost, and

packaging equipment and overall plant environment.

validity are the key factors in their development.

Organoleptic examination of yogurt

starter may be

helpful in eliminating the fungal contamination there

from. If warranted, direct microscopic view of the

Procedures for Analytical Tests

starter may reveal the presence of budding yeast cells

Various physical, chemical, microbiological, and

or mold mycelium filaments. Plating of the starter on *sensory analyses are typically conducted (See Chap-*

acidified potato dextrose agar would confirm the re-

ter 7) in accordance with the standard official proce-

sults. Avoiding contaminated starter for yogurt pro-

dures, developed and updated by AOAC International

duction is necessary.

(Horowitz, 2003) and American Public Health Asso-

Efficiency of equipment and environmental sani-

ciation (Marshall, 1993). For regulatory compliance

tation can be verified by enumeration techniques in-

of Standard of Identity, the FDA specifies certain an-

volving exposure of poured plates to atmosphere in

alytical tests to be performed on a dairy food.

the plant or making a smear of the

contact surfaces of

the equipment, followed by plating. Also, for a quick

check of food contact surfaces prior to production

Quality Control Programs

start-up, ATP detection can be used. ATP swabs and

use of an ATP luminator provide an indirect mea-

General

surement of microbes, food residue, or *other biolog-*

A well planned quality control program must be ex-

ical material that is an indicator of the effectiveness

ecuted in the plant to consistently produce products

of sanitation. In yogurt manufacturing a quick ATP

with high quality, to maximize keeping quality, and to

swab on filler valves, fruit hoppers, blending tanks, *deliver yogurt with the with most desirable attributes*

etc., can identify low levels of contamination in a mat-

of flavor and texture to the consumer. As part of this

ter of seconds. Filters on the air circulation system

should be on a maintenance schedule to be checked *r Visual appearance—Color, fill of container,*

and changed regularly. Walls and floors should be

syneresis, fruit bleeding, white specks in the

cleaned and sanitized frequently and regularly.

product, lumpiness, overall body and texture, fruit

The packaging materials should be stored in dust-

chunks/integrity.

free and humidity-free conditions. The filling room

In addition, the following laboratory analysis

should be fogged with chlorine or iodine regularly.

should be conducted:

Quality Control checks on fruit preparations, and

flavorings (Chapter 9) should be performed (spot

Titratable Acidity/pH Measurement.

Titratable

checking) to minimize yeast and mold entry into fruit

acidity (TA) is used as a measure of quality in

flavored yogurt. Certificate of analysis (COA's) con-

dairy products. %TA is obtained by titrating 9 g of

taining physical, chemical, and microbiological anal-

milk/yogurt with a standard alkali to pH 8.6 or the *ysis should be requested for each lot.*

phenolphthalein end point. It is expressed as % lactic

acid. A standard procedure for titratable acidity mea-

surement for yogurt is described in the International

Quality Control in Yogurt Plant

Dairy Federation publication (IDF1991a).

Quality control programs for finished yogurt include *control of product viscosity, flavor, body and tex-*

%TA = milliliters of 0.1 N alkali

10

ture, color, pH, and composition. In addition, daily

%TA is attributed to the constituents of serum

chemical, physical, microbiological, and organolep-

solids or milk solids-not-fat. In yogurt processing, *tic test programs must be in place for ingredients and*

TA is commonly used for following the progress of

finished product. Also, the quality control program

fermentation, as well as a quality parameter in fin-

should include a detailed "plan of control" for criti-

ished yogurt product. TA is composed of "appar-

cal processing parameters and milk

receiving. All of

ent" and "developed" acidities. Fresh milk should not

these should be included in the product specifications

have any significant lactic acid content, since it has

for the plant. A summary of typical quality tests in a

not been subjected to bacterial growth (acid produc-

yogurt plant is outlined in Table 15.4.

tion from lactose) or severe heat treatment. However,

There are many areas in formulation and process-

when fresh milk is titrated with a standard alkali, it

ing that when overlooked lead to quality issues in yo-

requires some alkali titer to reach phenolphthalein

gurt. The most common flavor defects are generally

endpoint. This is “apparent acidity,”

which is due to

described as high acid, weak flavor, or unnatural fla-

salts and proteins present in fresh milk. The approx-

voring. The sweetness level may be excessive, weak,

imate contribution of various constituents to TA is:

or may exhibit corn syrup flavor. The ingredients used

carbon dioxide 0–0.01%; caseins 0.05–0.08%; whey *may impart undesirable flavors like stale, metallic,*

protein 0.01–0.02%; phosphate 0.06%; and citrate

old ingredients, oxidized, rancid, or unclean. Lack

0.01%. Accordingly, an apparent TA of 0.13–0.18%

of control in processing procedures may cause over-

is contributed by milk constituents other than lactic

cooked, caramelized, or excessively

sour flavor notes

acid.

in the product. Proper control of processing param-

Developed acidity is the portion of TA that is at-

eters and ingredient quality assure a consistent good

tributed to lactic acid produced as a result of bacterial

flavor. Product standards for fat, total solids, viscos-

fermentation of lactose under anaerobic conditions

ity, pH (or, titratable acidity) and organoleptic char-

such as in yogurt. Certain yogurt plants prefer to use

acteristics should be strictly followed. Wheying off or

pH in place of TA. There is a correlation between

appearance of watery layer on the surface of yogurt is

%TA and pH. Depending on the milk

solids-not-fat

undesirable and can be controlled by judicious selec-

content of yogurt, a pH of 4.4 approximately corre-

tion of effective stabilizers and by following proper

sponds to 0.85% TA in yogurt processing.

processing conditions.

The current consumer preferred pH for yogurt is

The evaluation of yogurt quality should be approx-

in the range of 4.2–4.4 at D+1 stage of shelf life. If

imately 24 hours (D+1) after packaging. The follow-

incubation is not terminated in time to result in this

ing organoleptic evaluations are generally performed:

pH range at D+1, the lactobacilli may continue to

r Taste—Typical yogurt flavor, fruit

flavor, and

grow well below pH 4.2 during shelf life. When this

mouthfeel. Absence of any off-flavor.

occurs, the streptococci start to disappear, upsetting

r Aroma—Typical yogurt and fruit bouquet.

the optimum bacterial ratio and resulting in a product,

***Table 15.4.** Summary of a Typical Yogurt Plant Quality Tests and Their Purpose*

Incoming Material

Test

Purpose

Milk

Direct microscopic count

Microbiological quality

Sensory (odor, flavor)

General quality

Titratable acidity, freezing point

Freshness, handling practice

depression test, antibiotic

Water adulteration

assay, fat and total solids tests

Insure absence of antibiotics

Temperature

Verify chemical composition

Meet company and Regulatory

requirements

Starter

pH/titratable acidity, direct

Activity and integrity of yogurt culture

microscopic examination

Fruits, nuts, syrups,

Yeasts and molds

Microbial contamination

sweeteners

Osmophilic yeasts

Shelf life of the product

Packaging materials

Sterility testing

Safety/shelf life of the product

Verify printing standards

Check print quality

Fresh Product

Yogurt after 24 hours

pH/titratable acidity

Acidity control

of packaging

Evaluate flavor and texture

Assure sensory quality

Measure Viscosity

Yogurt after packaging

Coliform count

Detecting unsanitary processing or

(Day of

packaging conditions

manufacturing)

Indicator of postpasteurization

contamination

Yogurt 24 hours after

Preincubate product in its

Prediction of Shelf life

packaging (D+1)

container at 30◦C for 24

hours, followed by yeast and

mold count

End of Code (store

Assure quality standards are met at end

shelf life samples at

Sensory

of code

7.2◦C (45◦F)

pH

Observe spoilage

Inline Sampling and

Plant Sanitation

Yogurt mix

Fat and total solids after 10–15

Check on formulation

minutes of agitation.

Yogurt mix in

Titratable acidity/pH

Follow progress and determine end

fermentation tank

point of fermentation

HTST/Filler or

Preincubation followed by

Contamination with Psychrotrophic

packaging

Standard Plate Count and

organisms and general sanitation

machine/glycol or

coliform count

ice water and

equipment surfaces

Environmental air and

Standard Plate Count and

General sanitation practices

water samples

coliform count

Filler Checks

Seals, coding, record weights,

Assure proper filing requirements and

fill temperature

coding

ATP Swabs

Filler

Prestart up sanitation check of yogurt

Fruit hopper and/or blender

contact surfaces

Other contact surfaces

257

258

Part II: Manufacture of Yogurt

which is too high acid and weak in typical yogurt

Microscopic Examination.

Occasionally, the ra-

flavor.

tio of yogurt culture bacteria (S. thermophilus (ST) *and L. delbrueckii ssp bulgaricus (LB)) in the final*

Shelf-Life Test.

As a check for shelf-life quality,

yogurt product should be evaluated to provide the

incubate yogurt cups for 3 days at 30◦C to detect

history of culture performance. This check is also

yeast contamination, and for 7 days at 20◦C for mold *useful to detect slow down in acid production due to*

detection. This will give an indication of consumer

inhibitors or phage attack when one of the yogurt or-

shelf-life issues. For large production runs it is recom-

ganism ST may form abnormal shape and cell counts.

mended to take samples at the beginning, middle, and

end for each flavor. It is also

recommended to store

Microbiological Analysis.

Generally, yogurt is

yogurt cups at 8–10◦C until the end of code life to de-

tested for coliforms, which indicates postpasteuriza-

tect any organoleptic changes in the product. Yeast

tion contamination, since coliforms do not survive

and mold spoilage manifests on the

surface. Yeast

pasteurization. This sanitation test is important in

spoilage appears as colorless, flat, moist colonies and

clearing yogurt for shipping and marketing.

mold spoilage as white or blue-green spots with the

Another test, which has a strong bearing on the

eventual formation of film and overgrowth over the *shelf life of yogurt, is yeast and mold count, espe-*

whole surface. Also, the taste and smell of the product

cially in fruit flavored yogurt. This test should be

might indicate typical bacterial/yeast/mold spoilage

conducted on yogurt samples that have been prein-

or enzymatic degradation. It is important to record

cubated at 30◦C for 24 hours before

plating.

the percentage of spoiled cups at the end of code life.

Sensory Evaluation of Yogurt After 24 hours. *The*

plant should develop a quantitative rating scale on the

Compositional Analysis.

Record the fat and total

basis of marketing product objectives for flavor, con-

solids of plain yogurt and fermented

base before the

sistency, and appearance. It is important to establish

addition of fruit to insure conformation to propri-

the consumer "minimum acceptable" quality level.

etary and regulatory obligations. The fat content is

measured by the AOAC procedure (Horowitz, 2003)

Control of Overrun in Whipped Yogurt.

In the

and the total solids are determined by IDF procedure

production of whipped yogurt, the foam formation as

(IDF 1991b).

a result of aeration of yogurt mix is called overrun.

It is important in giving a fluffy texture to whipped

Viscosity Measurement.

An instrument such as

yogurt and must be controlled during the aeration

penetrometer, Brookfield viscometer, or Rheomat,

process. Overrun (OR) is the volume of yogurt ob-

provides a quantitative value that can be assigned to

tained over and above the volume of yogurt mix used

the viscosity of yogurt. An acceptable range can be

and can be calculated as follows:

established and maintained to help produce a more

consistent body of yogurt from production batch to

% OR = (Volume of whipped yogurt) − (Volume of yogurt mix used)

(Volume of mix used)

batch.

Using Brookfield viscometer, the following proce-

× 100

Equation 15b

dure is suggested:

On weight basis:

1. Temper yogurt sample in the cup to 3.3–4.4◦C.

% OR = (Weight of cup of yogurt mix) − (Weight of cup of whipped yogurt)

(Weight of cup of whipped yogurt)

2. Use Brookfield Viscometer model RVT or equiva-

lent and Spindle #5 at 10 rpm. Attach the spindle.

× 100

Place the yogurt cup on the counter and lower the

spindle through the surface of yogurt to level the

Frozen yogurt.

In the production of frozen yogurt

notch on the spindle to the surface of yogurt.

the overrun (OR) is an important parameter of the

3. Turn the viscometer on.

finished product texture and the overall *eating quality.*

4. Depress the lever after 25 seconds and take the

It can be calculated as shown in the section as above

reading.

for whipped yogurt.

5. Calculate the viscosity (in centipoises) of the sam-

In hard-pack frozen yogurt, a coarse and icy tex-

ple by multiplying the reading with

400.

ture may be caused by the formation of ice crystals

due to fluctuations in storage temperatures. Sandi-

Typically, most commercial yogurts fall within the

ness may be due to lactose crystals resulting from

range of 12,000 cps to 30,000 cps.

too high levels of milk solids. A soggy or gummy

active culture yogurt should undertake their best ef-

defect is caused by too high milk solids-not-fat level

forts to ensure that distribution practices, code dates,

or too high sugar content. A weak body results from

and handling instructions are conducive to the main-

too high overrun, insufficient total

solids or improper

tenance of live and active cultures.

stabilization.

To meet these NYA criteria, live and active culture

Color defects may be caused by the lack of inten-

yogurt must satisfy each of these requirements:

sity or authenticity of hue and shade. Proper blending

1. The product must be fermented with

both L. del-

of fruit preparations and yogurt mix is necessary for

brueckii subsp. bulgaricus and S. thermophilus.

uniformity of color. The compositional control tests

2. For refrigerated yogurt, the total viable count at the

are: fat, total solids, pH, overrun, and microscopic

time of manufacture will be 108 CFU per gram.

examination of yogurt culture to ensure desirable ra-

In the case of frozen yogurt, the total viable count

tio in LB and ST. Also, good microbiological quality

at the time of manufacture will be 107 CFU per

of all ingredients is necessary.

gram.

3. The cultures must be active at the end of the stated

NATIONAL YOGURT

shelf life as determined by the activity test de-

ASSOCIATION CRITERIA

scribed in the NYA "Sampling and Analytical Pro-

FOR LIVE AND ACTIVE

cedures." Compliance with this requirement shall

CULTURE YOGURT

be determined by meeting the criteria for the activ-

ity test on two of the three representative samples

National Yogurt Association (NYA) is a nonprofit

of yogurt, which have been stored at temperatures

association of major yogurt producers in the United

between 0◦C (32◦F) and 7.2◦C (45◦F) for refrig-

States. Their mission is to enhance consumption of

erated cup yogurt and at temperatures

of $-17.8\circ C$

yogurt and to protect consumer perception and in-

(0∘F) or colder for frozen yogurt for the entire

tegrity of yogurt. Accordingly, in the absence of FDA

stated shelf life of the product. The activity test

requirements for quantitative counts of yogurt bacte-

is met if there is an increase of one log during *ria in commercial yogurt, they have established cri-*

fermentation.

teria for live and active yogurt through their seal pro-

4. In the case of frozen yogurt, the product shall have

gram. It should be noted that any yogurt manufacturer

a total titratable acidity expressed as lactic acid of

in the United States may declare “live & active” yo-

at least 0.3% at all times. At least 0.15% of total

gurt culture on the label without using the NYA pro-

acidity must be obtained by fermentation. This is

prietary seal provided that the statement is true and

confirmed by demonstrating the presence of both

not misleading. According to NYA, live and active

D & L forms of lactic acid.

culture yogurt (refrigerated cup and frozen yogurt)

is the food produced by culturing Grade A dairy in-

The applicant should submit samples, each repre-

gredients with a characterizing bacterial culture in

senting a single line of product, ideally taken from the

accordance with the standards of identity for yogurt

beginning, middle, and end of a

manufacturing run

(21 C.F.R. S 131.200), low-fat yogurt (21 C.F.R. S

that demonstrates that the yogurt has met the stan-

131.203), and nonfat yogurt (21 C.F.R. S 131.206).

dard. The samples should be analyzed according to

In addition to the use of the bacterial cultures re-

the following procedures:

quired by the referenced federal standards of identity

and by the NYA criteria, live and active culture yo-

Refrigerated Yogurt

gurt may contain other safe and suitable food grade

bacterial cultures. The NYA offers a trademark seal

1. Total viable yogurt counts will be enumerated by

for use by its members for declaring the presence *the standard procedure (IDF, 2003a, 2003b). The*

of cultures of live and active yogurt cultures on the

total viable count is the sum of colony forming

label.

units of Streptococcus thermophilus and Lacto-

According to the NYA, heat treatment of live and

bacillus delbrueckii subsp. bulgaricus per gram *active yogurt is inconsistent with the maintenance*

of the product.

of live and active cultures in the product. Accord-

2. At the end of the stated shelf life designated by the

ingly, heat treatment, which is intended to kill the live

yogurt manufacturer, activity of the culture will

and active organisms should not be undertaken af-

be reported for at least two of the three random

ter fermentation. Likewise, manufacturers of live and

samples on the NYA "Laboratory Report Form."

260

Part II: Manufacture of Yogurt

The activity test is carried out by pasteurizing 12%

Raw Milk Quality Specifications

solids nonfat dry milk at 92◦C (198◦F) *for 7 minutes,*

It involves several parameters as discussed below.

cooling to 43◦C (110◦F), adding 3% inoculum of the

material under test and fermenting at 43◦C (110)◦F

r Standard Plate Count (SPC) is a measure of the

for 4 hours. The total yogurt organisms in the in-

total bacteria count and measures the overall *oculated milk substrate are to be enumerated both*

quality of milk. High SPC can cause reduced

before and after fermentation by IDF methodology

shelf life of the finished product and off flavors

(2003a).

from enzyme activity and elevated acidity.

The activity test will be reported as log increase in

Federal Standards allow 100,000 CFU/ml

yogurt organisms (CFU/g) following fermentation of

maximum for an individual producer (300,000

the defined substrate under the standard condition at

CFU, commingled). However, some states may

the end of the stated shelf life.

differ. For example, Idaho standard is 80,000

CFU/ml maximum and California standard is

50,000 CFU/ml maximum. It is recommended to

Frozen Yogurt

set the standard at 50,000 CFU/ml.

r

1. The titratable acidity of samples, one each rep-

Coliform Bacteria Count is a measure of milk

resenting beginning, middle, and end of *a man-*

sanitation. High coliform counts reflect poor

ufacturing run, will be determined (IDF, 1991a).

milking practices and unsatisfactory cleanliness

In addition, the manufacturer must certify that at

of the dairy operation. Occasionally, coliform

least 0.15% titratable acidity in the product was *count may indicate sick cows in smaller herds.*

derived from yogurt fermentation.

Coliform is an indicator that food poisoning

2. Total viable yogurt counts will be enumerated by

organisms may possibly be present. There are no

the IDF procedure (2003). The total viable count

Federal Standards for coliform counts in raw *is the sum of colony forming units of Streptococ-*

milk, but California does have a standard for

cus thermophilus and Lactobacillus delbrueckii

coliform (750 CFU/ml maximum). A

subsp. bulgaricus per gram of the product.

recommended standard is 500 CFU/ml.

r

3. At the end of the stated shelf life *designated by*

Laboratory Pasteurized Count (LPC) is a measure

the manufacturer, activity of the culture will be

of heat-stable bacteria, which may survive

reported for at least two of the three random sam-

pasteurization. It is performed by heat-treating

ples.

laboratory samples to simulate batch

pasteurization at 62.8◦C for 30 minutes and

The activity test is carried out by pasteurizing 12%

enumerating the bacteria that survive using the

solid nonfat dry milk at 92◦C (198◦F) for 7 minutes,

SPC method. High LPC results indicate potential

cooling to 43◦C (110◦F), adding 3% inoculum of the *contamination from soil and dirty equipment at*

material under test and fermenting at 43◦C (110◦F)

the dairy. High LPC will cause reduced shelf life

for 4 hours. The total yogurt organisms in the in-

of finished products. Bacillus cereus is a common

oculated milk substrate are to be enumerated both

soil microorganism that can survive

pasteurization

before and after fermentation by IDF methodology

resulting in a high LPC. There are no Federal

(2003).

Standards for LPC. However, California standard

The activity will be reported as Log increase in

for LPC is 750 CFU/ml maximum.

yogurt organisms (CFU/g) following

fermentation of

A recommended standard is 500 CFU/ml.

the defined substrate under the standard conditions at

r Preliminary Incubation (PI) count is a measure

the end of the stated shelf life.

of bacteria that will grow in refrigerated

conditions. The test requires holding the sample *at 10◦C for 18 hours followed by a Standard*

SPECIFICATION PROGRAM

Plate Count (SPC) test. PI type of bacteria will

A specification program should include parameters

be destroyed by pasteurization but can still

for raw materials, ingredients, and packaging mate-

result in lower quality milk due to enzymatic *rials as well as the product formulation, processing*

activity on the protein. High PIs (3- to 4-folds

steps and plan of control in the plant. It should also

higher than SPCs) are generally associated with

cover, milk receiving, HACCP, and rework controls,

inadequate cleaning and sanitizing of either the

and product storage and shipping. As

an example, the

milking system or cows and/or poor milk

specification for milk is shown below.

cooling.

There are no Federal Standards for PI results in

A recommended standard is that no off flavor ex-

raw milk. Since the type of bacteria and the initial

ists.

count of the SPC may vary, it is not possible to set

r Appearance is not a measured criterion but is as

a numerical standard for this test although counts

important as flavor for indications of quality.

higher than 50,000 CFU/ml are excessive for both PI

There are no federal standards for appearance.

and SPC. A recommended standard is less than two

Most receiving plants will note any color or

times the SPC count.

debris defect in the milk before accepting it. A

r Somatic Cell Count (SCC) is a measure of the

recommended standard is "White, clean, no *white blood cells in the milk that is used as an*

debris, and filter screen of two or less (sediment

indicator of herd health. High SCCs are

test)".

undesirable because the yield of all cultured

r Antibiotics and other drugs may not be present in

products is proportionally reduced, the flavor *milk. All raw milk must conform to Grade A law.*

becomes salty, development of oxidation

To be considered organic, no milk can be used

increases, and it usually relates to higher SPC in a

from a cow that has been treated with antibiotics.

time-lag process. Staphylococci and streptococci

For conventional milk, a treated cow

will be withheld

are heat-tolerant bacteria that normally cause

from the milking herd for about 5 days.

mastitis. Coliform bacteria that are easily killed

by heat may also cause mastitis. Federal

r Added Water is an adulteration. Testing the

Standards allow 750,000 Cells/ml maximum.

freezing point of milk using a cyroscope

State standards vary. For example, Idaho standard

indicates if abnormal amounts of water exist in

is 750,000 Cells/ml maximum and California

the load. In most states it is illegal to have a

standard is 600,000 Cells/ml maximum. A

freezing point above −0.530 Horvet

scale. A

recommended standard is 500,000 Cells /ml.

recommended standard should be −0.530 Horvet

r Titratable Acidity (TA) is a measure of the lactic

or less.

acid in milk. High bacteria counts will produce

r Sediment is measured by drawing 1 pint of sample *lactic acid as the bacteria ferment lactose.*

through a cotton disk and assigning a grade of 1

Elevated temperatures for extended time will

(good) to 4 (bad) to the filter. A grade of 1 or 2 is

allow the bacteria to grow quickly and generate a

acceptable. A processor also may monitor for

higher TA value. The normal range is

sediment by screening the entire load through a

0.13–0.16%. Lower values may indicate that

3-inch mesh filter at the receiving line. There are

alkaline/ buffering chemicals are added to the

no federal standards. Most receiving plants should

milk. A recommended standard is

require a filter grade of 1 or 2 although 3 may be

0.13–0.16%.

accepted.

r Temperature According to Federal Law, the

A recommended standard is “No excessive mate-

temperature of milk must never exceed

rial in a 3-in. sani-guide” filter.

7.2◦C. A recommended standard is 5.2◦C or

r

less.

Fat and milk solids-not-fat (MSNF) Milk is

r Flavor is an important indicator of quality. The

composed approximately of 88% water, 3.5% fat,

milk should be fresh, clean and creamy. Elevated

5.0% lactose, 3.5% protein, and < 1% of minerals.

bacteria counts can produce off flavors (i.e., acid, *MSNF is the percentage of total milk solids*

bitter). Feed flavors may vary from sweet to bitter

minus the fat portion. The Standard of Identity for

and indicate the last items in a cow's diet such as

milk is 3.25% fat and 8.25% MSNF. This is the

poor feed, weeds, onion, or silage. Elevated

recommended standard.

somatic cell counts will render milk taste salty

and watery. Water in the milk will taste weak.

Dirty, "barny," and "cowy" flavors occur from

Process and Product Specifications

sanitation conditions and air quality at the dairy

Process and product specifications pertain to formu-

farm. Oxidized or rancid flavors occur from *lation, target processes, and a process plan of control.*

equipment operation and handling.

A manual for the plant should detail finished prod-

There are no federal standards for flavor. All re-

uct characteristics, establish a target value, accept-

ceiving plants should flavor milk (laboratory pasteur-

able limits, and rejection values. The manual should *ized) for defects before accepting it.*

include equipment and processing parameters, plan

***Table 15.5.** Defects in Yogurt and Their Causes*

Defect

Causes

Whey separation

Low-fat content

Wrong choice of modified starch

Insufficient heat treatment of milk

Heating or disturbing the coagulum during

incubation or thereafter

Addition of rennet

Insufficient acid formation, e.g., pH 4.8

High incubation temperatures or too fast incubation

High acidification before cooling, resulting in too low pH in

finished product

Mechanical shaking of the gel

Low solids content in the mix

Air incorporation in the stirred yogurt

Poor culture

Weak body

Too low pasteurizing temperature and time

Too fast incubation

Poor culture

Too strong stirring of the gel or abuse in pumping

(high shear)

Low solids content of yogurt

Insufficient or improper addition of the stabilizer

Low protein content of the milk

Mechanical shaking of the gel before completed coagulation

Sandy/Grainy body

Poor culture

Severe heating of the milk causing unstable casein

Homogenization of the mix at high temperature and pressure

Excessive addition of nonfat dry milk

Vibration during incubation

Too fast set or incubation

Containers disturbed before sufficiently cooled

Excessive inoculation rate

Poor distribution of starter

Wrong type of modified starch

“Ropy”

Addition of slime producing strains of yogurt culture

Too low incubation temperature in the production

of the yogurt

Gummy

The use of unsuitable stabilizer

Faulty incorporation of stabilizers

Excessive addition of stabilizers

Slow acid development

Culture imbalance

Too low pasteurizing temperature

Too low incubation temperature

Insufficient inoculum

Weak cultures

Too high sugar

Inhibitors/antibiotics in milk supply

Phage infection

Fruity/fermented/yeasty flavor

Growth of microbial contaminants

Oxidized flavor

Effect of exposure to light

Metal catalyst

(Continued)

Table 15.5. *(Continued)*

Defect

Causes

Lacking in flavor

Culture imbalance

Starter growth slowed due to too low heat treatment

Bitter/ off flavor

Culture imbalance (too many lactobacilli)

Poor quality milk

Microbiological contamination.

Poor quality flavoring used

Color of flavoring fading

Microbiological contamination

Heavy metal contamination

Color unstable at low pH

of controlling them, and finished packaging param-

r Absolutely clean processing and packaging

eters. In addition, the manual should include quality

equipment.

control test methods and procedures, as well as clean-

r Proper inoculation of active pure cultures.

ing and sanitizing procedures.

r Maintenance of proper incubation time and

Similarly, specifications should be set up for fruit

temperature.

preparations, dairy ingredients, and dry milk (DMI,

r Use of high-quality ingredients and flavors.

2003) (Chapter 9, 10, and 11, respectively).

r Storage of yogurt in a temperature below 4◦C.

Weight Control Program.

To conform to weights

REFERENCES

and measure regulations, it is imperative to set up

a program on the basis of tolerances of the yogurt

Chandan RC. 1997. Dairy-Based Ingredients. Eagan

fillers. Based on the variations in the *weight of filled*

Press, St. Paul, MN. pp. 48–49.

cups from the weight set on the filling machine, a

Chandan RC, Shahani KM. 1993. Yogurt. In: YH Hui

statistical model is set up to calculate standard devia-

(Ed), Dairy Science and Technology Handbook,

tions for the weights of product contained in the cups.

Vol. 2. VCH Publishers, New York, pp. 1–56.

Final setting on the filler is then made to achieve a

Chandan RC, Shahani KM. 1995. Other fermented

given confidence limit, say 95–99% confidence level.

dairy products. In: G Reed, TW Nagodawithana

To minimize give away of the product, some compa-

(Eds), Biotechnology, Vol. 9, 2nd ed.

VCH

nies decide to set up fillers to deliver the weight de-

Publishers, Weinheim, Germany, pp. 386–418.

clared on the cup plus two standard deviations, giving

Christen GL. 1993. Analyses in Dairy Science and

95% confidence limits.

Technology Handbook vol. I. Y.H. Hui, Editor. VCH

Publishers, Inc. N.Y. pp. 83–156.

Dairy Management, Inc. (DMI). 2003. Concentrated

DEFECTS AND TROUBLE

and Dry Milk Ingredients. Dairy Ingredient

SHOOTING

Application Guide. Chicago, IL.

Horowitz W. 2003. Official Methods of Analysis, 17th

When using poor ingredients or improper process-

ed., 2nd Rev. AOAC International, Gaithersburg,

ing methods or improper formulation, several de-

MD.

fects can develop in the finished yogurt. Some of the

International Dairy Federation. 1991a. Yogurt:

more common defects and their causes are shown in

Determination of Titratable Acidity. IDF/ISO/AOAC

Table 15.5.

Standard 150:1991.Brussels, Belgium.

Finally, in the consistent manufacture of high-

International Dairy Federation. 1991b. Yogurt:

quality yogurt, it is important to give full considera-

Determination of total solids content.

tion to the following key areas:

IDF/ISO/AOAC Standard 151:1991. Brussels,

r

Belgium.

The use of high-quality milk with adequate

International Dairy Federation. 2003a. Yogurt:

protein content.

r

Enumeration of characteristic

Correct heat treatment and homogenization of *microorganisms-Colony Count Technique at 37◦C.*

yogurt mix.

IDF 117/ISO 7889 Standard, Brussels, Belgium.

International Dairy Federation. 2003b. Yogurt:

United States Department of Health and Human

Identification of characteristic

microorganisms

Services, Public Health Services, Food and Drug

(Lactobacillus delbrueckii subsp. bulgaricus and

Administration. Grade "A" Pasteurized Milk

Streptococcus thermophilus. IDF 146/ISO 9232

Ordinance. 1999 Revision. Publication no. 229.

Standard 150:1991.

Washington, DC.

Marshall, RT (Ed). 1993. Standard Methods for the

United States Department of Health and Human

Examination of Dairy Products. 16th ed. American

Services, Public Health Services, Food and Drug

Public Health Association, Washington, DC.

Administration (USDHHS FDA). 2003. Code of

Tamime AY, Robinson RK (1999). Yogurt Science &

Federal Regulations. Title 21. Section 131. US

Technology, 2nd ed. Woodhead Publishing Limited,

Government Publishing Office. Washington, DC.

Cambridge, England and CRC Press, Boca Raton,

USDHHS, FDA Revised April 1,

FL.

2003.http://www.cfsan.fda.gov/~1rd/FC

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

16

Sensory Analysis of Yogurt

Yonca Karagül-Yüceer and MaryAnne Drake

Introduction

quality is evaluated on the basis of reference to the

Sensory Analysis Techniques

individual's ideal product. In the case of grading a

Sensory Analysis of Yogurt

grade is issued; in the case of judging a numerical

Conclusions

quality score is issued.

References

Grading is still conducted by the US Depart-

ment of Agriculture through the Agricultural Market

INTRODUCTION

Service (www.ams.usda.gov). Any dairy product can

theoretically be graded,;however, grading has tra-

Sensory qualities (flavor and texture/mouthfeel) are

ditionally been conducted on Cheddar cheese, but-

crucial for consumer acceptance. As such, under-

ter, and skim milk powder. Standards also exist for

standing and measuring sensory properties of dairy

whey and buttermilk powder, condensed milk; and

products is important. Although sensory science is a

Swiss, Emmentaler, Colby, Monterey Jack, and bulk

relatively young field (ca 1940), the

importance of

American cheese. Specific grading criteria do not ex-

flavor and texture to the consumer has existed since

ist for other dairy products; however, they may still

products were first traded and sold in the market-

receive a USDA quality approval rating. The USDA

place. This chapter will focus on a brief review of *quality approval rating can be used on retail pack-*

sensory techniques followed by specific applications

aging as with USDA grades and is based on USDA

to yogurt and other fresh fermented dairy products.

inspection of the product and facility where it was

produced. A set of standards for yogurt to receive

SENSORY ANALYSIS

the USDA Quality Approved Inspection Shield was

TECHNIQUES

published by the AMS in 2001 (www.ams.usda.gov).

The primary function of grading is to provide a

The dairy industry has long recognized the impor-

specific set of criteria for quality, which can be ap-

tance of sensory quality and developed tools to assess *praised by an impartial individual (USDA grader).*

these parameters before mainstream sensory science

Such criteria can be useful for marketing products

evolved. These traditional tools are grading and judg-

and promoting product uniformity. A list of defects

ing of dairy products (ADSA, 1987; Bodyfelt et al.,

and grading criteria for skim milk

powder are listed

1988). Both of these tools are still used today for

in Table 16.1.

specific applications in the industry. These tools are

The flavor and texture guidelines published for yo-

not advised for research and product development, as

gurt are listed in Table 16.2. These criteria are gen-

they are not quantitative nor completely qualitative in

eral, and not specific. Products can have quite a dis-

nature (Drake 2004; Singh et al., 2003). Both grading

tinct flavor and/or texture properties and still receive

and judging were developed in the early 1900s (1913

uniform grades. This discrepancy has been demon-

and 1916, respectively) and were

designed to rapidly

strated with Cheddar cheese and skim milk powders

assess the overall product quality based on the pres-

(Drake, 2004). This does not devalue the applica-

ence or absence of predetermined defects. Product

tion of grading to the industry uniformity, but it does

Table 16.1. *US Standards for Grades of Nonfat Dry Milk (Spray Process).*

Ideal Flavor—Reconstituted nonfat dry milk shall possess a sweet, pleasing, and desirable flavor, but may possess slight intensities of the following attributes: Cooked, feed, flat and chalky Flavor Defect

US Extra Grade

US Standard Grade

Bitter

Not permitted

Slight

Chalky

slight

Definite

Cooked

slight

Definite

Feed

slight

Definite

Flat

slight

Definite

Oxidized

Not permitted

Slight

Scorched

Not permitted

Slight

Storage

Not permitted

Slight

Utensil

Not permitted

Slight

Not permitted—sensory attribute not allowed in product for this grade; slight—slight intensity allowed for this grade; definite—

definite intensity allowed for this grade
www.ams.usda.gov

mean that grading is not an appropriate tool for prod-

receive identical or very similar quality scores and yet

uct research where very subtle differences can impact

still display very distinct specific flavor and/or texture

experimental conclusions and consumer acceptance.

differences that the scoring criteria do not take into

Dairy products judging or scorecard

judging was

account. Scores are not uniformly spaced or assigned

developed to stimulate and promote student inter-

and thus cannot be subjected to parametric statistical

est in sensory quality of dairy products. Similar to

analysis. Finally, judgments are generally made by a

grading, products receive a score based on the pres-

few individuals, typically one or two and are not repli-

ence or absence of specific defined defects (Bodyfelt

cated. Even highly experienced or trained individuals

et al., 1988). Butter was the first product included in

can vary from day-to-day in their sensory acuity and

the contest. Today, six products are evaluated includ-

judgment. As a result, larger numbers

of panelists are

ing strawberry yogurt. A list of judging criteria for

recommended for sensitive, reproducible results. Al-

strawberry yogurt are listed in Table 16.3. As with

though the use of both grading and judging, as well

grading, product judging is a useful skill and can

as other overall quality-based analysis criteria can *provide valuable insight when troubleshooting in a*

be found in research literature and will be addressed

manufacturing facility. Neither of these approaches

in this chapter, mainstream sensory techniques have

are optimal tools for product research for several rea-

great and powerful application to dairy products re-

sons. Quality scores generated are not *discriminating*

search and should be used.

of subtle differences (both qualitative and quantita-

Grading and dairy products judging were de-

tive) among products. This means that products may

veloped in the United States. The International

***Table 16.2.** Quality Guidelines for USDA Specifications for Yogurt*

Flavor

Shall possess a clean acid flavor, free from undesirable flavors such as bitter, rancid, oxidized, stale, yeasty, and unclean. Flavoring ingredients shall be uniformly distributed, flavor shall be pleasing and characteristic of the flavoring used. Flavor shall not be harsh or unnatural.

Body/texture

Shall possess a firm, custard-like body with a smooth homogenous texture. A spoonful shall maintain its form without displaying sharp edges, flavoring ingredients shall be uniformly distributed throughout the *product.*

Color/appearance

Shall present a clean, natural color with a smooth velvety appearance. Unflavored yogurt may be a bright white to off-white color. Surface should appear smooth and not exhibit excess whey separation or surface growth or discoloration. Flavoring ingredients shall be uniform in size, distribution, and color.

www.ams.usda.gov

Table 16.3. *Quality Judging Criteria for Strawberry Yogurt—Approved by the American Dairy Science Association*

Attribute

Defects

Scoring

Appearance

Atypical color

Perfect score (no defects) is 5

Color leaching

Different deductions are subtracted based on the

Excess fruit

specific defect and the intensity (slight, definite,

Lacks fruit

or pronounced) of the defect

Lumpy

Free whey

Shrunken

Surface growth

Body/texture

Gel-like

Perfect score (no defects) is 5

Too firm

Different deductions are subtracted based on the

Weak

specific defect and the intensity (slight, definite,

Grainy

or pronounced) of the defect

Ropy

Flavor

High acid

Perfect score (no defects) is 10

Low acid

Different deductions are subtracted based on the

Acetaldehyde

specific defect and the intensity (slight, definite,

Cooked

or pronounced) of the defect

Lacks fine flavor

Too high flavor

Unnatural flavor

Lacks sweetness

Too sweet

Stabilizer flavor

Lacks freshness

Unclean

Oxidized

Rancid

Storage

Source: Bodyfelt et al., 1988.

Dairy Federation has also developed a quality-based

2 considerable deviation from the preestablished

method for sensory evaluation of fermented dairy

sensory specification

products (IDF, 1997), which covers the evalua-

1 very considerable deviation from the

tion of appearance, consistency, and flavor (Table

preestablished sensory specification

16.4). Products are given scores based on their vari-

0 unfit for human consumption

ability from a previously established specification.

1. The evaluation of appearance can be carried out

A numerical interval scale is used to

demonstrate

simultaneously by the whole panel with separate

the magnitude of the possible deviation from the

scoring; involving the filling and the surface of the

preestablished sensory product specification. The fol-

product, color, visible purity, presence of foreign

lowing scale shows the magnitude of the deviation for *matters, spots of mold, seepage of whey, and phase*

each attribute in scoring:

separation. The evaluation is made by examination

Points

in the opened package, if necessary by pouring out

the product from the package.

5 conformity with the preestablished sensory

2. The evaluation of consistency

involves thick-

specification

ness, stickiness, and coarseness. Evaluation can

4 minimal deviation from the preestablished

be made by blending the product with a (black)

sensory specification

spoon before evaluating the sample in the mouth.

3 noticeable deviation from the

preestablished

3. The evaluation of flavor is made by smelling and

sensory specification

tasting the product.

Table 16.4. *Fermented Milk Product Quality Terms*

Appearance

Consistency

Flavor

Overfilled

Setting

Watery

Underfilled

Lumps or flakes

Flat

Shrunken

Dripping

Bitter

Heterogeneous surface

Uneven

Cooked

Untypical color

Gritty

Burnt

Brown color

Sticky

Smoked

Non-uniform color

Too thick

Oily

Marbled

Too fluid

Chemical flavor

Air bubbles

Ropy/stringy

Feed flavor

Foreign matter

Dried

Foreign flavor

Separation of whey

Brittle

Light-induced flavor

Mould

Gelatinous

Defective aromatization

Yeast

Defective ingredients

Separation of phases

Cheesy

Sedimentation

Malty

Lack of, or poor distribution

Metallic

of ingredients

Musty

Oxidized

Acid

Sharp

Harsh

Sour

Tallowy

Yeasty

Rancid

Astringent

Unclean

Stale/old

Too sweet

Too salty

Soapy, alkaline

Source: IDF, 1997.

The IDF quality terms developed for fermented

between samples? These tests are often used to de-

milk products are listed in Table 16.4.

termine the effect of specific processing parameters

Mainstream sensory techniques, applicable to all

or ingredient substitutions. They can

provide useful

products, both food and nonfood items, include a va-

information when a trained descriptive panel is not an

riety of tools to explore and define sensory properties

option. Two common examples are the triangle test

and consumer perceptions. These groups of tools are

and the duo–trio test. Both tests are designed to com-

comprised of two basic groupings: analytical and af-

pare two products at a time (as are most difference

fective tests. Several comprehensive textbooks are

tests). If more than two products or treatments are

available on these topics (Lawless and Heymann,

involved, multiple pairwise comparisons will need

1998; Meilgaard et al., 1999).

Analytical tests in-

to be conducted. The triangle test involves the pre-

volve the use of screened or trained panelists whose

sentation of three randomly coded products. Two of

responses are treated as instrumental data. Such tests

the products are the same; one is different. The pan-

include discriminatory tests (difference and thresh-

elist is asked to indicate which of the three products

old) and the most powerful tool in the sensory arse-

is different. For the duo-trio test three products are

nal: descriptive analysis.

presented as with the triangle test, but one of the

Discrimination tests comprise of tests that are de-

products is labeled as a reference, and the panelists *signed to answer the question: Does a difference exist*

are asked to choose the product that is the same as

the reference. Correct results are tabulated and a bi-

requires a descriptive technique and a lexicon or

nomial calculation or statistical tables (provided in *language to describe the sensory properties. There*

most sensory textbooks) are used to determine if a

are several valid approaches to descriptive analysis

significant difference exists. A minimum of 15 in-

(Murray et al., 2001; Drake and Civille, 2003). These

dividuals are recommended for these tests and the

approaches include flavor profile

method, quantita-

discriminatory power is improved if larger numbers

tive descriptive analysis (QDA), the Spectrum tech-

are used. Several things are important to note about

nique, and other techniques, which have been taken

these types of tests. First preference or acceptance

from two or more parts of the previous methods. Sen-

questions are not asked in conjunction with a differ-

sory languages can be identified for any dairy food

ence determination. Such a question is meaningless

and/or dairy food property of interest using any of

as panelists do not even know if the product they

these approaches. Many sensory languages have been

choose is actually the different

product. Second, dif-

identified for cheeses (Delahunty and Drake, 2004),

ference tests provide evidence that a difference exists

and sensory languages have also been developed for

between products. They do not provide information

fluid milk (Chapman et al., 2001), dried dairy in-

on the type of difference nor the amount of differ-

gredients (Drake et al., 2003), and chocolate milk

ence. Finally lack of a statistical difference does not

(Thompson et al., 2004).

mean that two products are identical.

Panelist selection scales and scale usage, and train-

Attribute difference tests can be applied when more

ing are critical parts of any descriptive analysis *specific information is desired, but again extensive*

approach. These specifics are reviewed elsewhere

panel training is not an option. Some examples in-

(Drake and Civille, 2003; Meilgaard et al., 1999).

clude paired comparison tests and ranking tests. A

A panel or a group of individuals (generally 8–12)

paired comparison test allows

comparison of one par-

is used for descriptive sensory analysis rather than

ticular attribute between two samples. Ranking tests

one or two experts. A panel of individuals is used as

involve ranking a group of products based on the in-

factors such as age, saliva flow, and onset of fatigue

tensity of a single selected attribute (highest to low-

vary between them. Panelists also vary in sensitiv-

est, most to least). An example would be ranking a

ity to a particular stimuli, and it is highly probable

set of yogurts based on perceived thickness. Distinct

that they also vary in their concentration response

differences for a particular attribute can be provided

functions. Panelists, even highly

trained panelists or

but results are not quantitative. How close the prod-

experts, can vary in sensory function daily. Thus, a

ucts are to one another in that particular attribute is

group or panel is used rather than one or two in-

not known. Numbers of panelists used are similar

dividuals for consistent results. Training a descrip-

to those used for difference tests. Threshold tests can

tive panel requires time, persistence, practice, and

be used to determine the concentration of a particular

group effort. The amount of time varies with the

compound (such as a desirable or undesirable flavor

modality and number of attributes. Visual attributes

of a particular ingredient) that can be *added for sen-*

are generally quicker to train than texture attributes,

sory detection. There are several types of thresholds

which are generally quicker to train than flavor or

and the reader is referred to a sensory textbook for

odor attributes. Trained panelists are components of

complete definitions. Testing for thresholds are more *the sensory instrument (the panel). Thus, replication*

time-consuming than other discriminatory tests pri-

by each panelist is required for statistical analysis

marily because to obtain a realistic threshold, large

of results. Trained panelists as instrumental compo-

numbers of panelists are required (at least 50) and

nents are not consumers. Thus, liking

and preference

testing must cover the threshold range, which re-

measurements from these individuals have little or

quires multiple presentations. Difference, ranking,

no meaning. Descriptive sensory analysis provides a

threshold, and paired comparison tests can be used as *powerful platform for enhanced product understand-*

stand-alone sensory tools to solve research problems

ing, identifying chemical sources of specific flavor,

but they can also be used as quick preliminary tests

and understanding consumer results.

prior to descriptive sensory analysis.

Affective tests involve the use of untrained con-

The purpose of descriptive analysis is to train

sumers and measure consumer responses. Such tests

a group of individuals to evaluate specific sensory

evaluate consumer liking, attitudes, and perceptions.

properties analytically. Descriptive analysis is the

Focus groups involve qualitative analysis of con-

tool of choice for qualitatively and

quantitatively dif-

sumer perceptions, whereas quantitative question-

ferentiating foods. Descriptive analysis of any food

naires and ballots can be used to probe consumer

intensity and liking of specific attributes and/or con-

2004; Thompson et al., 2004; Hough

and Sánchez,

cepts. Focus groups involve guided discussion with

1998; Richardson-Harman et al., 2000). Similar

small groups of screened and selected consumers

approaches can be used to explore sensory and in-

(n = 10–12). The moderator is experienced in guid-

strumental relationships.

ing such discussions. Sessions are generally observed

through a two-way mirror or are taped for transcrib-

SENSORY ANALYSIS OF YOGURT

ing and observation of nonverbal as well as ver-

bal cues from participants. Focus groups can pro-

Several studies have addressed sensory properties of

vide powerful qualitative information for marketing, *yogurts. Quality judging, although far from ideal,*

product development, and product positioning. They

has been used prevalently (Tamime and Robinson

are not used often for research. Quantitative ques-

1987). Karagül-Yüceer et al. (1999) investigated sen-

tionnaires and ballots probing liking and other at-

sory properties of sweetened low fat

(1%) plain yo-

tributes are most commonly used in product research.

gurt and Swiss-style strawberry and lemon yogurts

A large number of consumers need to be polled if

with/without carbon dioxide treatment. Stored yo-

a reasonable projection of consumer response is to

gurts were evaluated for flavor and texture quality *be obtained. A minimum of 50 (untrained) individu-*

after 7, 21, and 45 days refrigeration. Preference test-

als is recommended for these types of evaluations,

ing with consumers was subsequently used to deter-

and more commonly 100 or more individuals are

mine preference. McGregor and White (1986) like-

polled. Acceptance and consumer

perception of spe-

wise used dairy product judging to evaluate flavor

cific product attribute intensities can be quantitatively

and texture quality of fruit flavored yogurts with dif-

measured using line or category scales (Lawless and

ferent sweeteners. Farooq and Haque (1991) used

Heymann, 1998). The 9-point hedonic scale is by *quality judging to demonstrate that sucrose esters im-*

far the best-known and established scale for measur-

proved quality of nonfat low calorie yogurt. Penna et

ing consumer responses. Following analysis of vari-

al. (1997) used sensory quality assessments of ap-

ance, product preference can be inferred from specific

pearance, texture, and flavor to

optimize the amount

differences in product liking. Alternatively, prefer-

of whey powder that could be added to yogurts with-

ence can be directly determined using a preference

out detrimental sensory effects. Quality assessments

question. Numerous questions including overall ac-

were used to determine sensory properties of plain *ceptance, liking, and intensity perception of specific*

yogurts with added oat fiber and fructose (Fernandez-

product attributes and preferences can be asked on

Garcia et al., 1998), drinkable yogurts (Penna et al.,

one consumer ballot. As mentioned previously, mea-

2001), the effect of milk somatic cell counts (Oliviera

suring hedonic responses of a trained

panel provides

et al., 2002), and to characterize application of butter-

little useful information and violates the basis for both

milk powder in yogurts (Trachoo and Mistry, 1998).

analytical and affective testing. They are different

Discrimination tests have been used to identify the

types of tests and use different groups of respondents.

effects of specific parameters. Triangle tests followed

Consumers provide information on product likes

by consumer testing were applied to evaluate sensory

and dislikes. Understanding what specific product

properties of yogurts with and without added fiber

attributes drive their likes and dislikes requires the

from different sources (Dello Staffolo *et al., 2004).*

application of descriptive analysis as well as con-

Pairwise difference tests were conducted to estab-

sumer testing. This approach is called preference

lish if differences existed between products with and

mapping. Preference mapping is a commonly used

without added fibers. Subsequently, consumers eval-

tool in understanding the descriptive sensory at-

uated overall acceptance of products. Triangle tests

tributes that drive consumer preferences (McEwan,

were also used to determine the effects of different

1996; Schlich, 1995). The procedure requires an

high-pressure treatments on yogurt mix prior to fer-

objective characterization of product

sensory at-

mentation (de Ancos et al., 2000), to determine the

tributes, achieved by descriptive analysis, which is

effect of carbon dioxide treatment of milk used for

then related to preference ratings for the product ob-

yogurt (Gueimonde et al., 2002), and to evaluate the

tained from a representative sample of consumers *effect of pasteurization and the addition of hydrogen*

(Murray and Delahunty, 2000). Both internal and

peroxide on labneh (strained or concentrated yogurt)

external preference mapping techniques have been

quality (Dagher and Ali, 1985).

implemented in a number of studies with a variety

Descriptive analysis has also been recently ap-

of products, including dairy products (Young et al.,

plied to yogurts. Al-Kadamany et al. (2003) used a

panel trained to score the intensity of yeasty flavor to

in other studies they have been defined and references

determine the shelf life of labneh. To conduct the *provided (Table 16.6). The use of specific definitions*

sensory analysis, seven panelists (four females, three

and references greatly enhances the application and

males; age 22–32 years) were selected. The panelists

the ability to reproduce published results. Drake et al.,

were served with commercial labneh samples, stored

(1999) used descriptive analysis of

aroma to char-

for different periods of time, and asked through group

acterize the sensory impact of different lactobacilli.

discussion to determine and agree on sensory fail-

The effect of varying levels of sugar (18, 20, 22%)

ure attributes. During training sessions, yeasty fla-

and fruit concentrations (15, 20, 25%) on the sensory *vor was detected at an earlier stage than yeasty odor.*

properties of frozen yogurt was investigated (Guven

Thus, yeasty flavor was selected as a key attribute

and Karaca, 2002). Sensory evaluation of the prod-

for determining labneh quality. Panelists were then

ucts was performed on a 20-point scale by five ex-

trained to rate the intensity of yeasty *flavor. At each*

perienced panel members. The attributes asked for

sampling time, panelists were presented with a fresh

panelists to evaluate were "color and appearance,"

sample labeled a control, fresh sample designated as

"structure and consistency," "taste and smell," and

a control, duplicate samples from a stored pack, and *"totals." The results indicated that frozen yogurts*

a blind control coded with three-digit random num-

with 25% strawberry, 20% sugar, and 22% sugar had

bers. Panelists used a 7-point intensity scale to rate

the potential for consumer acceptance.

the magnitude of difference of yeasty flavor of the

Skriver et al. (1999) investigated the sensory tex-

coded samples from the fresh control product.The

ture and instrumental rheological characteristics of

shelf life of labneh ranged between 18.5 and 18.9; 8

stirred yogurts varying in fermentation temperature,

and 9.5; and 2.7 and 3.1 days at 5◦C, 15◦C, and 25◦C,

heat treatment of milk, dry matter content, and com-

respectively.

position of bacterial cultures. Basically two sen-

In many cases, sensory attributes evaluated are pro-

sory texture attributes, nonoral and oral viscosity,

vided but have not been defined (Table 16.5), whereas

were evaluated. For sensory analysis a modified

***Table 16.5.** Sensory Descriptors Used for the Characterization of Fermented Milks and Yogurts for Which Definitions and References Were not*

Published

Appearance and

Odor

Texture on the Spoon

Flavor/Taste

Mouthfeel

Aftertaste

Intensity

Yellowish

Intensity

Light

Persistent

Milky

Bubbles

Creamy

Thick

Milky

Yogurt

Heterogeneous

Buttery

Floury

Sour milk

Cottage cheese

Compact

Cottage cheese

Sandy

Acid

Sour milk

Lumpy

Acid

Small lumps

Lemon

Pungent

Thick

Sweet

Graininess

Astringent

Onion

Smooth/coarse

Cooked

Firm

Bitter

Cooked

Bitter

Slimy

Acid

Astringent

Creamy

Sulfur

Sour milk

Smoothness

Acetaldehyde

Sour

Sharp

Watery

Fruity

Flat

Unclean

Yogurt

Diacetyl

Grassy

Cheddar

Fresh

Sweet

Bland

Sweaty

Old ingredient

Bandaid

Fusel oil

Whey

Source: Ott et al., 2000; Drake et al., 1999; Biliaderis et al., 1992; Lorenzen et al., 2002; Lee et al., 1990; Modler et al., 1983.

Table 16.6. *Sensory Attributes and References Used to Describe Sweetened Unflavored and Flavored Yogurts*

Attribute

Reference

Color (light to dark)

Visual appearance ranging from light to dark, plain low-fat

yogurt is the light reference

Dairy aroma/flavor

Plain low-fat yogurt

Dairy/culture

Buttermilk

Acid/sharp

Lactic acid

Acetaldehyde

0.66 and 2 ppm acetaldehyde in milk

Cooked milk

2% milk heated to 90◦C for 30 seconds

Caramel

Kraft caramels

Milky

2% milk

Buttery

Butter

Cheesy

Parmesan cheese

Yeasty

0.1% baking yeast in water

Fruity/sulfur

Cantaloupe

Rotten/sulfur

Boiled eggs

Creamy

Whipping cream/fat-free cream cheese

Sour cream

Sour cream

Cottage cheese

Low-fat cottage cheese

Fresh fruit strawberry (strawberry yogurt)

Fresh frozen strawberries

Jammy strawberry (strawberry yogurt)

Smuckers strawberry jam

Artificial strawberry (strawberry yogurt)

Premixed strawberry Koolaid

Fresh lemon (lemon yogurt)

Fresh wedge of lemon

Lemon juice (lemon yogurt)

Lemon juice

Artificial lemon (lemon yogurt)

Lemon jello

Metallic

Ferrous sulfate −0.1% in water

Chalky

Amount of chalk-like particulates

perceived in the mouth,

reference is yogurt with 7% added soy protein concentrate

Ropy

The degree to which a strand/rope forms when a spoon is

dipped into the product and slowly pulled out

Thickness

Force required to push tongue up through product against

palate and then back down

Sweet (sucrose)

Sucrose −7.3% in water, 5 and 10% sucrose in water

Sweet (aspartame) (APM)

APM −400 ppm in water

Bitter

Caffeine, 0.08% caffeine in water

Sour

Lactic acid, 0.32% lactic acid in water, 0.08 and 0.15%

citric acid in water

Salty

0.2% NaCl in water

Astringent

Alum −0.1% in water, soak 10 tea bags in 1 qt boiling

water for 1 hour

Aftertaste (after 30 seconds)

Overall aftertaste-driven by APM

Source: Harper et al., 1991; King et al., 2000; Barnes et al., 1991a; Drake et al., 2000.

quantitative descriptive analysis was conducted. The

Nonoral Viscosity (The panel chose "gel firmness,"

samples were evaluated by a trained panel of asses-

***but the alternative term was used for clarity).** This*

sors. A 150-mm unstructured line scale with anchor

was assessed by penetrating the yogurt gel with a tea-

points placed at 15 and 135 mm from

the left was used

spoon, placing about 5 ml on the surface of the undis-

to score nonoral viscosity and oral viscosity. The at-

turbed yogurt and observing how fast this dissipated.

tributes were defined thus, enhancing the clarity of

A high disappearance rate of the mounded spoonful

the study.

indicated a low nonoral viscosity.

Oral Viscosity (The panel chose "mouthfeel," but

scale and make sure that panelists rated samples co-

the alternative term was used for clarity).

This

herently. After training, the panel agreed on a list of *was assessed as the perceived degree of thickness*

33 terms and an evaluation protocol.

when the yogurt was placed in the mouth.

To prepare samples for sensory evaluation, the

The results indicated that nonoral viscosity was re-

samples were vigorously shaken until the yogurt was

lated to low deformation tests (G from oscillation* *homogeneous, and then poured into small glass pots,*

measurements and Brookfield viscosity) and oral vis-

which were closed to contain volatiles. Before serv-

cosity to large deformation tests (posthumus viscos-

ing, the samples were equilibrated to room temper-

ity and thixotropic behavior).

ature. In each session four samples were presented

The rheological, sensory, and chemical charac-

monadically to the panelists with random three-digit

teristics of yogurts made from skim milk (SM)

codes and in a balanced presentation order. Panelists

and ultrafiltered (UF) SM retentates were compared

were asked to open the lid and to evaluate odor first

(Biliaderis et al., 1992). Quantitative

descriptive anal-

and then the appearance and texture with the spoon.

ysis was used to profile selected sensory properties

After placing product in the mouth, flavor and texture

(thickness, graininess, sourness) of yogurt by seven

attributes in the mouth were rated. Finally, 10 seconds

trained panelists. Sensory results indicated a differ-

after swallowing the sample, they evaluated aftertaste

ence between the UF versus SM yogurt samples in

attributes. Each attribute was associated with a 12 cm

perceived thickness and graininess, but not in sour-

unstructured linear intensity scale with two anchors

ness when examined at similar solids level.

at 3 mm from each extremity. Rating

marks on the

The sensory properties of traditional acidic and

scale were converted to numerical values (left anchor

mild, less acidic yogurts were determined by a trained

= 0; right anchor = 100).

panel using descriptive sensory analysis (Ott et al.,

Descriptive sensory analysis and time inten-

2000). For sensory evaluation, odor, taste, and flavor

sity measures were investigated to measure flavor

terms were used:

changes and perceived sweetness in yogurt made

Odor refers to the organoleptic attribute percep-

with three concentrations of aspartame (APM) and

tible by the olfactory organ (nose) on sniffing cer-

fat (200, 400 or 600 ppm APM and 1% or 2% fat

tain volatile substances. The term "aroma" was used

respectively) (King et al., 2000). Twelve panelists

thereafter, like the term "odor," without any hedonic

were trained in descriptive methodology and time-

aspect.

intensity evaluation techniques. For descriptive sen-

Taste refers to sensations perceived by the taste

sory analysis, panelists rated samples using a 15

organ (tongue) when stimulated by certain soluble

cm anchored line scale. For time-intensity measure-

substances.

ments, panelists consumed a single tsp of sample,

Flavor refers to a complex combination of the *swirled it in their mouth for 5 seconds, and then*

olfactory, gustatory, and trigeminal sensations per-

swallowed. After swallowing assessors began to rate

ceived during tasting.

the sweetness aftertaste intensity for a total of 1

Panel training and language development were

minute. The results of this study showed that as-

well-characterized. During the first panel training

partame concentration had a greater effect on flavor

session, panelists were served four samples of yo-

characteristics and sweetness aftertaste than did fat

gurt prepared with strains of Str. thermophilus and Lb.

content. Addition of aspartame reduced the yogurt-

delbrueckii ssp. bulgaricus and were

asked to list the

based related flavor properties, while enhancing the

terms appropriate to describe the appearance, texture

sweetness and aftertaste in the product. Addition of

with spoon, aroma, flavor, mouthfeel, and aftertaste

fat reduced some of the sweetness impact demon-

of the samples. A total of 55 terms were generated.

strating that fat has the potential of reducing some of

Additional training sessions were used to (a) expose

the lingering sweetness that may be objectionable to

panelists to more yogurt samples, and possibly iden-

consumers.

tify new terms; (b) present other dairy foods (e.g.,

Sensory analysis was used to compare flavor and *cottage cheese, kefir) to help panelists characterize*

texture properties of milk-based yogurt to soymilk

some specific descriptive terms; (c) reduce the total

yogurt (Lee et al., 1990). Soymilk yogurts were char-

number of terms by eliminating redundant ones or

acterized by a lack of acidity and typical yogurt fla-

those for which the panel could not

reach a consensus;

vors. Drake et al. (2000) used descriptive analysis to

(d) agree on precise definitions of the terms and on

determine sensory properties of low-fat yogurts for-

the tasting protocol; (e) practice the use of the rating

tified with 0, 1, 2.5, or 5% soy protein concentrate *during 1-month storage at 5◦C. Descriptive analysis*

consumers following analytical sensory testing.

was conducted on the yogurts following the

However, consumer testing alone can be a useful

SpectrumTM procedures. During training, the pan-

tool provided a large enough sample of consumers *elists were asked to identify and define appearance,*

is polled. Carbonated and strawberry flavored yogurt

flavor, and texture terms for the yogurts. Panelists

drink was produced to attract customers who would

were presented with an array of yogurts with and

normally not enjoy a traditional yogurt product (Choi

without added soy protein to generate

the descrip-

and Kosikowski, 1985). For this purpose yogurt and

tive terms with definitions and references. Attributes

soft drink consumers evaluated products using a 7-

for appearance (color, free whey), aroma (fermented

point hedonic scale (where 1 = dislike very much to

dairy, soy), flavor/taste/feeling factors (soy, fer-

7 = like very much). Carbon dioxide had no effect on

mented dairy, acidity, sweetness, astringency),

specific sensory properties through 45 days of storage

and texture (ropiness, chalkiness, thickness) were

or consumer preference. Adhikari et al. (2000) used

selected.

consumer testing to determine acceptability of plain

Evaluations were divided into three categories in-

yogurts with and without encapsulated Bifidobacte-

cluding visual, flavor/aroma, and texture evaluation.

ria. Consumers (n = 547) were used to ascertain

Panelists evaluated sample sets for visual attributes

acceptance and attitudes toward soy-fortified dairy

followed by evaluation of separate

sample sets for fla-

yogurts (Drake and Gerard, 2003).

vor/aroma evaluation and texture evaluation. Yogurt

Harper et al. (1991) used a combined approach of

with 5% soy protein was darker, chalkier, and less

descriptive analysis and consumer testing to evalu-

sweet compared to control yogurt with lower con-

ate the sensory properties of commercial plain yo-

centrations of soy protein. In addition, yogurts with

gurts. Seventeen plain yogurts (whole, low fat, and

1 or 2.5% soy protein were most similar to control

fat free) were evaluated. Consumers (n = 153) eval-

yogurt. Descriptive analysis was subsequently used

uated yogurts for liking attributes

using a 9-point he-

to explore the specific effects of soy protein addition,

donic scale while sweetness, sourness, and thickness

sweetener type, and fruit flavoring on dairy yogurts

were evaluated for "just right" intensities using a 7-

(Drake et al., 2001).

point just right scale. Wide variability in attribute

Trained-panel sensory analysis of appearance and

intensities was noted among the yogurts. Consumer

texture demonstrated that whey protein concentrates

results indicated that consumers preferred plain yo-

produced yogurts with improved sensory attributes

gurts that were less sour and more sweet in taste.

compared to yogurts stabilized with

casein-based

Laye et al. (1993) likewise demonstrated that un-

products (Modler et al., 1983). Trained panelists eval-

trained consumers could differentiate between fresh

uated sensory properties of milks fermented with

plain yogurts. A similar descriptive and consumer

different mesophilic starter cultures as part of a *panel study was also conducted with strawberry and*

larger study to characterize the effect of different cul-

lemon yogurts (Barnes et al., 1991a). Acceptance of

tures on fermented milk properties (Kniefel et al.,

commercial flavored yogurts differed for men and

1992). Texture profiling (a form of descriptive tex-

women, but trained panel sweet taste

was correlated

ture analysis) was used to profile the texture prop-

with consumer acceptance. In a subsequent study, the

erties of yogurts made using exopolysaccharide-

same lab used descriptive analysis of sweet and sour

producing starter cultures (Marshall and Rawson,

tastes in combination with consumer testing to ex-

1999). Lorenzen et al. (2000) used attribute profiling

plore relationships between trained panel sweet and

with experienced assessors to determine the effect of

sour taste scores and consumer acceptance of plain,

enzymatic cross-linking of milk proteins on yogurt

strawberry, raspberry, and lemon yogurts (Barnes et

odor, flavor, and consistency. Hekmat

and McMahon

al., 1991b). Trained panel sweet and sour taste scores

(1997) used trained panelists to characterize the ef-

were useful in predicting consumer liking of fruit-

fect of iron fortification of yogurts on specific sensory

flavored yogurts.

attributes (oxidized and metallic flavors, bitter taste).

Trained panelist analysis of yogurt has also been used

CONCLUSIONS

as a model system to study the effect of fat on flavor

release and texture perception (Brauss et al., 1999).

Sensory quality (appearance, texture, flavor) ulti-

Many of the previously mentioned studies

mately determines consumer acceptance. The use *evaluated consumer acceptance using untrained*

of appropriately designed sensory tests, tools, and

statistical analyses is a powerful technique for mea-

concentrated yogurt (labneh). J. Food Prot.

suring the specific sensory effects of processing pa-

48:300–302.

rameters and ingredients. Testing with appropriate

de Ancos B, Cano MP, Gomez R. 2000. Characteristics

numbers of consumers provides compelling informa-

of stirred low-fat yogurt as affected by high

tion on consumer acceptance. Many recently devel-

pressure. Int. Dairy J. 10:105–111.

oped sensory tools have been effectively applied to

Delahunty CM, Drake MA. 2004. Sensory character of

other dairy foods. Future sensory work with yogurt

cheese and its evaluation. In: PF Fox, PLH

should focus on the application of these recent and

McSweeney, TM Cogan, TP Guinee (Eds), Cheese:

powerful tests.

Chemistry, Physics and Microbiology, Vol. 1,

General Aspects, 3rd ed. Elsevier, London, pp.

455–487.

REFERENCES

Dello Staffoloa M, Bertolaa N, Martinoa M,

Adhikari K, Mustapha A, Grun IU, Fernando L. 2000.

Bevilacqua A. 2004. Influence of dietary fiber

Viability of micro-encapsulated Bifidobacteria in set

addition on sensory and rheological properties of

yogurt during refrigerated storage. J. Dairy Sci.

yogurt. Int. Dairy J. 14:263–268.

83:1946–1951.

Drake MA. 2004. Defining dairy flavors. J. Dairy Sci.

ADSA. 1987. Committee on Evaluation of Dairy

87:777–784.

Products. Score Card and Guide for Cottage Cheese.

Drake MA, Chen XQ, Tamarapu S, Leenanon B. 2000.

Amer. Dairy Sci. Assoc., Champaign, IL.

Soy protein fortification affects sensory, chemical

Al-Kadamany E, Khattar M, Haddad T, Toufeili I.

and microbiological properties of dairy yogurts. J.

2003. Estimation of shelf-life of concentrated yogurt

Food Sci. 65:1244–1247.

by monitoring selected microbiological and

Drake MA, Civille GV. 2003. Flavor lexicons. Compr.

physicochemical changes during storage. Leben

Rev. Food Sci. 2(1):33–40.

Wiss Technol. 36:407–414.

Drake MA, Gerard PD. 2003.

Consumer attitudes and

Barnes DL, Harper SJ, Bodyfelt FW, McDaniel M.

acceptability of soy fortified yogurts. J. Food

1991a. Correlation of descriptive and consumer

Science. 68(3):1118–1112.

panel flavor ratings for commercial pre-stirred

Drake MA, Gerard PD, Chen XQ. 2001. Effects of *strawberry and lemon yogurts. J. Dairy Sci.*

sweetener, sweetener concentration and fruit flavor

74:2089–2099.

on sensory properties of soy fortified yogurt.

Barnes DL, Harper SJ, Bodyfelt FW, McDaniel M.

J. Sensory Stud. 16:393–406.

1991b. Prediction of consumer acceptability of

Drake MA, Karagul-Yuceer Y, Cadwallader KR,

yogurt by sensory and analytical measures of

Civille GV, Tong PS. 2003. Determination of the

sweetness and sourness. J. Dairy Sci. 74:3746–3754.

sensory attributes of dried milk powders and dairy

Biliaderis CG, Khan MM, Blank G. 1992. Rheological

ingredients. J. Sensory Stud. 18:199–

216.

and sensory properties of yogurt from skim milk and

Drake MA, Karagül-Yüceer Y, Chen XQ, Cadwallader

ultrafiltered retentates. Int. Dairy J. 2:311–323.

KR. 1999. Characterization of desirable and

Bodyfelt FW, Tobias J, Trout GM. 1988. Sensory

undesirable lactobacilli from cheese in fermented *evaluation of cultured milk products. The Sensory*

milk. Leben Wissen Technol. 32:433–439.

Evaluation of Dairy Products. AVI Publishers, New

Farooq K, Haque ZU. 1991. Effect of sucrose esters on

York.

the textural properties of nonfat low calorie yogurt.

Brauss MS, Linforth RST, Cayeux I, Harvey B, Taylor

J. Dairy Sci. 75:2676–2680.

AJ. 1999. Altering the fat content affects the flavor

Fernandez-Garcia E, McGregor JU, Traylor S. 1998.

release in a model yogurt system. J. Agric. Food

The addition of oat fiber and natural alternative

Chem. 47:2055–2059.

sweeteners in the manufacture of plain yogurt.

Chapman KW, Lawless HT, Boor KJ. 2001.

J. Dairy Sci. 81:655–663.

Quantitative descriptive analysis and principal

Gueimonde M, Alonso L, Delgado T, Bada-Gancedo

component analysis for sensory characterization of

JC, Reyes-Gavilan CG. 2002. Quality of plain

ultra-pasteurized milk. J Dairy Sci. 84:12–20.

yoghurt made from refrigerated and CO2-treated

Choi HS, Kosikowski FV. 1985. Sweetened plain and

milk. Food Res. Int. 36:43–48.

flavored carbonated yogurt beverages. J. Dairy Sci.

Guven M, Karaca OB. 2002. The effects of varying

68:613–619.

sugar content and fruit concentration on the physical

Dagher S, Ali A. 1985. Effect of pasteurization,

properties of vanilla and fruit ice cream-type frozen

centrifugation and additives on quality of

yogurts. Int. Dairy Technol. 55:27–31.

Harper SJ, Barnes DL, Bodyfelt FW, McDaniel MR.

of yogurt stabilized with milk proteins.

J. Dairy Sci.

1991. Sensory ratings of commercial plain yogurts

66:422–429.

by consumer and descriptive panels. J. Dairy Sci.

Murray JM, Delahunty CM. 2000. Mapping consumer

74:2927–2935.

preference for the sensory and packaging attributes

Hekmat S, McMahon DJ. 1997.

Manufacture and

for Cheddar cheese. Food Qual. Pref. 11:419–35.

quality of iron-fortified yogurt. J. Dairy Sci.

Murray JM, Delahunty CM, Baxter IA. 2001.

80:3114–3122.

Descriptive sensory analysis: present and future.

Hough G, Sanchez R. 1998. Descriptive analysis and

Food Res. Int. 34:461–471.

external preference mapping of powdered chocolate

Oliviera CA, Fernandes AM, Neta OCC, Fonseca LFL,

milk. Food Qual. Pref. 9(4):197–204.

Silva EOT, Balian SC. 2002. Composition and

IDF. 1997. Sensory Evaluation of Dairy Products by

sensory evaluation of whole yogurt produced from

Scoring—Reference Method. International IDF

milk with different somatic cell counts. Austr. J.

Standard. 99C:1997. Brussels: Belgium.

Dairy Technol. 57:192–196.

Karagül-Yüceer Y, Coggins PC, Wilson JC, White CH.

Ott A, Hugi A, Baumgartner M, Chaintreau A. 2000.

1999. Carbonated yogurt: Sensory properties and

Sensory investigation of yogurt flavor perception:

consumer acceptance. J. Dairy Sci. 82:1394–1398.

Mutual influence of volatiles and acidity. J. Agric.

King SC, Lawler PJ, Adams JK. 2000. Effect of

Food Chem. 48:441–450.

aspartame and fat on sweetness perception in

Penna ALB, Sivieri K, Oliveira MN. 1997.

yogurt. J. Food Sci. 1056–1059.

Optimization of yogurt production using

Kniefel W, Kaufmann M, Fleischer A, Ulberth F. 1992.

demineralized whey. J. Food Sci. 62:846–850.

Screening of commercially available mesophilic

Penna ALB, Sivieri K, Oliveira MN. 2001. Relation

dairy starter cultures: Biochemical, sensory, and *between quality and rheological properties of lactic*

microbiological properties. J. Dairy Sci.

beverages. J. Food Eng. 49:7–13.

75:3158–3166.

Richardson-Harman NJ, Stevens R, Walker S, Gamble

Lawless HT, Heymann H. 1998. Sensory Evaluation of

J, Miller M, Wong M, McPherson A. 2000. Mapping

Food: Practices and Principals. Chapman and Hall,

consumer perceptions of creaminess and liking for

NY.

liquid dairy products. Food Qual. Pref . 11:239–

Laye I, Karleskind D, Morr CV. 1993. Chemical,

246.

microbiological, and sensory properties of plain

Schlich P. 1995. Preference mapping: Relating

nonfat yogurt. J. Food Sci. 58:991–995.

consumer preferences to sensory or instrumental

Lee SY, Morr CV, Seo A. 1990. Comparison of

measurements. In: P Etiévant, P Schreier (Eds),

milk-based and soymilk-based yogurt. J. Food Sci.

Bioflavour=95. Analysis/Precursor Studies/

55:532–536.

Biotechnology. INRA Editions, Versailles, pp.

Lorenzen PC, Neve H, Mautner A, Schlimme E. 2002.

231–245.

Effect of enzymatic cross-linking of milk proteins

Singh T, Drake MA, Cadwallader KR. 2003. Flavor of

functional properties of set-style yogurt. Int. J. Dairy

Cheddar cheese: A chemical and sensory

Technol. 55:152–157.

perspective. Compr. Rev. Food Sci. 2:139–162.

Marshall VM, Rawson HL. 1999. Effects of

Skriver A, Holstborg J, Qvist KB. 1999. Relation

exopolysaccharide-producing strains of

between sensory texture analysis and rheological *thermophilic lactic acid bacteria on the texture of*

properties of stirred yogurt. J. Dairy Res.

stirred yogurt. Int. J. Food Sci. Technol. 34:137–143.

66:609–618.

McEwan JA. 1996. Preference mapping for product

Tamime AY, Robinson RK. 1987. Yoghurt Science and

optimization. In: T Naes, E Risvik (Eds), *Technology. Oxford: Pergamon Press.*

Multivariate Analysis of Data in Sensory Science .

Thompson JL, Drake MA, Lopetcharat K and Yates

Elsevier, Amsterdam, pp. 71–80.

MD. 2004. Preference mapping of commercial

McGregor JU, White CH. 1986. Effect of sweeteners

chocolate milks. J. Food Sci 69(11/12):S406–S413.

on the quality and acceptability of yogurt. J. Dairy

Trachoo N, Mistry VV. 1998. Application of

Sci. 69:698–703.

ultrafiltered sweet buttermilk and sweet buttermilk

Meilgaard MC, Civille GV, Carr BT. 1999. Sensory

powder in the manufacture of nonfat and low fat

Evaluation Techniques, 3rd ed. CRC Press, Boca *yogurts. J. Dairy Sci. 81:3163–3171.*

Raton, FL.

Young ND, Drake MA, Lopetcharat K, McDaniel MR.

Modler HW, Larmond ME, Lin CS, Froehlich D,

2004. Preference mapping of Cheddar cheese with

Emmons DB. 1983. Physical and sensory properties

varying maturity levels. J. Dairy Sci. 87:11–19.

Part III

Manufacture of Fermented Milks

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

Copyright © 2006 by Blackwell Publishing

17

Cultured Buttermilk

Charles H. White

r

Milk Supply

Buttermilk provides an excellent base for making

Processing of Milk

various kinds of dressings and baked goods,

Buttermilk Starter Culture

which require a smooth, tangy flavor.

Breaking, Cooling, Bottling, and Distribution

Acknowledgment

Buttermilk has steadily declined in per capita con-

References

sumption from 4.7 pounds in 1975 to 2.1 in 2001

(USDA-IDFA). Some of this decline is because of

more interest in buttermilk for baking *purposes rather*

The term buttermilk can be somewhat confusing in

than just for drinking. Also, the unfamiliarity with

that buttermilk can mean:

cultured buttermilk as a refreshing drink has spread

1. The liquid remaining after cream is churned into

in the current generation. As a result, the poor quality *butter.*

of some buttermilk has caused first-time consumers

2. The milk product made by adding a bacterial cul-

to not want to become a repeat consumer. A lack of

ture to fat free, low fat, reduced fat, or whole milk.

good refrigerated temperature control results in poor

quality buttermilk in many restaurants. The Ameri-

The second product is a topic that merits our

can Cultured Dairy Products Institute has held an-

discussion. The product has great popularity as a

nual product clinics. At these clinics, cultured dairy

baking aid but also as a satisfying milk beverage. As

products of members would be evaluated by expert

a milk beverage, it is a product that fits *the image of*

sensory judges. During a 4-year period (1972–1975),

a nutritious food that can be extremely refreshing.

of 87 samples of buttermilk, 55 (63%) were found to

Vedamuthu (1985) stressed the sales potential for

have a flavor of only fair or poor quality. Only one

buttermilk by considering:

sample was judged to be excellent. Since that time,

r

the flavor quality of buttermilk has not changed ap-

Buttermilk contains all the high-quality nutrients

preciably. From a technical point of view, buttermilk

that are found in milk. It is rich in calcium, and

should be the easiest cultured dairy product to make;

unlike cheeses, there is no loss of the high-quality

however, this product consistently scores lower than

whey proteins in its production.

r

other cultured products in product clinics.

There is little or no milk fat in buttermilk, since it

Many people judge a dairy processor based on the *is made from skim milk (buttermilk can be made*

quality of buttermilk produced, since this product can

with milk of varying fat content, which can even

be the showcase of a dairy. The thinking tends to be

taste better than that made from skim).

r

that if a company produces good buttermilk, the other

Unless salted, which in many cases is

products also have to be good. Vedamuthu (1985) in-

unnecessary, buttermilk can be labeled as a

dicates that the successful marketability of buttermilk

sodium free or low sodium product (many people

is based on four major product characteristics:

agree that buttermilk tastes better with added salt).

r There is about 15% less lactose in buttermilk as

1. Body—Thick body

compared with milk.

2. Texture—Smooth texture

279

280

Part III: Manufacture of Fermented Milks

3. Flavor—Good blend of acid, diacetyl, and some *and/or whey protein concentrate (WPC) as a source*

carbonation, and

of added milk solids, stabilizer, and culture.

4. Freshness—Shelf-life or keeping quality

Fresh fluid milk should be used whenever possible.

When using milk powder, fat should be incorporated

Many times body and texture are put together but *to approximately 1% with 40% cream, which appears*

they are different characteristics. Flavor is extremely

to be superior to whole milk as a source of fat. The fat

important and can actually consist of more than just

content of buttermilk ranges all the way from approx-

taste. Aroma is a big part of flavor as are mouthfeel

imately 0.05% to 3.5% milkfat. For

optimal flavor,

and aftertaste.

most processors find that milk with at least 1.0–1.8%

Lundstedt (1975) suggested that there are five

fat produces the most acceptable product.

phases, which must be considered in the manufac-

Regardless of the source of solids, there must be the *ture of cultured buttermilk:*

absence of any stale or "off" note, which will almost

1. Quality of the milk

certainly carryover into the finished product. Care

2. Preparation of the milk for buttermilk

must be taken to ensure a consistent product with

3. Cultures and ripening of the milk

regard to the body and viscosity when

using different

4. Cooling and pumping the buttermilk to the filling

sources of fat and solids. Seasonal variations can also

machine

reflect changes in the body and flavor of buttermilk.

5. Storage and distribution of the buttermilk

Solids may be added in high-volume periods to keep *the body constant.*

In looking more specifically at these major phases,

Sodium citrate may be added as a basis for di-

White (1977, 1979) outlined the key steps in good

acetyl production. A recommended level of addition

buttermilk manufacture:

is 0.10% w/w (legal maximum is 0.15% w/w). In *times of the year, when solids are reduced more, cit-*

Key Steps in the Manufacture of Cultured Buttermilk

rate may be required for good diacetyl production

1. Milk supply

than is naturally present in the raw milk. Many pro-

a. Never use returned milk

cessors add sodium citrate on a regular basis to en-

b. Free of inhibitory substances (antibiotics and

sure a ready source of citrate for the Leuconostocs or

sanitizers)

"flavor producers" (Petersen, 1997). Diacetyl is a key

c. High bacterial quality

flavor compound, which can result in excellent but-

d. Needs some fat, 1.0–1.8% minimum

termilk. In the past some processors

did not believe

e. Standardized milk solids-not-fat content

that one needed to add stabilizer to make good but-

2. Processing of milk

termilk. These thoughts have changed due to longer

a. Standardization

distribution chains and buttermilk being packaged in

b. Homogenization

clear plastic containers. Extensive syneresis or whey-

c. Heating

ing off can look very unattractive in the dairy case.

85◦C (185◦F) for 30 minutes

One should avoid using too much stabilizer to elim-

88–91◦C (190–195◦F) for 2.5–5.0 minutes

inate the possibility of a "slick" body. Follow the

3. Addition and development (acidity and flavor) of

recommendation of the stabilizer supplier for best re-

lactic starter culture

sults. In an excellent overview of buttermilk, Danisco

4. Breaking, cooling, bottling, and distribution

(2003) summarizes the commonly used stabilizers in

making cultured buttermilk.

MILK SUPPLY

1. Food starch or modified food starch—Added to in-

crease viscosity, the modified product is reported

Buttermilk may contain cream, milk, partially

to give better water-binding properties, improved

skimmed milk, or skim used alone or in combination.

acid tolerance, and shear stability.

It may also be made from concentrated skim, nonfat

2. Locust bean gum—Increases viscosity. Synergis-

dry milk (NFDM), or other milk derived ingredients

tic with carrageenan.

to increase the nonfat solids content of the food (CFR,

3. Carregeenan—Added to reduce tendency of but-

2000). Not just the raw milk but all ingredients used *termilk to whey-off.*

in making buttermilk must be of high quality. Such

ingredients include salt, sodium citrate (a source of

The direct microscopic count and the standard

diacetyl for the flavor producing bacteria), NFDM,

plate count are still the most commonly used methods

17 Cultured Buttermilk

to evaluate the microbial quality of the raw milk. Al-

the desired viscosity) and destroying the microbial

though the legal maximum for commingled raw milk

contaminants, milk should be heated either to 85◦C

in the United States is 300,000 cfu/ml, a lower stan-

(185◦F) for 30 minutes or 88–91◦C (190–195◦F) for

dard should be utilized by the processor to further

2.5–5 minutes. Although most processors using the

ensure that only high-quality milk is being used. The

batch method claim a better body in the finished but-

coliform test can also provide meaningful informa-

termilk, heating to higher temperatures at the same

tion as to the quality of the raw milk.

Although most

hold results in a thinner body. Extended holding tubes

states do not have coliform standards for raw milk,

on the high-temperature-short-time (HTST) pasteur-

high numbers can indicate that the milk has been

izing give plants more flexibility with regard to their

handled in an unsanitary manner, e.g., improperly *heating capabilities.*

cleaned/sanitized equipment. Just as with pasteurized

Prior to final heating, the milk should be homog-

products, coliforms are "indicator" organisms, in that

enized at approximately 1800 psi to improve the

their presence indicates that conditions are suitable

body/viscosity of the finished product. The tempera-

for the presence of enteric pathogens. A reasonable

ture of the milk at the homogenizer should be main-

goal would be < 100 coliforms per milliliter of milk.

tained approximately at 49∘C (120∘F).

At any rate, the quality of raw milk must be high.

It has been reported (Danisco, 2003) that the pump-

Each raw milk load should be tested for the following

ing and cooling steps can have the biggest influence

(at a minimum) prior to unloading the milk:

on the final viscosity. These reports indicated that

r

intermittent cooling with side swept agitation is the

Direct microscopic count (DMC)

r

best. In moving the buttermilk from the *buttermilk*

Inhibitory substances (antibiotics)

r

vat/tank to the filler, avoid the use of a centrifugal

Temperature

r

pump, which adds air and reduces the product vis-

Sensory evaluation (aroma and taste after lab *cosity.*

pasteurization)

r Sediment

Other tests may be run after the milk has been

BUTTERMILK STARTER

pumped into the silo storage tanks. These could be

CULTURE

normal compositional tests or troubleshooting tests

After processing, the milk is cooled to a temperature

such as the acid degree value (for rancid milk),

from 22.2◦C (72◦F) to 23.3◦C (74◦F) and pumped

lab pasteurization count (for thermodurics), titratable

to the buttermilk vat/tank when it is ready to be in-

acidity, etc. If there is a high psychrotrophic popula-

oculated with the starter culture. The *culture manu-*

tion in the raw milk, heat-stable proteases and lipases

facturer's directions for storage and handling of the

can cause flavor problems in any type of dairy food.

starter should be strictly followed. To understand the

Some estimate of the psychrotophs needs to be done

temperature and time of product inoculation required *on a regular basis.*

for good flavor and body characteristics, one must re-

alize the characteristics of the bacteria in the starter

PROCESSING OF MILK

culture. There are two types of bacteria:

The milk should be standardized to a minimum of

1. Lactic acid producers. Typically Lactococcus

9.0% solids-not-fat if fresh skim is being used. If

(formerly streptococcus) lactis subsp. cremoris

using a low-heat powder, a 10% SNF should be re-

and Lactococcus lactis subsp. lactis are used.

quired (White, 1979). The firmer the body desired,

These two bacteria with many different strains are

the higher the SNF level needed. In no *case should the*

homofermentative, since they convert lactose to

total solids of the buttermilk be allowed to fall under

only lactic acid (Harrits, 1997). Their optimum

10% if full-bodied buttermilk is desired. Salt should

temperature is 30◦C (86◦F).

be added prior to pasteurization to get the desired

2. Flavor (diacetyl) producers. Leuconostoc mesen-

taste. A level of 0.10–0.20% by total batch weight

teroides subsp. cremoris. This is a heterofermenta-

is common and yields a recognizable and desirable

tive bacterium with an optimum growth tempera-

diacetyl flavor (Danisco 2003).

ture of 20–22◦C (70–72◦F) (Harrits, 1997). Strains

Following standardization/fortification, milk is

of this species metabolize the sodium citrate dis-

subjected to a heat treatment. To achieve the desired

cussed previously to produce diacetyl and CO_2

effects of denaturing the whey proteins (to achieve

(Harrits, 1997).

Thus, with the two types of bacteria in the starter

diacetyl reductase activity even at low tempera-

culture, it is imperative to select a temperature that

tures. Filling machines are probably the largest

would be compatible for both. If the incubation tem-

single source of contamination

microorganisms.

perature is too high, the lactic acid producers are fa-

Following addition of the starter, the mixture

vored. As a result, an acid flavor predominates and a

should be agitated at high speed for 15–30 minutes,

pleasing culture flavor is lacking. On the other hand,

depending upon the type of tank and agitation em-

if the incubation temperature is too low, the growth of

ployed.

the leuconostocs are favored, but the acid production

The buttermilk should be checked after 12–14

will take significantly longer, which can further inter-

hours for acidity and flavor (taste plus aroma). Many

fere with processing schedules. Therefore, a common *processors have a rule on “breaking” the buttermilk*

ground is needed and 22.2◦C (72◦F) to 23.3◦C (74◦F)

at pH 4.50–4.60, plus desired aroma or flavor. All

appears to provide the opportunity to maximize both

too often though, the only criterion is acidity without

bacterial types.

proper regard for flavor development. Many times in-

The primary flavor problem seen in buttermilks in

cubation for an additional hour or two will result in

the United States is a "high acid" and "lacks cultured

the delicate aroma and flavor desired.

flavor." Normally, this occurs due to incubation at too

If "breaking" buttermilk on titratable acidity (TA)

high a temperature and too short an incubation time.

consider that this measurement is dependent on the

The temperature must be low enough to allow for the

solids content. Since a minimum total of solids of

secondary growth (after pH drop) of the leuconos-

10.0–10.5% is desired, a "breaking" TA of 0.90%

tocs. Also, there needs to be sufficient sodium citrate

should be the rule.

as a source of diacetyl. Vedamuthu (1985) reported

that the increase in diacetyl concentration slows down

as the citric acid content decreases and the maximum

BREAKING, COOLING,

level of diacetyl is attained in 14–18 hours of incu-

BOTTLING, AND DISTRIBUTION

bation. The exact time is determined by:

r

Knowing when to "break" a tank of buttermilk is

The culture used

r

many times the difference between a good and poor

The citric acid concentration of the raw milk

r

product. As a rule, there will be several small pockets

The temperature of incubation

or bubbles of whey on top of the buttermilk when the

Vedamuthu (1985) listed five ways to prevent the

tank is ready. When the decision is made (based on

loss of diacetyl in buttermilk:

pH/acidity reading and aroma evaluation) that further

incubation would be injurious to the quality of the

1. Rapidly cool the vat once the desired acidity is

product, the ice water is circulated through the jacket

reached. He indicated that when the buttermilk is

10–15 minutes prior to turning on the agitator. With

cooled, the diacetyl destroying enzyme (diacetyl

a two-speed agitator, the agitator should be turned

reductase) is retarded and the high

level of flavor

on high speed until the product is moving easily in

concentration is preserved. Diacetyl reductase acts

the vat and the body is smooth–this is "breaking"

rapidly at the incubation temperature of cultured

the buttermilk (White, 1976, Personal communica-

buttermilk, but slows down considerably at lower *tion). The agitator should then be switched to low*

temperature, e.g., 3.3◦C (38◦F) to 4.4◦C (40◦F).

speed and cooled to 17◦C (45◦F) for bottling. Rapid

2. Fortify the vat milk with sodium citrate. This helps

cooling is essential to retard further bacterial ac-

due to the fact that fortification evens out any sea-

tion and stop excessive acid

development. Agitation

sonal variations or deficiencies in citric acid con-

should be stopped when bottling to prevent any exces-

tent of raw milk.

sive air incorporation and adverse effects to the final

3. Slow, gentle agitation during cooling. Oxygen or

viscosity. As indicated previously, air incorporation *air that is worked into the buttermilk greatly in-*

causes shrinkage during storage and contributes to

hibits diacetyl reductase.

syneresis.

4. Holding the buttermilk in a cooler for one or two

The cooled buttermilk should be pumped to the

days. This step will also enhance the diacetyl level.

filler with a positive pump. After packaging, the but-

Due to the longer distribution system, this step

termilk should be held at a temperature of less than

may not be feasible.

4.4◦C (40◦F). This will retard the continued acid

5. Strict sanitation during the filling operation. Psy-

production and help keep the growth of microbial *chotrophic bacteria are known for having a high*

contaminants to a minimum. Temperature control

must be maintained throughout the storage and dis-

results in the starter bacteria breaking down

tribution system.

the protein in the milk. Bitter flavor is *usu-*

Finished product testing is needed to ensure that

ally more pronounced as the age of the prod-

specifications are attained. The following test should

uct increases. Check for improperly cleaned

provide the manufacturer adequate control (one

equipment, especially from the buttermilk *should not feel limited to these and these alone):*

vat through the filler and eliminate psy-

chrotrophic contamination.

1. Sensory evaluation—Taste samples at the follow-

(d) Acid

ing:

Cause. Over-ripening, inadequate, and/or

a. At "breaking"

slow cooling

b. When bottled—Packaging operator

Prevention. Determine the solids-not-fat con-

c. Daily production samples—QA staff

tent of the milk and break at the proper titrat-

2. Milk fat—Prior to inoculation and bottled product

able acidity or pH (9.0% SNF → 0.85% TA;

3. Coliform—Goal should be < 1

coliform/ml

10.0% SNF → 0.90% TA: 11.0% SNF →

4. pH/titratable acidity

0.95% TA)

5. Viscosity—Use of a Zahn cup or equivalent is rec-

(e) Stale

ommended. A minimum of at least 25 seconds in a

Cause. Use of old powdered milk. Use of whey

#2 Zahn cup at 10◦C (50◦F) yields desirable prod-

powder along with nonfat dry milk.

uct viscosity

Prevention. Check the quality of the fresh milk

6. Temperature

powder. Check the rotation of the inventory

7. Shelf life—Measured at 7◦C (45◦F)

of powder especially if the defect occurs

8. Competitor product evaluation—Evaluate blind

only occasionally. Never use whey solids.

samples to ensure competitive properties of fin-

(f) Cheesy

ished product

Cause. Due to psychrotrophic contamination.

Custer (1982) reviewed the sensory evaluation

Prevention. Never use returned dumped milk

defects of buttermilk. He mentioned the cause/

for making buttermilk.

prevention of each defect.

(g) Unclean

Cause. Usually caused by bacterial contam-

1. Flavor defects

ination at some point such as poor qual-

(a) Green (yogurt flavor)

ity starter milk, poor quality skim, and es-

Cause. Accumulation of acetaldehyde

pecially poor quality cream when used as

Prevention. Avoid starters containing Lacto-

a source of milk fat for buttermilk. Dirty

coccus lactis subsp. diacetylactis

equipment almost always results in

bacte-

(b) Lacks flavor

rial contamination.

Cause. High incubation temperature, insuffi-

Prevention. Use only excellent quality, fresh

cient citric acid in milk, low acid develop-

dairy ingredients in the manufacture of but-

ment

termilk. Clean all equipment thoroughly.

Prevention. Incubate at 22◦C (72◦F) to 23.3◦C

(h) Cooked

(74◦F) to obtain a “balanced” growth of acid

Cause. Excessive heat treatment either in milk

producers, as well as aroma bacteria. To in-

or more commonly in reconstituted milk *sure sufficient citric acid in the milk for the*

powder.

starter bacteria add 227 g sodium citrate per

Prevention. If NDM is used, ensure proper ro-

379 liters (100 gallons) of milk. To prevent

tation. Avoid over heating of milk.

low acid development increase the incubat-

2. Body and texture

ing time, increase the amount of starter, be

(a) Weak

certain the incubation temperature is not

Cause. Low level of milk solids not fat in the

lower than 22◦C (72◦F) minimum.

milk. Low heat treatment. Low acid devel-

(c) Bitter

opment.

Cause. Poor quality milk, temperature fluctu-

Prevention. Use proper level of milk solids

ation during handling, psychrotrophic con-

(at least 9.0%.) This provides sufficient ca-

tamination

sein, which is a natural stabilizer involved

Prevention. Use only fresh-quality milk; elim-

in coagulation as well as water retention.

inate excessive acid production, which

Use of sufficient high-heat treatment of milk

partially denatures the whey proteins. This *done at the "right time." When the correct manufac-*

contributes to the thickening of the butter-

turing procedure coincides consistently with people

milk body.

who care about quality, the customer will recognize

(b) Slick

these attributes and the sales of this nutritious and

Cause. Excessive use of stabilizer. Bacterial

delicately flavored product will likely increase.

contamination.

Prevention. Cut back on use of stabilizer or

eliminate stabilizer completely. Check for

ACKNOWLEDGMENT

psychrotrophic bacterial contamination.

Approved for publication as Book Chapter No. BC-

(c) Grainy

10613 of the Mississippi Agricultural and Forestry

Causes. Excessive acidity, undissolved salt, or

Experiment Station, Mississippi State University.

milk powder, high incubation temperature,

poor-quality milk.

Prevention. Check acidity or pH of butter-

REFERENCES

milk at both top of vat and outlet valve.

Code of Federal Regulations. 2002. Part 131.112.

Break buttermilk at correct acidity (9.0%

Custer EW. 1982. Cultured dairy foods: Quality

SNF → .95% TA; 10.0% SNF → .90%

improvement manual. Am. Cult. Prod.

Inst.

TA etc.) and cool rapidly. Too high incu-

Orlando, FL.

bation temperature results primarily in fast

Danisco. Fall. 2003. Dairy News. Cultured products.

acid development and the tendency of ca-

Cultured buttermilk. Danisco USA Inc., New *sein precipitation in a similar manner as*

Century, KS 66031.

in the manufacture of cottage cheese. Use

Harrits J. 1997. Culture nomenclature. In: Cultures for

of poor-quality milk, which causes physi-

the Manufacture of Dairy Products , Chr. Hansen,

cal casein precipitation during the heating

Milwaukee, WI, pp. 18–26.

process.

Lundstedt E. 1975. All you wanted to know about

buttermilk. Cult. Dairy Prod. J. 10:18–22.

Although the procedures in the manufacture of but-

Petersen LW. 1997. Buttermilk, sour cream and related

termilk seem fairly straightforward and simple, still *products. In: Cultures for the Manufacture of Dairy*

very poor-quality buttermilks are seen. Companies

Products, Chr. Hansen, Milwaukee, WI,

with multiple processing plants may have the same

pp. 106–110.

basic formula and very similar equipment. Thus, the

Vedamuthu ER. Better buttermilk. 1985. Microlife *only variable (other than the raw milk) remaining is*

Technics, Sarasota, FL, 34230

the "people-factor." No matter how basic the steps, to

White CH. 1977. Manufacturing better buttermilk.

make good buttermilk, there must be that one person

Cult. Dairy Prod. J. (Feb.) 12:16–20.

who "cares" enough to do the right thing at the right

White CH. 1979. Buttermilk—Love it or leave it.

time. In this regard, it is very important to keep daily

Am. Dairy Review. (July) 41:34–38.

records to ensure that each "right thing" is in fact

White, HW. 1976. Personal Communication.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

18

Cultured/Sour Cream

Bill Born

Early History

party held during this period in Ur consisted of an ap-

Present Standards

petizer of garlic in sour cream, Tigris salmon, roast

Summary of Procedures

pig or lamb, unleavened bread, dates, goat cheese,

Problems and Correction

and plenty of beer and wine (Editors of Life, 1961).

Sour Cream Products

By this time agriculture and dairy products had been

References

well-established and somewhat refined. As the art *of making sour milk foods was carried from tribe*

EARLY HISTORY

to tribe though Europe, each local artesian put an

individual touch to his work and a variety of prod-

Historians speculate that man began domestication

ucts evolved. Some of those products surviving today

of animals around 10,000 years ago. With the advent *are "quark" of Germany, "crème fraîche" of France,*

of herding and milking mammals, sour milk foods

"clotted cream" of England, and "yogurt" from the

came about naturally (Pariser, 1975). Milking was by

Mediterranean area (Food News Service, 2003).

hand and there was no such thing as sanitation. Milk

While dairy cows arrived at the

Jamestown Colony

that was not consumed with in a few hours turned

in 1611, sour cream, as we know it today, had not

sour. The type of fermentation that took place was

developed to its present form until 1890 to 1900

determined by temperature and type of organisms in

(FarMore, 2003). First sour cream products were

the milk. As mammals grazed though pastures, they

either incubated in the package or in a ten-gallon

picked up organisms from plants and soil on their

can. Invention of homogenization in 1919 greatly

udders. During hand milking, these organisms were

helped give sour cream a more uniform body and tex-

imparted to the milk. Lactic bacteria

are found on

ture (International Dairy Foods Association, 2003a).

plant blossoms and are usually the predominant flora,

This was a time of entrepreneurs, and in 1919, Harry

although pathogens could be picked up from the mud

Bovarnick developed his secret process for making

of streambeds and manure. Rapid souring of milk by *heavily bodied sour cream, and he would allow no*

lactic organisms allowed them to dominate the fer-

one in the room when he prepared the mix. Harry's

mentation (Clark and Goldblith, 1975). Prompted by

secret was to add 0.5 ml of rennet per ten gallons

hunger and guided by his nose, man began to con-

of sour cream mix (Fig. 18.1).

Breakstone Broth-

sume sour milk products. Through ingenuity, trial,

ers in Walton, New York bought Harry's process in

and error, samples of good sour milks were added to

1923. Then Breakstone was bought by Kraft in 1928,

new milk to improve the chance of an eatable product

and Breakstone/Kraft became one of the largest pro-

on the next batch. Techniques and information were

ducers of sour cream and cream cheese in the world

passed on and cultured dairy products evolved.

(Lundstedt, 1977). In the mid 1940s Martin Kloser

In the ancient city of Ur, archaeologists unearthed

of Bowman Dairies in Chicago eliminated ten-gallon

frieze dating 2900 bc. A part of the

frieze depicts

cans for incubation and set sour cream in a large

a man milking while other workers make sour milk

tank. When the product reached correct acidity, it

products in pottery containers. The menu of a dinner

was pushed out of the tank with 5 lb air pressure to

Figure 18.1. Sour cream production in the 1920s.

force the sour cream through a

stainless steel screen

Moss, and 15% Karaya gum was a good substi-

to smooth the product as it was packaged. At that

tute for gelatin, which was more expensive. Arthur

time consumer packages were glass jars that were

Ambrose's pioneer work was followed by profes-

returned, washed, and used again.

sional stabilizer manufacturers, which developed

Some East Coast dairy manufacturers made both

sour cream stabilizers that greatly improved body,

cream cheese and sour cream. It was a logical step

texture, and palatability of sour cream (Lundstedt,

for them to use the processing procedures from cream

1977).

cheese to make a hot-pack, long shelf-life sour cream.

University researchers developed considerable

After sour cream was fermented to pH 4.5, it was

knowledge of sour cream technology for the dairy in-

stirred and heated to kill all organisms, pumped

dustry to use. Some of the hallmark names that set the

through a homogenizer, and packaged

hot into her-

standards for our present sour cream processing and

metically sealed glass containers. As the product

composition are: FJ Doan and CD Dahle, Pennsyl-

cools, a vacuum forms producing a stable product that

vania Agricultural Station; LD Hilker, ES Gutherie,

maintains its quality up to 12 months. When exposed *and FV Kosikowski, Cornell University; HE Calbert,*

to light, the glass-packed sour cream did develop an

University of Wisconsin; and S Tuckey, University

oxidized flavor. Hot-pack sour cream differed from

of Illinois (Tuckey, 1963).

cream cheese processing in that it was not drained

Gutherie (1952) developed a method to measure *and no salt was added. Hot-pack sour cream flavor*

the body strength of sour cream using a plummet of

differs from conventional sour cream in that it has no

given weight and dropped from a given height. The

diacetyl or carbon dioxide (CO2) and has a cooked,

plummet was divided in ten equal segments and was

lactic acid flavor (Kosikowski and

Mistry, 1997).

used to measure body strength by depth of penetration

The first sour cream stabilizer was gelatin and

into a sour cream sample. This was used to evaluate

this did a reasonably good job. In the 1930s Arthur

results from their experiments on factors effecting

Ambrose of the Kraft-Phoenix Cheese Company, *sour cream. Their experiments encompassed fat con-*

while working on ice cream stabilizers, tried some

tent, time and temperature of pasteurization, homog-

gum combinations in sour cream. He discovered

enization techniques, use of rennet, addition of milk

that a mixture of 60% locust bean gum, 25% Irish

solids not fat (MSNF), effect of

stirring, and cooling

sour cream to 40◦F after incubation. They found that

fermentation to produce a smooth body with im-

sour cream could be made by either vat pasteurization

proved moisture binding properties. Vat pasteuriza-

or high temperature/short time (HTST).

A composi-

tion at 73.9–79.4◦C (165–175◦F) for 30 minutes or

tion of 18% fat, 9.5% MSNF, and addition of ren-

HTST at 82.2–85◦C (180–185◦F) for 3–4 minutes

net gave the most desirable consistency. It was also

hold will denature sufficient whey proteins. Vat pas-

found that cooling the incubated product to 40◦F be-

teurization lower than 65.6◦C (150◦F) or more than

fore packaging weakened the body (Gutherie, 1963).

85◦C (185◦F) for 30 minutes will produce a weaker

The work of these early researchers set the standards

body that is more susceptible to syneresis when prod-

for our present sour cream.

uct is stressed. Firmness of body is also determined by *methods of homogenization. Temperature and pres-*

PRESENT STANDARDS

sures of homogenization are key factors in the body

of sour cream. A long used method, giving an ex-

Federal standards require that sour cream be 18%

cellent body and texture, is two single-stage 2500 psi

butterfat (International Dairy Foods Association, *passes using a Manton–Gaulin homogenizer. This re-*

2003b). Acidification may be by a lactic culture or by

quires two available tanks and much processing time.

direct acid addition using an approved blend of acids.

The same effect can be accomplished by HTST with

The acid blend most often used is a combination of

a long hold tube and two homogenizers

positioned

lactic and citric acid. Other food grade acids, such as

in line after the holding tube. This system requires

acetic, propionic, or phosphoric are commonly used

one pass and saves much processing time and tank

to achieve a particular flavor or improve keeping qual-

space (Gutherie, 1963). Mix goes back through the *ity. Lactic, acetic, and propionic have bacterial static*

regeneration and cooling section where it is cooled

effects, while citric can be fermented by many organ-

to 21.1–23.9◦C (70–75◦F) and on to the fermentation

isms, and if used in high levels or out of proportion

tank for setting. The high heat treatment and homog-

with other acids can cause excessive

gas production

enization technique produces enough free fat crystal-

which will result in bloated cartons. One advantage

lization and fat clumping to form a firm-bodied sour

of direct acidification is extended an shelf life. Direct

cream without the use of stabilizers.

acidified sour cream and dips do not have the fine

As the popularity and sales of sour cream in-

flavor of cultured sour cream for the first 2 weeks

creased, the use of stabilizers allowed the produc-

of shelf life. Starting on about the 15th day, depend-

ers to simplify processing and install larger, higher

ing on storage temperature, enzymes from the culture

speed operations. Stabilizer companies *have met the*

will start producing a noticeable “aged” flavor similar

demands of cultured product manufacturers for sta-

to aging Cheddar or other cured cheeses. Proteolysis

bilizers to produce sour cream with excellent body

becomes apparent as bitter, cheesy, and stale flavors.

and texture. Stabilizers may be composed of gums, *The action of culture enzymes on dip spices becomes*

gelatin, modified food starch, whey proteins, and pro-

particularly unpleasant. If sour cream is made by di-

tein conditioners such as phosphates. A stabilizer spe-

rect acidification, it must be so labeled.

cialist can furnish stabilizers to give the body and

Body and texture of sour cream, which does not *texture of sour cream for a particular market.*

contain stabilizer, is determined by composition and

The majority of sour cream is incubated in large

processing. Mix should contain high-quality cream

tanks rather than 10-gallon cans, as was done in

and high-protein MSNF. Natural solids-not-fat con-

the early history of cultured products.

Usual incu-

tent of an 18% cream will be between 7.1% and

bation temperature is between 22.2◦C (72◦F) and

7.5%. To produce an optimum quality sour cream,

23.9◦C (75◦F). This temperature range produces a

solids-not-fat should be increased to 9.0–9.5%, us-

good balance between organic acids and aromatic fla-

ing high protein condensed skim milk or non-fat dry

vor compounds. Higher temperatures produce more

milk (NFDM). Standardized mix, ready for process-

acid flavor and less aromatic flavor. In sour creams

ing, should test 18.5% fat and 27.5–28.5% total solids

for industrial applications that do not require a fine

(Calbert, 1961).

flavor such as in baking and dips, incubation tem-

Processing can be accomplished by different meth-

peratures of 26.7–31.1◦C (80–88◦F) are often used

ods. Mix is heat treated by vat or HTST pasteuriza-

to reduce set times of 14–18 hours to 6–8 hours.

tion. In both cases, time and temperature of heating

A good sour cream culture is a blend of

Lactococ-

should denature a consistent amount of whey pro-

cus lactis and cremoris plus leuconostoc or Lc. lactis teins, which then coprecipitates with casein during

sp diacetylactis. For fast-set industrial sour cream,

cottage cheese cultures containing no flavor organ-

in the tank. End point of fermentation is determined

isms are often used at 31.1◦C (88◦F) to give sets

by titratable acidity or pH (pH is preferred). The titrat-

as fast as 4–5 hours. Citric acid or sodium citrate

able acidity will range from 0.70 to 0.90% depending

is often added to consumer sour cream to enhance

on the amount of MSNF used in mix.

The pH should

flavor and produce a small amount of CO_2. Exces-

be 4.45–4.5. Proper level of MSNF added to mix

sive CO_2 can cause problems. Since sour cream is

buffers acid development so that it is rare for sour

usually packaged at incubation temperatures, culture

cream to develop a harsh acid flavor. When correct *continues to ferment citrate until the product cools. If*

acid is developed, cup sets are placed in a cooler and

cooling is slow, which often happens when the case

tank incubated product is broken with a slow-sweep

is corrugated and palletized, excess carbon dioxide

agitator. Agitation should be used only intermittently

will swell carton and pop lids. This is *particularly*

during packaging. Tank sets are not usually cooled

severe when cartons have a gas tight seal and CO2

below 18.3◦C (65◦F) before packaging because body

cannot escape. Customers think that swelled cartons

will be thin. Cups are filled at 22.2–23.9◦C (72–75◦F)

indicate spoilage. Culture should produce enough di-

and product is cooled while quiescent in package.

acetyl for a balanced flavor without overcarboniza-

With tank-set sour cream, a positive pump is used

tion. The high fat content of sour cream smoothes

to pump the product through a screen, backpressure

out the sharp acid flavors that would be noticeable in

valve, or similar devise to smooth out *the texture.*

buttermilk. Some manufacturers take advantage of

When pumping at 18.3◦C (65◦F) or above, body will

this trait to shorten incubation time by increasing set

resist thinning by shear. As temperature is reduced

temperature to 29.4–31.1◦C (85–88◦F). Product will

below 18.3◦C (65◦F), viscosity is reduced and body *have a clean acid flavor, but will lack the pleasant lin-*

does not reset firmly in the cup. Warming cups to

gering aroma produced at lower incubation tempera-

21.1◦C (70◦F) and cooling again will restore some

ture. Direct set cultures work very well to inoculate

body. This procedure would only be used to correct

sour cream. These are the most reliable *methods and*

a mistake.

are consistently balanced between acid and flavor-

producing organisms.

Summary of Procedures

Rennet may be added at set time to produce a firmer

A summary of sour cream processing is available

body. If sour cream is to be used for dips, salt content *in Gourmetsleuth (2001). Use only those ingredients*

of dip seasonings will cause product to thin if stabi-

that are free of defects. Do not try to salvage old and

lizers or rennet are not used. Usage level of single-

off-flavored ingredients by using them in cultured

strength rennet varies between 0.5 and 50 ml per 100-

products. Best advertising dollars are *spent on quality*

gallon mix. The upper level is close to that used for

products.

Cheddar cheese and is not recommended. The usual

level is 5 ml per 100 gallon. Even at this level caution

1. Standardize mix to 18.5% fat and 27.5% total

must be taken to have rennet well diluted with cold, *solids. Avoid incorporation of air while blending*

pure water and limit agitation after addition so that

mix.

product is quiescent before rennet coagulates casein.

2. Vat pasteurize at 73.9–79.4◦C (165–175◦F) for 30

If rennet reacts with casein, while mix is still in mo-

minutes or HTST 82.2–85◦C (180–185◦F) for 3 *tion, a grainy texture will develop and whey-off may*

to 4 minute hold.

occur. Rennet should be added after culture is added.

3. To produce a firm-bodied sour cream, homogenize

At 22.2–23.9◦C (72–75◦F), usual incubation time is

two single-stage 2500 psi passes. High-speed op-

14–18 hours.

erations that use the same homogenizer for milk

The automated mix blending operation shown in

and sour cream processing and two-pass system

Figure 18.2 is for a sour cream and dip base. Tanks

cannot be used. A stabilizer will be required to

are on load cells, liquid ingredients are metered into

give a proper viscosity to the sour

cream.

tanks, and dry ingredients are added through a liq-

4. Cool to 21.1–23.9◦C n(70–75◦F) and set with di-

uefier. Mix is circulated through a shear pump un-

rect set or bulk sour cream culture. Use 5 ml rennet

til uniform. It is analyzed for fat and solids before

per 100-gallon mix.

processing through HTST and homogenization. Mix

5. Break at pH 4.5 with slow-sweep agitation, then

goes to a fermentation tank at 22.2◦C (72◦F) for fer-

turn off agitator and start packaging. Turn agitator

mentation to pH 4.5.

on periodically during packaging to blend in any

Sour cream may be incubated in the cup, 10-gallon *pockets of whey. Agitation should be automated*

can, or tank. Most large volume operations incubate

so each batch is consistent.

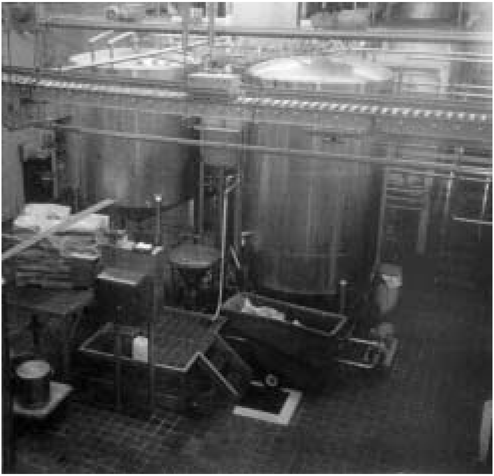


Figure 18.2. *Automated mix blending in*

modern sour cream plant.

6. Pump sour cream with positive pump through a

b. Agitator left on through part or all of incuba-

screen, backpressure valve, or similar smoothing

tion: (tank set)

devise to packaging machine.

c. Low casein milk: (spring and summer milk)

7. Package at incubation temperature and cool in

d. Homogenizer difficulty: (bad valves, type of

package for maximum body firmness.

valve, pressure not correct)

e. Excessive agitation before packaging and pack-

aging sour cream too cold

Problems and Correction

f. Excessive heat treatment

g. Consistently weak-bodied: (basic mix formula

Simple mistakes account for many problems but are

should be changed and processing methods

often the most difficult to find. People do not like

evaluated)

to admit a mistake especially if they

think their job

2. Weak body at beginning of packaging and heavily-

is in jeopardy. Because of incubation time, cultured

bodied at end: (often fat test is low on first product

products are usually made at the end of the day or at

and high at end of packaging)

night when supervision is minimal and low seniority *a. Steam valve leaked on tank during incubation*

personnel are working; therefore, good methods of

causing bottom of tank to be warm. Whey forms

communication are essential in determining and pre-

in bottom and fat rises to top. Often pH is differ-

venting problems. Working atmosphere should en-

ent in top and bottom of the tank

because of tem-

courage workers to tell a supervisor immediately if

perature difference. Sweep agitation will not

a problem is suspected. Problems can often be cor-

completely blend viscous mass. Double valves

rected if found early.

should be used on steam and refrigerated lines *to insure no leakage*

b. Some homogenizer systems will promote fat

Body and Texture

clumping sever enough that fat will rise before

1. Weak body

acid is sufficient for coagulation

a. Stabilizer or milk solids left out of mix: (have

c. Excessive agitation at set can cause fat to churn *a check list for mix personnel)*

and rise to top of tank

3. Different pH on top and bottom of tank

4. Bitter

a. Temperature is different at top and bottom of

a. Lactic culture that produces high levels of pro-

tank. Steam valve or refrigerated water valves

teolytic enzymes

leak

b. High psychrotrophic bacteria counts in raw

b. Excessive air incorporation in mix. Air rises

milk supply

to top of tank. Cultures are microaerophilic

5. Rancid

and will work faster at bottom of tank than

a. Raw milk contains heat-stable lipolytic en-

top

zymes

4. Grainy texture

b. Old and poorly handled cream

a. Excessive rennet, which was insufficiently di-

6. Absorbed and unnatural flavors

luted with water when added to mix, will coag-

a. Sour cream stored next to fruits, vegetables,

ulate casein before mix is quiescent

solvents, cleaning supplies, etc.

b. Excessive heat treatment of mix

b. Mix contaminated with sanitizers or other

c. Culture agglutination: (should not occur if heat

agents used in plant

treatment is sufficient)

d. Stabilizer reaction with milk protein: (certain

SOUR CREAM PRODUCTS

pectin, algin, and carrageenan will react with

milk protein unfavorably)

In the beginning it was determined that 18% fat made

e. Screen or backpressure device left out of line

the optimum sour cream and the Food

and Drug Ad-

between tank and filler

ministration (FDA) set this as the standard. Those

f. Fat churning due to excessive agitation at set

were the days when butter was the king and skim

5. Free whey on packaged product

milk was a by-product. Later came heart disease re-

a. Packaged sour cream has suffered

physical

search that indicated butterfat was a potential villain.

and/or temperature shock

Media-hyped various nutritional papers denouncing

b. Improper heat treatment of mix

any food containing high fat and high cholesterol and

c. Insufficient acid development: (above pH 4.6 at

this redirected the diet of the general *populous. Dairy*

packaging)

marketing people requested products to satisfy public

d. Wrong stabilizer

demand for low fat and low cholesterol products. This

e. Low solids mix: (low casein resulting in weak,

led the way to development of lower fat sour cream

fragile body)

products. In November 1996 the FDA changed the

6. Slick texture or gummy body

standard of identity for sour cream to cover products

a. Wrong or too much stabilizer

lower than 18% fat. To give the consumer a wide

b. Using a culture that produces high levels of

selection, sour cream was divided into lower fat cat-

polysaccharides

egories. Sour half and half, reduced fat, light sour

cream, and nonfat or fat free are some names now in

use (refer to FDA standards for labeling). Sour skim

Flavor Defects

milk is identified as fat-free sour cream, and it must be

1. Lacks flavor

stabilized heavily enough to have a

sour cream-type

a. Incorrect incubation temperature

body otherwise it is buttermilk. Replacing butterfat

b. Not enough acid development

with vegetable fat is called a filled sour cream. Tak-

c. Culture does not contain flavor-producing or-

ing it a step further, replacing butterfat with vegetable

ganisms

fat and skim milk solid with sodium caseinate pro-

d. Low citrate level

duces an imitation sour cream. It must be noted that

e. Flavor mask by high level or wrong stabilizer

some vegetable fats do more damage to the human

2. Green flavor (like a green apple flavor, occurs

circulatory system than butterfat.

when diacetyl is reduced to acetaldehyde)

Producing a firm-bodied reduced fat sour cream

a. Wrong culture selection

is not a difficult project. By increasing NFDM and

b. High temperature and over incubation

selection of the correct stabilizer blend, reduced fat

3. Oxidized

sour cream can be made that is about comparable

a. Mix exposed to copper in processing system

to 18% sour cream. Making a good fat-free sour

b. Product exposed to sunlight or fluorescent

cream is difficult. Skim milk solids must be increased

light

with NFDM, whey solids or whey protein, and a

Figure 18.3. *Production of sour cream dips.*

compatible stabilizer blend is essential *to give a body*

bases can be formulated to keep a fresh flavor for

close to sour cream. Correct selection of emulsifiers

long periods of time and stand up to abuses received

can produce a texture similar to milk fat, but the fi-

in the distribution chain. Three flavor blending tanks

nal product still falls short of 18% fat sour cream.

are shown at center left in Figure 18.3. Dry dip spices

Culture selection is also more critical for no fat sour

are palletized on deck to be added to each tank.

cream. Because of high levels of MSNF, cultures pro-

To make an acceptable imitation sour cream re-

duce excessive amounts of CO2 giving a sharp bite

quires skilled research. Correct

vegetable fats, emul-

to the product. If the product is packaged with a gas-

sifiers, sodium casein, whey powder, whey proteins,

tight seal, the carton puffs up and alarms consumers

and some times corn syrup solids and other body

that something may be wrong with it. Making an ac-

builders are used to develop a usable formula. The *ceptable no fat sour cream requires close attention to*

vegetable fat and emulsifier must produce a creamy

every detail, but there are acceptable products in the

consistency, which resist crystallization when heat

market.

shocked. Some imitation sour creams on the mar-

Filled sour creams have found a niche in the sys-

ket have a body more like lard than sour cream due

tem. By selecting the correct vegetable oil and com-

to excessive fat crystallization. Body building solids

patible emulsifier system, a heart-healthy sour cream

should work together to give coagulation similar to

product can be produced that is pleasing to eat. An-

MSNF and without off-flavors. Caseins

in particular

other large volume use for filled sour cream is in the

can produce off-flavors tasting like glue. When all

manufacturing of chip dips (Fig. 18.4). For the first

elements are compatibly put together, a reasonably

2 weeks of shelf life, there is nothing better than a

eatable product can be made. But why make an imi-

dip made with butterfat. Then bacteria and enzymes

tation sour cream when the others will usually make

from dip seasonings start to decompose butterfat and

a better product? There is a small market for peo-

unpleasant flavors develop. Chip dips often have a

ple with specific health problems, and people who

shelf life of over 90 days. Using direct *acid in place*

will not eat animal products of any kind. Also an

of cultures and vegetable fat in place of butterfat, dip

imitation sour cream can be made to meet Orthodox

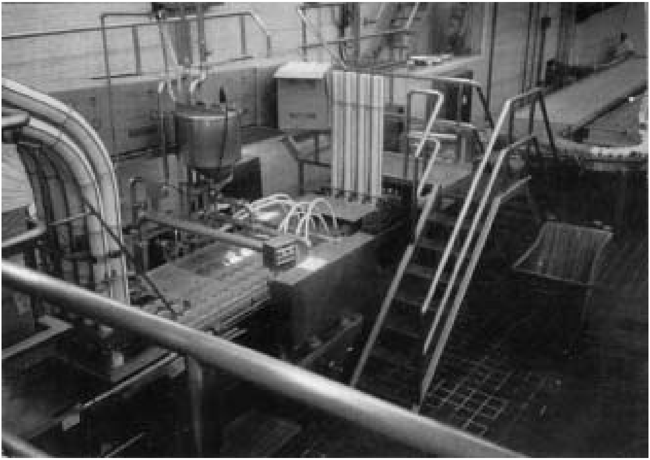


Figure 18.4. *Production of filled sour cream dips.*

Jewish laws. (Note that kosher gelatin is available, but

cream to adhere to an oily piece of fish requires a

mixing any animal gelatin with milk is not kosher).

combination of emulsifiers and starch. Each applica-

Imitation sour cream has found favor with some in-

tion of sour cream is an individual challenge, which

dustrial bakers, dessert, and salad

makers because it

when met with expertise, will increase sales. The fu-

is cheap and fat crystallization produces a firm body

ture sour cream, in many forms, will continue to grow

when mixed with other ingredients.

as these challenges are met.

Sour cream's popularity has grown logarithmically

since its development on the East Coast *in early*

1900. Homemakers and professional chefs have de-

REFERENCES

veloped thousands of recipes using sour cream. Many

of the products that were developed became very

Calbert H. 1961. Cultured sour cream. Manufacturers'

popular and are now manufactured by large food

Conference, University of Wisconsin, Madison.

companies (i.e., sour cream for cheesecake toppings,

January.

sour cream for herring, sour cream in salad dress-

Clark J, Goldblith S. 1975. Processing foods in ancient

Rome. Food Technol. 29(1):30–32.

ings, freeze/thaw-stable sour cream, and sour cream

Editors of Life. 1961. The epic of man. Time, Inc. p. 76.

that can stand temperature and agitation of ultra-high

FarMore F. 2003. Milk history: Milestones of milk

temperature [UHT] sterilization). Each of these ap-

history in the United States. Retrieved February

plications requires the research person to find the

2004 from

http://www.wegotmilk.com/milk history

correct combinations of stabilizer, starch, and emul-

.html

sifier for the specific conditions. If sour cream is to

Food News Service. 2003. Ochef—Questions: What

be combined with other ingredients containing amy-

are all the dairy products under the sun? Retrieved *lase, starch cannot be used because it will be degraded*

February 2004 from http://www.ochef.com/100.

and the product becomes thin with free whey present.

htm

UHT destroys the protein structure of sour cream;

GourmetSleuth. 2001. How to make sour cream.

therefore, body must be achieved with a combination

Retrieved February 2004. Available at http://

of gums and special modified starches. To get sour

www.gourmetsleuth.com/recipe sourcream.htm.

Gutherie E. 1952. Study of the body of cultured cream.

Retrieved February 2004 from. Available at

Bull. 880, Cornell University, Ithaca, NY.

http://www.idfa.org/facts/milk.cfm

Gutherie E. 1963. Further studies of the body of

Kosikowski FV, Mistry VV. 1997. Cheese and

cultured cream. Bull. 986, Cornell University,

fermented milk foods: Origins and principles.

Ithaca, NY.

Vol. 1, 3rd ed. Westport, CT. p. 82.

International Dairy Foods Association. 2003a. Industry

Lundstedt E. 1977. Manufacture of superior sour

facts-milk: Milestones of milk history in the U.S.

cream. Cult. Dairy Prod. J., 10(1):20–22.

Washington, DC: Milk Facts, 2002 ed. Retrieved

Pariser E. 1975. Food in ancient Egypt and classical

February 2004. Available at http://www.idfa.org

Greece. Food Technol. 29(1):23–27.

/facts/milk.cfm

Tuckey S. October, 1963. Sour cream processing.

International Dairy Foods Association. 2003b. Industry

Dairy Conference, University of Illinois,

facts-milk: Definitions of fluid milk and milk

Urbana.Available at http://em.wilipedia.org/

products. Washington, DC: Milk Facts, 2002 ed.

wikicream.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

19

Other Fermented and

Culture-Containing Milks

Ebenezer R. Vedamuthu

Introduction

geographical region of their origin but also the types

Dahi

of milk used in their production, the gradation in the

History

technology employed, the cultural conditions, and

Production and Packaging

the types and species of microflora involved in those

Product Description and Keeping Quality

fermentations. Short descriptions of the various cul-

Microbiology

tured milks in the following paragraphs illustrate that

Kefir

diversity:

History

Dahi is a semisolid cultured product popular

Production, and Packaging

Product Description and Quality

throughout South Asia, but there are subtle variations

Microbiology

in the body and flavor of Dahi made in different parts

Koumiss

of the subcontinent. In a large portion of the coun-

History

try, Dahi is made from cow milk. There are pock-

Production

ets where a mixture of cow milk and buffalo milk

Product Description

is used, and in certain areas buffalo milk is almost

Microbiology

exclusively used. Buffalo milk being high in solids

Acidophilus Milk and Sweet Acidophilus Milk

content, yields a very firm product, while cow milk

History

Dahi is a relatively softer product. In terms of fla-

Production of Acidophilus Milk

vor, in certain regions a mildly acidic, yeasty-sweet

Production of Sweet Acidophilus Milk

Quality Standards

product is desired, whereas in other regions a more

Microbiology

acidic Dahi is preferred. Because of the higher solids

Probiotic Milks

content of buffalo milk, the acidity of buffalo milk

History

Dahi is higher. There is general agreement among

Production of Probiotic Milks

the scientific community that the microorganisms in-

Quality Standards

volved in Dahi fermentation consist of dairy lacto-

Bulgarian Milk

cocci , leuconostocs, and certain yeasts (Rangappa

Skyr

and Achaya ,1975) although the yeasts may be con-

Vilii

sidered as secondary contaminants that are carried

Microbiology

over by the extensive “back-slopping” that is prac-

References

ticed in households and cottage industry involved in

Dahi production. Back-slopping is the

practice of

INTRODUCTION

using a small remnant of the previous day's prod-

uct to inoculate a fresh batch. The Bureau of Indian

Dahi, Kefir, Koumiss, Acidophilus Milk, Probi-

Standards recognizes a category called "Sour Dahi"

otic Milk, and other cultured milks represent the *for which additional secondary flora consisting of*

great diversity of cultured dairy products produced

themotolerant "coccus-rod" mixtures used in Yogurt

around the world. The diversity not only reflects the

may be included (Aneja et al., 2002).

295

296

Part III: Manufacture of Fermented

Milks

Kefir is popular in Russia, and originated in the area

Lactobacillus acidophilus bacteria have been de-

abutting the Caucasus mountain range. Traditional

signed. These products are generally called "Sweet

Kefir is produced using Kefir grains as inoculum.

acidophilus milks" (Foster et al., 1957).

The incubation is at room temperature. Kefir is an

The definition for the term "probiotics" varies from

acidic–alcoholic product as both lactic acid bacteria

a general description such as, "live microorganisms

and yeasts are involved in the fermentation. Accord-

administered in adequate amounts that confer a health

ing to Kosikowski and Mistry (1997), in

Russia, Kefir

effect on the host" (Skovsende, 2003) to a more

may be made from goat, sheep, or cow milk. The lac-

narrow specification, which states, "probiotics are

tic acid content is usually around 0.8% and alcoholic

live microbial food supplements, which benefit the

level about 1.0%. Carbon dioxide is the other ma-

health of consumers by maintaining, or improving

jor fermentation byproduct in Kefir. Modern produc-

their intestinal balance” (Mattila-Sandholm et al.,

tion of Kefir in Russia and other European countries

2002). Several species comprising the genera Lac-

where it is popular varies from the traditional pro-

tobacillus and Bifidobacterium are

normal inhabi-

cess. The microflora involved in Kefir fermentation is

tants of healthy human gut, and have been shown

complex.

to play a regulatory role in the ecology and the mi-

Koumiss is acidic–alcoholic cultured milk that has

crobial flora of the gut (Sanders and Huis in't Veld, *considerable commercial and public health signif-*

1999). Regular intake of probiotic-rich foods may

icance in Russia (Kosikowski and Mistry, 1997).

contribute to maintaining intestinal health and gen-

Koumiss is made from mare's milk. Koumiss has a

eral well-being. Various other health benefits, such

milky white appearance with a grayish

tint. Unlike

as improvement of lactose metabolism, reduction in

most other cultured milk products, which form co-

serum cholesterol, antimicrobial, anticarcinogenic,

agula of different consistencies, Koumiss remains a

antimutagenic effects, and immune stimulation have

fluid even after the fermentation is complete. The *been ascribed to the regular intake of probiotics*

protein in mare's milk is different from the pro-

(Shah, 2001). Skovsende (2003) has cited other re-

tein in milk from other species, and does not coag-

ported benefits. The scientific evidence, however,

ulate even with increase in acidity or when rennet

is stronger and more equivocal with

respect to the

is added (Kosikowski and Mistry, 1997). According

maintenance of intestinal health. Although several

to Vedamuthu (1982), mare's milk does not coag-

food products other than dairy foods like sausages,

ulate at the isoelectric point of casein and hence,

breakfast cereals, health food bars have been ex-

Koumiss, which may contain about 0.7–1.8% lactic

plored as vehicles for the delivery of probiotics, by

acid and 1.0–2.5% ethanol, is not a curdled product.

far the greatest success has been with dairy prod-

Robinson et al. (2002) report that Koumiss or

ucts, especially fluid milk (Skovsende, 2003). A more

Koumiss-like products carrying names

such as Airag,

comprehensive discussion of the benefits of adding

Arrag, Chige or Chigo are produced in Mongolia and

probiotics to milk is found in Chandan's review

Western Chinese provinces.

(1999).

Vedamuthu (1982) defines Acidophilus milk thus,

Besides the products discussed in the

foregoing

“Acidophilus milk or reform yogurt is the product

paragraphs, there are few other cultured dairy prod-

obtained by fermenting milk with an authentic cul-

ucts that are either confined to limited geographical

ture of Lactobacillus acidophilus.” Acidophilus milk

areas or little known beyond the areas where they are *may be considered the prototype of all the present day*

produced and consumed.

probiotic milks. One of the unique features of Lacto-

Bulgarian milk is cultured milk that is popular in

bacillus acidophilus is its ability to survive the severe

the Eastern European countries. This product may

environmental conditions found in the intestinal tract *be considered to be the forerunner of the present day*

of man, animals, and birds. This bacterium is com-

traditional Yogurt. The appellation "Bulgarian" came

monly a part of the total microbial flora of healthy

about because the product originated in Bulgaria. For

humans. Scientific evidence has been steadily accu-

the product produced in Bulgaria, only

Lactobacillus

mulating to establish that the normal intestinal flora

delbrueckii ssp. bulgaricus (rod) is used as starter.

contributes in no small measure to gut health. Tradi-

In other places, the "coccus" (Streptococcus ther-

tional Acidophilus milk is an extremely sour product

mophilus) may be included along with the "rod." It *and does not contain other balancing flavors. Hence,*

is believed that the species name "bulgaricus" was

it has not been a popular product. Accordingly,

derived from Bulgarian milk from which the Lacto-

alternative means to deliver gut health promoting

bacillus species was first isolated. It is a highly acidic

19 Other Fermented and Culture-Containing Milks

297

product with a green acetaldehyde flavor reminiscent

of those times presumably were aware that green

of traditional Yogurt.

plants are the natural habitat for lactic acid bacteria.

In Scandinavian countries unique cultured milk is

In many of the art forms of India depicting the mytho-

consumed. The well known among those products is

logical legends of the exploits of Lord Krishna (incar-

Viili, also known as Pitkapiima, or just Piima and

nate of Lord Vishnu), show young

Krishna stealing

Fiili. This product is popular in Finland. In other

Dahi curd from earthen pots in the larder, or frolick-

Scandinavian countries, similar products carry names

ing with milkmaids carrying earthenware, containing

such as Langfil, Taettemelk, and Keldermilk. The

Dahi.

unique feature about those milks is their ropy, stringy,

In Vedic times as well as at present, Dahi is made

and viscous texture. When a spoon is inserted into

for consumption as such or as a starting material for

one of those products and lifted out, the coagulum

secondary products. In Southern India, Dahi may be

clings to the spoon and forms long

stringy threads

eaten as curds or mixed with rice. Sometimes, a va-

as the spoon is drawn away from the surface of the

riety of spices and condiments cooked in hot edible

curdled mass. Special capsular slime-forming dairy

oil are added to Dahi, and the mixture is used to fla-

lactococci are included along with noncapsular lac-

vor the rice staple. Plain Dahi or the product embel-

tococci in starters for those products. The Finnish

lished with hot spice-oil mixture may be used as salad

Viili also has a thin layer of mold on the surface.

dressing (raitha, the modern equivalent of rayata—

The mold, Geotrichum candidum is considered to

royal food item of Vedic times). A

doughnut shaped,

impart a unique flavor to the product. The immediate

deep fat-fried product made from a batter consisting

layer below the surface of the mold, is less acidic, be-

of cereal-legume mixture called "vada" soaked in

cause Geotrichum candidum metabolizes lactic acid

plain Dahi or Dahi containing hot spice-oil mixture, *formed by the lactococci.*

is served in Indian homes as “Dahi vada. ”

Skyr is Icelandic cultured milk. It has been in-

In Northern India, where wheat is the staple, Dahi

troduced in Denmark. The product is a variation of

is eaten with flat wheat breads of different kinds. An-

Yogurt. It may be considered as a concentrated Yo-

other favorite in Northern India is salty or sweet lassi,

gurt. The starter flora for Skyr is similar to Yogurt, and

which is Dahi mixed and whipped with cold water,

consists of a symbiotic combination of "rod" (Lac-

spices and salt (for salty lassi) or sugar (for sweet

tobacillus delbrueckii ssp . bulgaricus) and "coccus"

lassi). This drink is popular to quench *the thirst dur-*

(Streptococcus thermophilus). Skim milk is used in

ing hot summer months. The South Indian equivalent

its production and the concentration of the coagu-

is "buttermilk" (or moar). Dahi is also the interme-

lum is achieved by removing sufficient whey to in-

diate in the production of desi butter or makhan. For *crease the solids level in the product from 18% to*

conversion into makhan, the dahi curd with or with-

20%, which increases the initial acidity range from

out the addition of cold water is churned with a man-

1.4–1.6% to 2.5–3.0% (Foster et al., 1957).

ual wooden paddle until the butter granules separate

There are other concentrated

variations of Yogurt,

from the serum. The granules are collected and con-

and other cultured milks made with mesophilic dairy

solidated to form a lump or a pat. The serum portion

lactococci known by different local nomenclatures,

and the residual solid is consumed as a refreshing

and are listed in Chapter 1.

drink, or mixed with rice and consumed. Desi butter

is largely used for making ghee, the preferred short-

ening in Indian cooking. In some homes, the upper

DAHI

cream layer on the surface of Dahi made from whole

milk is removed and stored until enough material is

History

gathered, for churning into makhan. Another impor-

The origin of Dahi is shrouded in antiquity. Accord-

tant product made from dahi is Shrikhand, popular

ing to Aneja et al. (2002), numerous references to

in the Western States of India. Srikhand is a con-

Dahi are found in Vedic literature, which comprise

centrated curd of dahi by draining off *the whey, and*

the sacred books of Hinduism. In the major sacred

fortifying the concentrated curd with sugar and fla-

book, the Rig Veda, various means of curdling milk

vorings like nutmeg and cardamom.

(for Dahi) with a starter consisting of a small portion

Besides the foregoing, there are various other dahi *of an earlier stock, or by introducing greens from the*

derivatives. Those products are discussed by Aneja

putika creeper, the bark from palasha plant or the fruit

et al. (2002), Rangappa and Achaya (1975), and Pra-

of the kuvala (Ziziphus spp.) are mentioned. People

japati (2003).

Production and Packaging

small. The manufacturing process and the equip-

ment used are similar to other cultured dairy prod-

Dahi is largely made in individual households for

ucts in the West. Double-jacketed stainless steel vats

the immediate needs of the family. In villages and *equipped with suitable agitators and in-place heating*

towns, the product is often made on a cottage in-

and cooling design, and incorporating cleaning-in-

dustry scale for sale, as such or for converting it to

place (CIP) piping and equipment are used. Milk may

makhan, and ultimately to ghee. Ghee is essentially

be vat pasteurized or run through a

high- temperature-

clarified butter oil, which is made by evaporating the

short- time (HTST) or an ultra high temperature

moisture off the desi butter by heating on an open

(UHT) equipment and piped into stainless steel vats

fire. The heat treatment and the drastic reduction in

equipped with thermostatic temperature controls (for *moisture content render the shortening a relatively*

incubation and cooling). To monitor the course of

stable product under ambient conditions, which could

fermentation, the vats may have sanitary ports for

be easily transported to urban markets. Greater care

pH probes coupled with a recording chart, or sam-

is exercised in making dahi for direct *consumption*

ple ports. After incubation is completed, the curd is

than for conversion into butter or ghee (Rangappa

gently broken by turning on the agitators and con-

and Achaya, 1975).

comitantly cooling the curd mass by circulating chill

In preparing dahi in households and in cottage *water (sweet water) in the vat jacket. After sufficient*

scale production centers, milk is boiled to destroy

cooling, the curd is gently conveyed to a filling ma-

contaminants, and after cooling to body or ambient

chine. To preserve the desired body and texture, grav-

temperature in a covered vessel, is inoculated with a

ity flow is desirable. If pumping is

necessary, a posi-

portion of the previous day's product. The vessel may

tive displacement pump with a back-pressure device

be left undisturbed in a warm place (next to a warm

is recommended. Plastic cups with lids and display-

oven) or wrapped with a cloth or straw and placed in

ing attractive graphic designs are used for packaging *a straw box to prevent loss of warmth by radiation*

industrially manufactured dahi. For a more detailed

for anywhere from 6 to 24 hours depending upon the

description of the equipment and processes used in

ambient temperature. Rangappa and Achaya (1975)

industrial production of dahi, the reader is referred

state that the amount of inoculum

would vary de-

to Aneja et al. (2002).

pending upon the ambient temperature. In very cold

There are definite differences in process parame-

weather, 5–10% by volume may be used, and dur-

ters between the small-scale and industrial-scale pro-

ing summer about 1–2% may be used. During very *duction of dahi. These differences relate to the heat*

hot summer months, the vessel containing the in-

treatment of milk, the incubation temperature and

oculated milk may be wrapped in a moist cloth to

the starter flora. Another variation is the homoge-

keep the content insulated from getting too warm.

nization of the milk or the sweetener

containing mix.

The authors further opine that the seed used is never

Homogenization ensures uniformity in body and tex-

a pure culture but mixed with the predominance of

ture, and prevents the formation of the "cream line."

lactic acid bacteria. The final acidity after incuba-

In small-scale production, the milk is brought to a *tion may range from 0.7% to 1.0%. And, for good*

complete boil before it is slowly cooled down with-

dahi, Rangappa and Achaya (1975) suggest a final

out any external coolant to body or ambient temper-

pH range of 4.6 to 5.2. After incubation and attaining

ature. On an industrial scale, by low temperature—

the desired curd formation and acidity, *the product is*

long hold (LTLH) procedure, milk is heated to 63◦C

kept in a cold spot or held in clean, covered earth-

and held at that temperature for 30 minutes; and,

enware to achieve evaporative cooling, or immersed

when sweeteners are added to milk, the mixture

in a shallow pan containing cold water. A similar *heated to, and held at 66◦C for 30 minutes. This*

process is mentioned by Aneja et al. (2002). In vil-

is usually vat pasteurization. For HTST treatment,

lage markets and bazaars in towns, dahi portioned

milk is heated to 73◦C and held for 15 seconds, and

out in small pottery is offered for sale. The product

milk with sweetener is heated to 75◦C

and held for

may also be ladled out of a large earthen vessel into

15 seconds. The temperature-time parameters for

receptacles brought to the market or bazaar by the

UHT treatment may range from > 90◦C to 148◦C

customers.

for 2 seconds. When direct culinary steam injection

To cater to the urban populace of India with

heating is practiced, the temperature attained is 94◦C

greater purchasing power , dahi is also made on an

with suitable adjustments made for dilution of the mix

industrial scale. The volume is, however, relatively

by condensation of steam (Aneja et al., 2002). On an

19 Other Fermented and Culture-

industrial scale, after heating, the milk/mix is cooled

prepared from buffalo milk shall apply" (Aneja et al.,

rapidly to the desired temperature by external cooling

2002).

devices.

The keeping quality of dahi made in the unor-

The incubation for cottage industry preparation of

ganized sector varies considerably. Normally, dahi

dahi is at ambient temperatures, which may range

made in individual homes and sold in unorganized

from 28◦C to 30◦C during summer, and in winter

sector is consumed immediately, with a small portion

months, the temperatures may vary

from 20◦C to

retained for inoculating the next batch. If properly

24◦C. Aneja et al. (2002) report that in industrial

handled and refrigerated, dahi made in unorganized

production of dahi, the incubation temperature is

sector may have a shelf life of 2 to 3 days. Industri-

37◦C, and is thermostatically controlled. Because of *ally manufactured, packaged dahi would have a shelf*

the accelerated growth at higher temperatures, the

life of 7 to 10 days when properly refrigerated and

incubation period is shorter for industrial produc-

handled.

tion. Shorter incubation probably fits with rapid turn

Dahi is often described as the Indian equivalent *over of equipment and work schedules needed for*

of yogurt. In reality, however, there are distinct dif-

industrial operations. At the end of fermentation,

ferences between the two products. Plain yogurt cur-

in industrial operations, the dahi is rapidly cooled

rently made is a firm, smooth product that can be

to $< 5^\circ C$ to arrest excessive acid *development and*

spooned without much distortion of the curd body

"whey-off."

and structure. This is attained by the fortification of

the mix with additional milk solids and (or) the use

of stabilizers. Dahi, on the other hand, is a soft coag-

Product Description and Keeping

ulum that is lumpy, and would display

jagged edges

Quality

when the curd is broken, and exude whey near the

Rangappa and Achaya (1975) describe dahi as,

cut edges. While yogurt mixes are homogenized to

"Good dahi is a weak gel, like junket." That is a very

give a smooth body, lack of homogenization and sta-

good description. The coagulum is soft and "livery."

bilizers in dahi manufacture (except in industrial pro-

The body of dahi may be termed as somewhat lumpy,

duction) give dahi a lumpy texture and tendency for

and the texture as smooth. Dahi made from buffalo

whey off. In terms of flavor, yogurt is characterized

milk tends to be somewhat firmer than

the product

by sharp acid tartness (recent trends in yogurt show

made with cow milk or a mixture of cow and buffalo

a preference for mild acidity) and the characteristic

milk. Limited volume of dahi made from goat milk

"green," acataldehyde flavor (lately, a barely percep-

also displays a firmer curd than cow milk product.

tible greenness is preferred). Dahi, on the other hand,

Those differences are reflective of higher solids con-

is mildly acidic, and diacetyl is the prominent fla-

tent of buffalo and goat milks. Dahi made industrially

vor compound. The difference in the flavor between

usually contains added solids and sweetener, and the

yogurt and dahi is because of the

starter flora used.

mix is homogenized. The coagulum made from such

This will be addressed in the next section. Indus-

fortified mixes is firmer, which is desired because,

trial scale dahi, where coccus or coccus-rod combi-

postfermentation operations such as breaking of the

nation is used, the product will have a flavor typical *coagulum, pumping and filling, tend to weaken the*

of yogurt. Those aspects are discussed by Aneja et

curd structure, and loss of desired body characteris-

al. (2002).

tics. The firmer body attained industrially compen-

sates for such postfermentation losses in body char-

Microbiology

acteristics.

The Pure Food Act in India defines dahi or curd

The predominant bacteria in dahi starter cultures

"as a semisolid product, obtained from pasteurized

consist of dairy lactococci and leuconostocs. The

or boiled milk by souring (natural or otherwise),

dairy lactococci are homofermentative, and produce *using a harmless lactic acid or other bacterial cul-*

> 99% lactic acid from lactose. The dairy leuconos-

tures. Dahi may contain additional cane sugar. It

tocs are herterofermentative, and produce about 70%

should have the same minimum percentage of fat and

lactic acid from sugars, and the remaining 30% of

solids-not-fat as the milk from which it *is prepared.*

the byproducts are made up of acetic acid, ethyl al-

Where dahi or curd, other than skimmed milk dahi,

cohol, and carbon dioxide. The dairy leuconostocs

is sold or offered for sale without any indication of

also metabolize the citrate present in milk to form di-

the class of milk, the standards prescribed for dahi *acetyl and its reduced derivatives. While lactic acid*

imparts the pleasant, mild acidic flavor, diacetyl con-

for kefir was carried out in a leather bag made of

tributes to a buttery, nut-meat like flavor. The other

goat hide on a continuous basis by periodic with-

components (acetic acid, alcohol, and carbon diox-

drawal of a portion of the fermented product and

ide) impart a balanced rounded flavor to dahi, much

replenishing the container with fresh milk. During

like Cultured Buttermilk. The presence of Strepto-

warm months of the year, the fermentation bag was

coccus thermophilus and Lactobacillus

delbrueckii

hung outdoors, and brought indoors during winter to

subsp . bulgaricus in factory scale dahi starters, leads

keep it warm. An interesting practice was to hang the

to the formation of acetaldehyde as in yogurt. The

leather bag containing the fermenting milk near the

characteristics and the roles played by the starter flora *door step, so that each person going past can kick or*

of dahi and yogurt are summarized by Aneja et al.

shake the bag to keep the contents mixed (Foster et

(2002).

al., 1957). Now, kefir is popular all over Russia, and

Because dahi is largely made in the unorganized

the annual per capita consumption amounts to 4 to *sector, where back-slopping is widely practiced, and*

5 kilograms.

controlled process conditions are not used, the bacte-

rial flora of dah i is highly variable. Those aspects are

Production, and Packaging

discussed in detail by Rangappa and Achaya (1975).

Because dahi is a cultured dairy product, bacterial

The complete starter flora of kefir is contained within

count such as Standard Plate Count on a general me-

and on the surface of the kefir grains. Kefir grains

dia is unsuitable to provide the index of quality. Be-

vary in size and may measure from 0.5 to 3.5 cm in

ing an acid food, coliform count on dahi is unsuit-

diameter. The grains are gelatinous

white- or cream-

able as a sanitary index. Count for enterococci would

colored irregular granules ranging in size from that

be more applicable as a sanitary index. In addition,

of a wheat grain to a walnut. They have convoluted

yeast and mold count would be more relevant in qual-

irregular folded surfaces resembling cauliflower flo-

ity attributes of dahi. For microbiological examina-

rets and an elastic consistency (Robinson et al.,

tion of dahi and its significance, the methods and the

2002; Vedamuthu, 1982; Kosikowski and Mistry,

discussion provided for fermented dairy products in

1997). Vedamuthu (1982) states that the granules are

the Compendium of Methods for the

Microbiologi-

largely composed of a polysaccharide called kifran ,

cal Examination of Foods (Richter and Vedamuthu,

which according to Kosikowski and Mistry (1997) is

2001) should be consulted. Aneja et al. (2002) have

made up of glucose-galactose heteropolymer. There

also detailed the procedures for chemical and micro-

could be some denatured milk protein associated

biological quality control of dahi.

with kifran matrix. The grains are insoluble in water

Dahi, being an acid food containing lactic acid bac-

and resistant to enzymes. When soaked in water, the

teria, is not a conducive menstruum for the growth

grains swell and turn to a slimy, jelly-like product.

and survival of pathogens. Unless grossly contami-

Within the involutions or folds of the grains, bacteria

nated with pathogens, from a public health viewpoint,

and yeasts that form the characteristic flora of kefir

dahi is a relatively safe product.

are found, and there appears to be a symbiotic as-

sociation between the bacteria and the yeasts in that *ecological niche (Vedamuthu, 1982).*

KEFIR

The attractive feature about kefir grains is that they

could be reused several times if proper sanitation is

History

observed in recovering, drying, and storing the grains

Kefir is made using kefir grains. Although the ori-

from batch to batch. When kefir curd is *agitated, the*

gin of kefir grains is unknown, the prevailing legend

grains migrate to the surface carried up by the en-

attributes that the grains were given to people inhab-

trapped carbon dioxide. The grains are strained out,

iting the region around Caucasus mountain range by

rinsed in chill water, and either could be stored and

Prophet Mohammed (Koroleva, 1991). Kosikowski

refrigerated in cold water or drained and dried in a

and Mistry (1997) state that the grains, which sus-

warm oven and stored in foil pouches. Wet-stored

tain kefir fermentation were called "the gift of the

grains last up to 8 to 10 days without loss of ac-

gods." Kefir may be made with milk

from different

tivity, while dried grains may be active as long as

animal species. Kosikowski and Mistry (1997) men-

18 months (Kosikowski and Mistry, 1997). Dried ke-

tion that milk from the sheep, goat, and cow may

fir grains need to be activated by three consecutive

be used for that product. Traditional fermentation *passes in milk.*

In traditional manufacture of kefir, whole milk pas-

decrease in the concentration of lactose and milk

teurized at 85◦C for 30 minutes is cooled to 22◦C,

proteins, the composition of kefir does not differ *and inoculated with kefir grains. After overnight in-*

from the milk used in its preparation. For further de-

cubation at that temperature, a smooth curd is ob-

tails, the chapter by Robinson et al. (2002) should be

tained. The curdled milk is run through a wire sieve

consulted.

to recover the grains. The product is then chilled and *is ready for consumption (Kosikowski and Mistry,*

Microbiology

1997). Commercial manufacture of kefir is described

by Robinson et al. (2002). The process essentially

The microflora of kefir grains are complex and highly

consists of pasteurizing whole milk at 95◦C for

variable. The flora associated with the grains varies

5 minutes, and cooling the milk to 23◦C. Incubation

from one geographical region to another and of-

at 23◦C follows inoculation with kefir grains. After

ten within the same region. Sanitation during han-

20-hour incubation, the grains are removed, and the

dling of the grain also introduces variability in the

curdled milk is used as a bulk starter *for fresh batches.*

flora. Robinson et al. (2002) state that the microflora

The bulk starter is added to the pasteurized (95◦C for

of kefir grains consists of an undefined mixture of

5 minutes), tempered milk (at 23◦C) at 3.5% (v/v).

species of bacteria and yeasts. The bacterial species

The inoculated milk is incubated at the same tem-

include members of the genera Lactobacillus, Lacto-

perature for 20 hours. After cooling to $< 7^\circ C$, the

coccus, Leuconostoc, Acetobacter, and Streptococ-

product is held at that temperature for several hours

cus thermophilus. Often the mold, Geotrichum can-

to "ripen." Ripening imparts "stability" to the prod-

didum is also found. In some countries *where kefir*

uct. After a sufficient period of ripening, the curd is

is consumed, the presence of Acetobacter aceti and

gently broken and packaged to preserve the viscosity

(or) Acetobacter rasens and Geotrichum candidum

preferred by consumers.

is considered to be as undesirable contaminants in

Variations of that basic procedure are used when

some areas, although in other areas, their presence is

lyophilized kefir cultures (without kefir grains) serve

desired. The authors report that several species be-

as the inocula. For further details on the variations

longing to different yeast genera are present in kefir

used in the manufacture of kefir, the

reader is referred

grains. The complexity of the microflora associated

to Robinson et al. (2002).

with kefir grains as depicted by the authors is repro-

duced in Figure 19.1.

Kosikowski and Mistry (1997) also attest to the

Product Description and Quality

variability in the flora associated with kefir, but state

Good quality kefir is distinguished by a smooth soft

that the dominant yeasts are Saccharomyces kefir,

curd, and a thick body preferred by discerning cus-

Torula or Candida kefir. The dominant bacteria in-

tomers. When agitated, kefir fizzes and foams like

clude Lactobacillus kefir, Lactococcus spp. and Leu-

beer (Kosikowski and Mistry, 1997).

The flavor of

conostoc spp. They also mention Acetobacter spp.

kefir may be described as mildly alcholic, yeasty-

and Geotrichum candidum. Furthermore, they state

sour with a tangy effervescence (Vedamuthu, 1982).

that frequently the kefir grains are found to be covered

The effervescence and foaming is caused by the es-

with white cottony mycelia of Geotrichum candidum,

caping carbon dioxide entrapped within the curd. The

which does not affect the quality of kefir produced

carbon dioxide is generated by the yeasts and hetero-

from such grains. Improper handling of the grains

fermentative lactic acid bacteria present in the kefir

introduces contaminants like coliforms, *micrococci,*

grains.

and bacilli, which cause rapid spoilage of kefir.

The quality and characteristics of kefir are highly

Other bacteria reported to be present in ke-

variable. According to Robinson et al. (2002), the

fir grains are Lactobacillus brevis and a capsular *quality is greatly influenced by the origin and mi-*

polysaccharide-producing strain of Lactobacillus ki-

croflora of kefir grains used and the quality and type

firanofaciens (Robinson et al., 2002). The architec-

of milk (sheep, goat, or cow) used for its manufac-

ture of the kefir grains appears to consist of highly

ture. With storage, there is a

progressive increase

convoluted laminar sheets of yeasts, with the periph-

in the concentration of lactic acid, ethanol and car-

eral sheets dominated by various bacteria and the in-

bon dioxide in kefir. The peptide level also increases

ner core dominated by yeasts.

with aging. With the exception of the accumulation

Kefir made in Russia and the neighboring East

of the metabolic byproducts of fermentation, and a

European countries makes use of the traditional kefir

MICROFLORA OF

KEFIR GRAINS

CONTAMINANTS

Geotrichum spp.

YEASTS

Pediococcus spp.

LACTIC ACID

Micrococcus spp.

Saccharomyces spp.

BACTERIA

Bacillus spp.

Kluyveromyces spp. Lactobacillus spp.

Escherichia spp.

Candida spp.

Lactococcus spp.

Enterococcus spp.

Mycotorula spp.

S. thermophilus

Torulopsis spp.

Leuconostoc spp.

Cryptococcus spp.

ACETIC ACID

Pichia spp.

BACTERIA

Torulaspora spp.

Acetobacter aceti

Figure 19.1. *Microflora of Kefir grains. From*

rasens

Dairy Industries International, 1999. 65(5),

32–33. Reproduced with permission.

grains. Recently, however, several ***nonyeast contain-***

tursuks or burduks. The microflora adhering to the

***ing** flavored and unflavored fermented milks bearing*

hides served as the inoculum. After sufficient length

the label kefir have appeared in several Western coun-

of incubation, the product was drained out of the

tries including the United States. Such products do

hide containers and refilled with

another batch of

***not** qualify as "traditional" kefir. There is no standard*

mare's milk, essentially employing a back-slopping

*definition for kefir. Most of the **nontraditional** kefirs*

process (Robinson et al., 2002). Kosikowski and

found in the Western markets are cultured with a mix-

Mistry (1997) add that when mare's milk incubated *ture of dairy lactobacilli, lactococci, Streptococcus*

in hide containers fails to ferment properly, a piece

thermophilus, and a few probiotic bacterial species.

of fresh horse skin, a tendon of a dead horse or a cop-

per coin encrusted with copper sulfate verdigris were

KOUMISS

added to impel the progress of fermentation. They *speculate that those materials probably contained the*

History

needed flora.

The name Koumiss may be spelt differently in litera-

Several different commercial processes have been

ture. The various spellings used are Kumiss, Kumys,

developed in the last four decades. Most of those *and Coomys (Robinson et al., 2002). Although the*

methods use cow's milk as the starting material. In

product is fermented and has a titratable acidity rang-

one of the processes, skimmed cow's milk fortified

ing from 0.54% to 1.08% it is a liquid product show-

with 2.5% sucrose, and heated at 90◦ C for 2 to

ing no curdling. Koumiss is made from

mare's milk.

3 minutes, was cooled to 28◦C. Tempered milk was

It is believed to have originated among the Tartars,

inoculated with starter culture consisting of Lacto-

and spread across the Asiatic Steppes to Western re-

bacillus delbrueckii ssp . bulgaricus and a strain of

gions of China and Mangolia. In China, the product is

Torula yeast at the rate of about 10% (v/v). After mix-

known by different names as mentioned in an earlier

ing for 15 to 20 minutes, the mix was incubated at

section.

26◦C, until the titratable acidity reached about 0.9%.

Other blends that were used as starting materials con-

sisted of a mixture of whole and skim milk and whey

Production

powders, a mixture made up of five parts of cow's

Traditional production was carried out by filling

milk and eight parts of ultrafiltered rennet whey (with

smoked horse's hide with raw mare's milk, and

2-fold concentration of whey proteins), and a third

incubating at ambient temperatures. The smoked *blend made up of a 50/50 mixture of cow's milk and*

horse-hide used for Koumiss production was called

clarified whey (Robinson et al., 2002).

Kosikowski and Mistry (1997) have described a

included different blends of lactobacilli and yeasts, *commercial process using mare's milk alone or a*

which were mainly chosen for their ability to func-

mixture of cow's milk and mare's milk. They have

tion in that substrate. A microbial survey of Koumiss

also described other variations in the manufacturing

made in Kazakhstan, showed the predominant pres-

procedures. In addition to

Lactobacillus delbrueckii

ence of a galactose-fermenting Saccharomyces unis-

ssp. bulgaricus, they also mention the inclusion of

porus. That yeast, however, does not ferment lactose.

Lactobacillus acidophilus and Saccharomyces lactis

The latter characteristic leads to slower fermentation,

instead of Torula spp. as starter flora for Koumiss *and a variety of metabolic byproducts such as glyc-*

production from cow's milk.

erol, succinic acid, and acetic acid, which impart off-

flavors to Koumiss.

In Koumiss (known as Chigo) made in inner

Product Description

Mangolia and China, the majority of lactobacilli

Traditional Koumiss is characterized

by its milky gray

found were identified as Lactobacillus paracasei ssp.

color, with no tendency for "wheying off." The taste is

paracasei and ssp. tolerans and Lactobacillus cur-

described as, "sharp alcoholic and acidic" (Robinson

vatus. The yeast species found were Kluveromyces

et al., 2002). The main byproducts of Koumiss fer-

marxianus ssp . lactis and Candida kefyr (Robinson

mentation are lactic acid, ethanol, and carbon diox-

et al., 2002).

ide. Carbon dioxide gives the "fizziness" in the fin-

ished product. The viable bacterial counts in Koumiss

may attain 50 million/ml and the yeast cell count

ACIDOPHILUS MILK AND

about 14 million/ml. Depending on the extent of fer-

SWEET ACIDOPHILUS MILK

mentation, the product is classified as weak, medium,

History

and strong. The percent titratable acidity will vary

from 0.54 to 0.72, 0.73 to 0.90, and 0.91 to 1.08 for

Original Acidophilus Milk is a highly acidic, acrid *weak, medium, and strong categories, respectively.*

product with no balancing flavors. The acidity in the

Alcohol content in percentage will vary from 0.7 to

product may range from 1.5% to 2.0%. Because of

1.0, 1.1 to 1.8, and 1.8 to 2.5 for weak, medium,

its acidic flavor, it is not generally relished by most

and strong categories, respectively

(Robinson et al.,

consumers. Physicians in the United States have pre-

2002; Kosikowski and Mistry 1997).

scribed Acidophilus Milk in the diet of persons suffer-

Koumiss is prized as a therapeutic drink in

ing from either constipation or diarrhea and also for

Russia, and has been claimed to have curative prop-

persons who experience intestinal distress on con-

erties for pulmonary tuberculosis (Kosikowski and

suming ordinary milk. The latter effect is mainly

Mistry, 1997).

related to the alleviation of lactose malabsorption.

Lactobacillus acidophilus is found in large numbers

in the intestines of normal, healthy individuals. There

Microbiology

is some difference among strains of Lactobacillus

The microflora of Koumiss is highly variable from

acidophilus to establish in the human intestine. The

region to region. In general, the bacterial species

strains capable of establishing in the human intestine

consist of lactobacilli (Lactobacillus delbrueckii ssp .

exhibit the ability to survive and grow in the pres-

bulgaricus and Lactobacillus acidophilus), lactose-

ence of normal levels of surface tension-depressing

fermenting yeasts (Sacchamyces sp. and Torula

bile salts found in the enteric environment. Over

koumiss), nonlactose-fermenting Sacchromyces car-

the years, regular intake of Acidophilus

Milk was

tilaginosus, and Mycoderma spp. which do not fer-

found to be an excellent means of maintaining in-

ment carbohydrate substrates. In Koumiss made in

testinal health. And, research showed that ingest-

Mongolia, lactococci have been isolated, but their

ing high numbers of selected, viable Lactobacillus *presence is undesirable, because of their rapid acid-*

acidophilus bacteria provided similar enteric-health

generating property, which retards the development

effects. To promote wider consumption of such bene-

of yeasts that are necessary to give the characteris-

ficial bacteria, modifications in the delivery of the mi-

tic properties of finished Koumiss

(Robinson et al.,

croorganisms via milk were sought. That search gave

2002).

rise to a product called "Sweet Acidophilus Milk. "

Most of the starter cultures developed was for

(Foster et al., 1957). Actual widespread commer-

Koumiss made from cow's milk. Such cultures *cialization of Sweet Acidophilus Milk came about in*

1970s. This was the forerunner of Probiotic Milks

human enteric system and intensively studied in the

widely prevalent today.

laboratory at North Carolina State University. A re-

liable fermentation procedure to propagate the strain

in a food compatible medium to high numbers was

Production of Acidophilus Milk

developed. Further work was pursued to concentrate

Traditional Acidophilus Milk is made from low-fat

the cells, preserve the cell concentrate by freezing,

(partially skimmed) milk. The milk is sterilized at

and testing the cells for viability in cold, pasteurized

120◦C for 15 minutes to stimulate Lactobacillus aci-

milk over 15 to 21 day storage under normal refriger-

dophilus, which is used as a pure culture. Lactobacil-

ation conditions prevalent during distribution chan-

lus acidophilus lacks a good proteolytic system for

nels in retail trade. Based upon the

results, a suitable

hydrolyzing milk proteins. The high heat treatment

usage rate was established. The bacterial strain des-

used denatures and releases peptides from milk pro-

ignated Lactobacillus acidophilus NCFM, and the

teins, which helps the growth of the organism. After

technology developed in the laboratory was licensed *heat treatment, the milk is tempered to 37 to 38◦C,*

by the North Carolina State University Foundation

and inoculated with a milk starter at the rate of 5%.

to a marketing firm. The name "Sweet Acidophilus

The inoculated milk is gently stirred to mix the in-

Milk" was registered as a trademark. The market-

oculum, avoiding much incorporation

of air, and in-

ing company under an exclusive licensing agreement

cubated quiescently for 18 to 24 hours. When the

with a commercial starter company popularized the

acidity reaches 1.0%, the product is cooled to less

sale of the branded name product. An arbitrary mini-

than 7∘C, and bottled (Vedamuthu, 1982). A simi-

mum cell count of 2 million colony forming units per

lar process is described by Kosikowski and Mistry

milliliter (cfu/ml) was recommended in "Sweet Aci-

(1997).

dophilus Milk" over the normal "open dating" period

used in the industry for pasteurized low-fat and skim

milk (usually 14 days). This stipulation was adopted

Production of Sweet Acidophilus

by most States in the United States, and the State of

Milk

California later amended the requirement to 4 million

The original idea for delivering health-imparting

cfu/ml throughout a 14-day shelf life.

Lactobacillus acidophilus bacteria in unfermented

Other starter companies also sold

frozen concen-

sweet milk was mooted by Myers in 1931 (Myers,

trated cultures for making a similar product. Products

1931). He reported that Lactobacillus acidophilus

made with cultures from nonlicensed culture manu-

is inhibited by storage temperatures between 18◦C

facturers were not allowed to use the registered trade-

and 20◦C, and the development of acid is entirely

mark, "Sweet Acidophilus Milk." The frozen culture

prevented in milk held below 10◦C. He also found

concentrate (also in pelletilized form) was sold in

that milk containing Lactobacillus acidophilus cells

170 to 200 gram containers for inoculation into 2000

could be kept "sweet" for as long as 7 *days if kept*

liters of cold pasteurized milk. The manufacturing

refrigerated at 2 to 5◦C. The first prototype of the

process was simple and consisted of adding the re-

product that was commercialized in the 1970s was

quired amount of frozen culture concentrate to cold

made in Oregon State University and was described *pasteurized low fat or skim milk, mixing to distribute*

by Duggan et al. (1959). That product was made by

the cells evenly, and bottling the product.

adding a concentrated cell suspension of the organ-

ism to cold (5◦C), pasteurized milk, mixing to ob-

Quality Standards

tain homogenous distribution of the culture, bottling, *storing, and enumerating the bacterial numbers in the*

There were no definite standard counting procedures

milk held under refrigeration. The Lactobacillus aci-

for establishing the viable count of Lactobacillus aci-

dophilus cells retained their viability, when handled

dophilus cells in Sweet Acidophilus Milk, when the

thus for a week, but did not cause any *fall in the pH*

product was first introduced in the market. The proce-

of the milk.

dure(s) adopted by State regulatory agencies gradu-

The idea was revived in the 1970s, and a strain

ally evolved over time. Early procedure used plating-

of Lactobacillus acidophilus isolated from a human *suitable dilutions (according to Standard Methods*

subject, was subjected to taxonomic regime required

for the Examination of Dairy Products—APHA) of a

to confirm its identity. The strain was further tested

well-mixed sample of milk on deMan/Ragosa/Sharpe

for resistance to low pH and bile levels encountered in

agar (MRS agar) and incubating the

plates in an

anaerobic jar at 35 to 37◦C for 72 hours. Later, the

used as probiotics (Chandan, 1999; Sanders and Huis

method called for the use of MRS agar containing

in't Veld, 1999; Shah, 2001). Members of the afore

0.15% bile salts (Ox bile Salts). Certain establish-

mentioned two-bacterial genera are normal inhabi-

ments required the use of a more stringent Ragosa

tants of healthy human gut, and have been shown to

agar (or acidified Lactobacilli Selective agar) con-

play a regulatory role in the ecology and microbial

taining 0.15% bile salts.

flora of the gut (Chandan, 1999; Sanders and Huis in't

Veld, 1999). Among the various benefits reported for

the intake of probiotics, the evidence for maintenance

Microbiology

of gut health is equivocal. For extensive discussion of

There has been a considerable discussion among the

the role of those bacteria in maintaining gut health, *academic, industrial, and regulatory circles of the*

the reviews by Sandine (1972), Speck (1976, 1978),

need to establish the exact species identity, strain

Vaughan et. al (2002), and Hopkins (2003) should be

history, and salient characteristics that distinguish

consulted.

their suitability for enteric therapy of various cell

One of the earliest marketed Probiotic Milks

concentrates offered for sale to produce Sweet Aci-

contained Lactobacillus acidophilus and Bifidobac-

dophilus Milk. That led Sanders et al. (1996) to ex-

terium spp., and bore the trade name A/B Milk.

amine several commercial cultures on the market

Presently, several Probiotic Milks with *different*

for the aforementioned features. The problem has

brand names containing a variety of lactobacilli and

been compounded by the introduction of "Probiotic

bifidobacteria are available in the market in North

Milks" recently, which contain several different bac-

America, Europe, and the Far East (Sanders and Huis *terial strains and species. Those aspects will be dis-*

in't Veld, 1999; Shelke, 2003). Every passing day,

cussed later.

purported new clinically proven probiotic strains are

The most widely studied Lactobacillus aci-

being added to the list.

dophilus strain for enteric therapy is Lactobacillus *acidophilus NCFM. The published findings are sum-*

Production of Probiotic Milks

marized by Sanders and Klaenhammer (2001).

Probiotic Milks are made in the same manner as Sweet

Acidophilus Milk. Probiotic cultures in concentrated

PROBIOTIC MILKS

form are added to cold pasteurized low fat or skim *milk to give the desired numbers in the milk over*

History

the normal open dating target period. After mixing

Probiotic Milks came into prominence over the last

to get uniform distribution of the cells, the milk is

two decades. The term probiotic is of a relatively re-

bottled. Several different probiotic strains are added *cent origin. Currently, probiotics form a distinct cat-*

presently.

egory under "Functional Foods." Functional foods

(or nutraceuticals) are food components that pro-

Quality Standards

vide demonstrated physiological benefits or reduce

the risk of chronic disease beyond their basic nutri-

There are no regulatory standards for Probiotic Milks

tional functions (Shah, 2001). According to the U.N.

except those that apply to pasteurized milk. For A/B

Agency, Food and Agriculture Organization, "probi-

type milk, the consensus in the industry was to re-

otics are live microorganisms, which, when adminis-

quire a viable cell count of 2 million *cfu/ml for*

tered in adequate amounts, confer a health benefit on

Lactobacillus acidophilus and Bifidobacterium spp.

the host" (Shelke, 2003). The benefits of regular in-

respectively. When products with multiple strains

take of probiotics are many, including alleviation of

appeared in the market, there was confusion in the *lactose maldigestion, reduction in serum cholesterol,*

trade as to the exact requirements that should be stipu-

immune stimulation, antimicrobial, antimutagenic,

lated to meet an "informal standard." Guidelines have

and anticarcinogenic effects, maintaining intestinal

been developed by regulatory agencies with respect

health and general well-being (Shah,

2000). Other

to "health claims" that could be made on the labels on

purported benefits are discussed by Sanders and Huis

the packages. Presently, most Probiotic Milks in the

in't Veld (1999), Chandan (1999), and others. Bacte-

market list the cultures present in the milk on their

ria, especially species belonging to the genera, Lacto-

labels. The technological challenges in the selection,

bacillus and Bifidobacterium are almost exclusively

propagation, preservation, and handling of cultures

306

Part III: Manufacture of Fermented Milks

for probiotic applications are extensively discussed

higher), is used to seed a bulk starter made up of *by Mattila-Sandholm et al. (2002).*

milk. Bulk starter is added at the rate of 1–2% to the

A major hurdle in fixing the exact viable cell

prepared milk tempered at 37◦C, incubated till the

counts (cfu/ml) for each of the probiotic strains is

acidity reaches 1.0%, cooled to 5–7◦C, and packaged.

the lack of a reliable, accurate, reproducible, and

Most consumers do not relish acidities > 1.0% in

routinely usable method(s) to get differential counts

Bulgarian Milk offered for sale (Foster et al., 1957,

of the strains/species added to the milk. Several at-

Kosikowski and Mistry, 1997).

tempts have been made in developing suitable meth-

ods (Shah, 2000), but so far none is adequate for *regulatory purposes.*

SKYR

As referred to earlier, one of the primary concerns

Skyr has been produced in Iceland from the tenth

is establishing the exact identity of the strains/species

century. The product was introduced into Denmark

used and declared on the labels of Probiotic Milks.

in the mid-1900. It is actually a concentrated form

Bacterial taxonomy has undergone rapid changes

of Yogurt curd. The manufacturing procedure is very

with the advent of genetic probes, and with that devel-

similar to the production of Yogurt. In commercial

opment, the taxonomic status of many strains/species

production, skim milk heated to 93◦C

for a few min-

has eroded and in many cases entirely altered. Re-

utes, is tempered at 42–44◦C, and inoculated with

alizing the need for establishing modern criteria to

a mixture of Streptococcus thermophilus and Lacto-

establish the taxonomic status of strains/species used

bacillus delbrueckii ssp . bulgaricus (0.1–0.5%). This *in Probiotic Milks, Yeung et al. (2002) examined a*

is followed by the addition of 0.005% rennet. After

large number of cultures using newly developed ge-

uniform distribution of the additives, the seeded milk

netic probes, and published a status paper on the sub-

is incubated at 42–44◦C. Under those conditions, co-

ject. Their work would go a long way in *establishing*

agulation is achieved in 3–4 hours. When the acidity

the credibility of the industry in marketing a truly

reaches 1.4–1.6% (after approximately 20–24 hours),

probiotic product.

the curd is transferred into cloth bags for the drain-

ing of sufficient whey to achieve a curd-solid content *of 18–20%, and a titratable acidity of 2.5–3.0%. The*

Bulgarian Milk is also known as Bulgarian Butter-

product is then packaged and cooled (Foster et al.,

milk. As the name suggests the product originated

1957).

in Bulgaria. The longevity enjoyed by people in and

Robinson et al. (2002) report that lactose-

around Bulgaria, who regularly consumed Bulgarian

fermenting yeasts and Lactobacillus helveticus are

Milk prompted one of Elias Metchinkoff's associate

often found in starters used for Skyr. They have also

to study that product. He isolated a Lactobacillus cul-

described three mechanized processes,

where the use

ture from that product, which was later assigned the

of a nozzle separator and membrane filtration of curd

nomenclature, Lactobacillus bulgaricus (now, Lac-

could be used for concentration of solids. Another

tobacillus delbrueckii ssp. bulgaricus). Metchinkoff

variation involves the preformulation of milk solids *studied the organism for its therapeutic value. From*

and fat to attain the desired solids concentration, be-

his observations, Metchinkoff postulated that high

fore the fermentation step.

acid produced by the isolate had a suppressive effect

on toxin-producing organisms in the large intestines,

VIILI

and prevented putrefaction and autotoxification in the

individual consuming fermented milk rich in Lacto-

Viili is known by several different names in the

bacillus delbrueckii ssp . bulgaricus. Later, he wrote

Scandinavian countries. The product is extremely

a book, entitled, The Prolongation of Life. His obser-

popular in Finland. It is a mildly acidic *product made*

vations laid the foundation for the present interest in

with specially selected exopolysaccharide (capsular

probiotics (Kosikowski and Mistry, 1997).

slime) producing strains of dairy lactococci. Such

In the production of Bulgarian Milk, milk is heated

strains develop a mucoid and (or) stringy (ropy) coag-

at 82–85◦C for 30 minutes, and cooled to 37◦C.

ulum. Often Geotrium candidum, a mold is included

An inoculum of a pure culture of Lactobacillus del-

in the starter. Being strictly aerobic, the mold forms

brueckii ssp. bulgaricus made in sterile milk (incu-

a fuzzy mat on the surface of the product. The mold

bated at 37◦C, and a final acidity of

1.0% or slightly

metabolizes lactic acid generated by the lactococci

in the curd layers immediately below the mycelial

Deveau H, Van Calsteren M–E, Moineau S. 2002.

mat. The product is often eaten with the addition of

Effect of exopolysaccharides on phage-host

powdered cinnamon.

interactions in Lactococcus lactis. Appl. Environ.

The product is produced from whole or low-fat

Microbiol. 68:4364–4369.

milk. After heat treatment at 80◦C for 30 minutes

Duggan DE, Anderson AW, Elliker PR. 1959. Frozen *or modified HTST pasteurization (78∘C for 2 min-*

concentrate of Lactobacillus acidophilus for

utes), the milk is cooled to 20–21∘C and 1.0% starter

preparation of a palatable Acidophilus milk. Food

is added, and mixed. The seeded milk is filled into

Technol. 13:465–469.

packages. The filled packages are rolled into a walk-

Foster EM, Nelson FE, Speck ML, Doetsch RN, Olson

JC Jr. 1957. Microbiology of fermented milks. Dairy

in incubator held at 20–21◦C. When the pH reaches

Microbiology, Prentice-Hall, Inc., Englewood Cliffs,

4.6, the containers are rolled into a cooler.

NJ, pp. 318–333.

Hopkins M. 2003. The intestinal microflora.

Microbiology

Understanding the Symbiosis. John Libbey

Eurotext, Montrouge, France, p. 47.

Starter culture for Viili consists of a mixture of ropy

Koroleva NS. 1991. Products prepared with lactic acid

(mucoid) and nonropy (nonmucoid) strains of Lac-

bacteria and yeasts. In: RK Robinson (Ed), *tococcus lactis ssp. lactis and cremoris. Many of*

Therapeutic Properties of Fermented Milks. Elsevier

the mucoid lactococci are sluggish acid producers.

Applied Science, London, pp. 159–179.

To compensate, nonmucoid, relatively rapid acid-

Kosikowski FV, Mistry VV. 1997. Cheese and

generating lactococci are included in the starters.

fermented milk foods. In: FV Kosikowski (Ed),

Mucoid lactococci are as susceptible to phages as

Origin and Principles. Fermented Milks, Vol. 1.

nonmucoid types (Deveau et al., 2002). Because of

LLC, Westport, Ct, pp. 57–74.

the likelihood of phage infection of lactococci in in-

Mattila-Sandholm T, Myllarinen P, Crittenden R, *dustrial settings, phage-unrelated strains are used in*

Mogensen G, Fonden R, Saarela M. 2002.

starter rotations. There is a paucity of suitable mucoid

Technological challenges for future probiotic foods.

lactoccal strains for use in starter rotations for Viili

Intern. Dairy J. 12:173–182.

manufacture. Exopolysaccharide production among

Myers RP. 1931. Transformation of the intestinal flora

lactococci is an unstable characteristic. Exopolysac-

through the feeding of unfermented acidophilus

charide production is easily lost upon repeated

milk. Amer. J. Public Health 21:867–872.

transfer of cultures, high-temperature incubation,

Prajapati JB. 2003. Fermented foods of

India.

and abuse during propagation. Some of the genes

Abstract, International Seminar and Workshop on

associated with exopolysaccharide production are

Fermented Foods, Health status and Social

Well-being (Souvenir), Gujarat Agricultural

found on plasmids (Vedamuthu and Neville, 1986).

University, Anand, India, pp. 1–4.

Technology for converting nonmucoid (Muc−) lac-

Rangappa KS, Achaya KT. 1975. Preparation, Quality

tococcal strains to muciod phenotypes (Muc+)

and Composition of Dahi and Lassi. Indian Dairy

through conjugative transfer of plasmid-carrying

Products, Asia Publishing House, Bombay, India,

mucoid genes (Muc–plasmid) has been patented

pp. 124–136.

(Vedamuthu, 1989). The entire molecular charac-

Richter RL, Vedamuthu ER. 2001. Milk and Milk

terization of exopolysaccharide production among

Products. In: FP Downes, K Ito (Eds), Compendium

lactococci was elucidated by van Kranenburg

of the methods for the microbiological examination

(1999).

of foods, 4th ed. American Public Health

Association, Washington, DC, pp.483–496.

REFERENCES

Robinson RK, Tamime AY, Wszolek M. 2002.

Microbiology of Fermented Milks. In: RK Robinson

Aneja RP, Mathur BN, Chandan RC, Banerjee AK.

(Ed), Dairy microbiology handbook: The

2002. Cultured/fermented products. Technology of

microbiology of milk and milk products, 3rd ed.

Indian Milk Products. A Dairy India Publication,

Wiley-Interscience, John Wiley & Sons, New York,

Delhi, India, pp. 159–182.

pp. 367–430.

Chandan RC. 1999. Enhancing market value of milk

Sanders ME, Huisin't VJ. 1999. Bringing a

by adding cultures. J. Dairy Sci. 82:2245–2256.

probiotic-containing functional food to the market:

Dairy Industries International. 1999. Microflora of

microbiological, product, regulatory and labeling

Kefir Grains. 65(5):32–33.

issues. Antonie van Leeuwenhoek 76:293–315.

Sanders ME, Klaenhammer TR. 2001. Invited review:

Speck ML. 1978. Acidophilus food products.

The scientific basis of Lactobacillus acidophilus

Developments Indus. Microbiol. 19:95–101.

NCFM functionality as a probiotic. J. Dairy Sci.

van Kranenburg R. 1999. Exopolysaccharide

84:319–331.

biosynthesis in Lactococcus lactis: A molecular

Sanders ME, Walker DC, Walker KM, Aoyama K,

characterization. Ph. D. dissertation, Wageningen

Klaenhammer TR. 1996. Performance of

University, The Netherlands. Ponsen & Looijen NV,

commercial cultures in fluid milk applications.

Wageningen, The Netherlands.

J. Dairy Sci. 79:943–955.

Vaughan EE, de Vries MC, Zoetendal EG, Ben-Amor

Sandine WE, Muralidhara KS, Elliker PR, England

K, Akkermans ADL, de Vos WM. 2002. The

DC. 1976. Lactic acid bacteria in food and health: A

intestinal LABs. Antonie van Leeuwen hoek.

review with special reference to enteropathogenic

84:341–352.

Eschericha coli as well as certain enteric diseases

Vedamuthu ER. 1982. Fermented Milks. Economic *and their treatment with antibiotics and lactobacilli.*

Microbiology, Vol. 7, Fermented Foods, pp.

J. Milk Food Technol. 35:691–702.

199–226.

Shah NP. 2000. Probiotic bacteria: Selective

Vedamuthu ER. 1989. Method for producing mucoid

enumeration and survival in dairy foods. J. Dairy *and phage resistant group N Streptococcus strains*

Sci. 83:894–907.

from non-mucoid and phage sensitive parent strains.

Shah NP. 2001. Functional foods from probiotics and

United States Patent, 4, 874, 616.

prebiotics. Food Technology 55(11):46–53.

Vedamuthu ER, Neville JM. 1986. Involvement of a

Shelke K. 2003. Gut news. Food Processing

plasmid in production of ropiness (mucoidness) in

64(7):36–38.

milk cultures by Streptococcus cremoris MS. Appl.

Skovsende A. 2003. Probiotics: Good for what's

Environ. Microbiol. 51:677–682.

bugging you. Nutraceuticals World 6(9):84–88.

Yeung PSM, Sanders ME, Kitts CL, Cano R, Tong PS.

Speck ML. 1976. Interactions among lactobacilli and

2002. Species-species identification of commercial

man. J. Dairy Sci. 59:338–343.

probiotic strains. J. Dairy Sci. 85:1039–1051.

Part IV

Health Benefits

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

Copyright © 2006 by Blackwell Publishing

20

Functional Foods and Disease

Prevention

Ramesh C. Chandan and Nagendra P. Shah

Introduction

demands. Consumers are starting to regard foods as

Functional Foods

"miracle medicine;" (d) Increasing cost of health

Bioactive Dairy Ingredients

care. Accordingly, prevention rather than cure, is

Milk Proteins

increasingly being recognized; (e) Increases in the

Bioactive Peptides

proportion of older persons in general population;

Lactose

(f) Technical advances in the food industry leading

Milk Fat

to a shift in focus from removing harmful compo-

Minerals and Vitamins

nents to replacing or enhancing positive components;

Probiotics

Beneficial Microflora

(g) Changes in regulatory attitudes. The struggle be-

Health Benefits of Probiotic Products

tween the Food and Drug Administration and the

Requirements for Effective Probiotics

food industry in relation to health claims for foods

Production of Enzymes, Vitamins, and Bacteriocins

is a good example; (h) The recent discovery of phy-

Bioavailability of Calcium

tochemicals and probiotcs has boosted the search for

Reduction in Serum Cholesterol

and the development of functional foods.

Prevention of Diarrhea, Vaginitis and Dermatitis

Depending on the supplement, the functional foods

Anticarcigoenesis

can be called designer foods, nutraceutical, phar-

Immunomodulatory role

mafood, or phytochemical food (Goldberg, 1994;

Manufacture of Probiotics for Use as Food Supplements

Shah, 2004). With the current emphasis on cost-

Fortification

Physiologically Active Ingredients

effective health care, the importance of dietary

References

changes to optimize health continues to gain recogni-

tion and acceptance. As a result, the food industry is

responding to consumer demands for a

more health-

INTRODUCTION

ful food supply by developing nutrient-rich food

products, including products lower in fat and sodium

The foods that contain significant levels of biologi-

that are consistent with the U.S. dietary guidelines for

cally active components that impart health benefits

Americans. In another effort to help the public make

beyond basic nutrition are generally referred to as

sound dietary choices, the nutrition labeling and edu-

functional foods. The driving forces behind the de-

cation act has resulted in more responsible labeling of

velopment of functional foods are ascribed to: (a)

all food items. Food labels provide a

reliable source

Scientific advances in our understanding of the role

of applicable nutrition information for consumers to

that foods play in disease prevention. Six out of the

help them make informed purchase decisions.

ten leading causes of death in the Western world can

Nutrient-rich foods can be developed either by for-

be linked to diet, e.g., cancer, coronary heart dis-

tifying a component that improves the nutritional

ease, stroke, diabetes, atherosclerosis, and liver dis-

value or by effective plant breeding by genetically en-

eases; (b) The finding that 70% of certain cancers are

gineering of the plants. Success is already seen in pro-

primarily caused by dietary factors; (c)

Consumer

duction of oranges with high vitamin C content and

311

312

Part IV: Health Benefits

high phytochemical broccoflower (Goldberg, 1994).

segment of the food industry. Such foods in diet fur-

Yet another potential area to generate an array of *nish traditionally recognized nutrients and in addi-*

products that fit into the current consumer demand

tion provide specific health benefits. The objective of

for health driven foods is the milk-based dairy prod-

consuming these foods is to rectify or manage certain

ucts (Chandan, 1999). The reader is referred to a book

disease states, reduce the risk of

disease, or maintain

titled Functional Dairy Products, edited by Mattila-

good health. This category of foods includes medical

Sandholm and Saarela (2003) for comprehensive in-

foods, supplements, biofoods, performance foods,

formation on this topic.

special infant formulas, as well as foods specially for-

Diet-health link is now an integral part of a healthy

mulated to deliver ingredients such as insoluble and

life style. The role of diet and specific foods for the

soluble fiber, vitamins and minerals, antioxidants,

prevention and treatment of disease and improvement

phytosterols, concentrates of specific dairy proteins,

of body functions is now being

recognized. Present

soy preparations, probiotics, and healthy fats and oils.

day consumers prefer foods that promote good health

The epidemiological, experimental, and clinical

and prevent disease. Such foods need to fit into cur-

research has shown that consumption of diets high

rent lifestyles providing convenience of use, good *in fiber lowers the risk of colorectal cancer and*

taste, and acceptable price-value ratio. The dairy in-

cardiovascular disease. For example, a diet contain-

dustry offers foods with established health-related

ing viscous polysaccharides lowers the low-density

benefits and therefore constitutes a family of natu-

lipoproteins (LDL) and total serum

cholesterol by

ral functional foods.

bile acid turnover and lipid absorption. Furthermore,

This chapter presents an overview of functional

the beneficial effect may be ascribed to slow down in

foods and various bioactive ingredients present in

carbohydrate absorption, increase in stool bulk, and *milk and fermented milks. Current trend is to of-*

production of short-chain fatty acids in the colon.

fer products or ingredients specifically enriched for

It is now known that factors in diet influencing the

application in various foods to enhance their func-

reduction in cardiovascular disease are generally

tional spectrum. Furthermore, the use

of probiotics is

constituents of plant foods including antioxidants,

discussed briefly as a means to supplement the func-

phenolics, carotenoids, and flavonoids. The phy-

tional attributes in milk products. For detailed dis-

toestrogens (namely, coumesterol) of certain beans

cussion of probiotics, the reader is referred to Chap-

may reduce bone loss. Isoflavones present in soy

ter 22. Possible health benefits of consuming cultured

are recognized to be beneficial in reducing risk of

and culture-containing milks have been briefly sum-

cancer and heart disease.

marized in this chapter.

Vitamin E and folic acid are now considered to be *important for their role in preventing heart disease.*

FUNCTIONAL FOODS

Folic acid is also important in lowering the risk of

neural tube defect in babies. Thus, new diet strategies

The current trend to provide specific health bene-

for optimum health involve consumption of much

fits beyond sustenance accorded by food intake has *higher level of fruits, vegetables, legumes, nuts, and*

roots in ancient medicine systems. The prevention

whole grains than previously believed.

and management of disease was recognized in In-

dia some 5,000 years ago with the development of

BIOACTIVE DAIRY

Ayurvedic (Science of Life) system of medicine. Use

INGREDIENTS

of active ingredients isolated from plants, herbs, min-

erals, and animals formed the core of this medical

Milk has been described as nature’s nearly perfect

practice to prevent disease and treat certain disor-

food as it provides vital nutrients including proteins,

ders. The emphasis was prevention and management *essential fatty acids, minerals, and lactose in bal-*

of common disorders by following specific dietary

anced proportions. Leading nutrition experts recog-

pattern in response to individual body requirements.

nize milk and milk products as important constituents

Later, in third century bc, Chinese emperor Shen

of a well-balanced and nutritionally

adequate diet. In

Nong discovered that certain plants and herbs have a

this regard, milk products complement and supple-

medicinal value.

ment nutrients available from grains, legumes, veg-

Currently, an interactive discipline of nutrition and

etables, fruits, meat, seafood, and poultry.

food science has produced an array of food prod-

Milk is composed of a unique set of constituents.

ucts that represent a vibrant, dynamic, and emerging

More information on the composition of milk is given

Milk

Water

Milk solids

87. 4%

12.6%

Milk fat

Milk solids-not-

3.6%

fat, 9%

Lactose

4.9%

Minerals

0.7%

Proteins

3.4%

Caseins

2.7%

Whey proteins

0.7%

Figure 20.1. *Nutritional composition of milk.*

in Chapter 2. The major components are shown in

The protein efficiency ratio of whey protein is

Fig. 20.1. It is necessary to understand the nutritional

slightly lower than that of whole egg protein, which

composition of milk to comprehend the functional

is considered as the best protein. Compared to plant

aspects of its constituents.

proteins, dairy proteins provide highest quality and

These constituents perform nutritional function as

absorption characteristics. In other words, to achieve

well as physiological functions. They act indepen-

the requisite amino acids, our requirement for protein

dently and synergistically with each other. The role

is much lower when milk proteins are

included in our

of major and minor constituents in human nutrition

diet. Table 20.4 illustrates this point.

is intertwined with newly discovered physiological

It is apparent from this table that minimum require-

benefits. We will briefly highlight both nutritional

ment for lactalbumin is lower than that of potato, but *and physiological benefits of consuming yogurt and*

a combination of 30 parts of potato and 70 parts of

fermented milks.

lactalbumin balances the amino acids in a synergistic

Typical nutritional profile of yogurt is shown in

way and the requirement of the mixture is lower than

Table 20.1.

that of either potato or lactalbumin. Thus, a combina-

tion of whey protein and cereal-based food or potato

can enhance the nutritional profile.

Milk Proteins

Various milk constituents contribute to the phys-

The major proteins of milk are casein and whey pro-

iological effects. Table 20.5 illustrates some of the *teins in the ratio of 80 to 20. Casein further consists*

potential benefits.

of various fractions including ⎵S1- and ⎵S2-casein,

Both caseins and whey proteins of milk possess

NL-casein and □-casein (Table 20.2). Also shown are

biological and physiological properties. For more in-

the major whey proteins of milk.

formation on the physical and chemical character-

Nutritional value of milk proteins has been recog-

istics of milk proteins, refer to Chapter 2. Hutch

nized for many years. Table 20.3 shows the nutritional

et al. (2004) have examined the emerging role of

value of milk proteins compared with other proteins.

dairy proteins and bioactive peptides

in nutrition

Table 20.1. *Typical Nutritional Profile of Yogurt*

Nutrient

Plain

Fruit-Flavored

Light, Vanilla

(Per 8 oz. serving = 227 g)

Nonfat

Low Fat

Whole Milk

Nonfat

Low Fat

Nonfat

Moisture

85

85

88

75

74

87

Calories (kcal)

127

144

139

213

231

98

Protein (g)

13

12

8

10

10

9

Total fat (g)

0.5

4

7

Tr

2

Tr

Saturated fatty acids (g)

0.3

2.3

4.8

0.3

1.6

0.3

Monosaturated fatty acids (g)

0.1

1.0

2.0

0.1

0.7

0.1

Polyunsaturated fatty acids (g)

Tr

0.1

0.2

Tr

0.1

Tr

Cholesterol (mg)

4

14

29

5

10

5

Carbohydrate (g)

17

16

11

43

43

17

Total dietary fiber (g)

0

0

0

0

0

0

Calcium (mg)

452

415

274

345

345

325

Iron (mg)

0.2

0.2

0.1

0.2

0.2

0.3

Potassium (mg)

579

531

351

440

442

402

Sodium (mg)

174

159

105

132

133

134

Vitamin A (IU)

16

150

279

16

104

0

Thiamin (mg)

0.11

0.1

0.07

0.09

0.08

0.08

Riboflavin (g)

0.53

0.49

0.32

0.41

0.40

0.37

Niacin (mg)

0.3

0.3

0.2

0.2

0.2

0.2

Ascorbic acid (mg)

2

2

1

2

2

2

Note: Data is for yogurts fortified with *nonfat dry milk, except for plain whole milk yogurt (Chandan, 2004).*

Source: United States Department of Agriculture, 2002.

***Table 20.2.** Casein Fractions and Whey*

and health. The biological properties of milk proteins

Proteins of Cow's Milk

are summarized in Table 20.6.

In studies with mice, it has been shown that

Concentration

whey proteins enhance humoral immune response.

Casein Fractions

(g/liter)

The sulfhydryl containing aminoacids, cysteine and

␣-s1-Casein

10.3

glutathione, are related to immune response. Whey

␣-s2-Casein

2.7

proteins are rich in cysteine. □-Lactoglobulin con-

□-Casein

9.7

tains 33 mg of cysteine per gram protein, while

□-Casein

3.5

□-lactalbumin and bovine serum albumin contain 68

C-terminal κ-Casein

0.8

and 69 mg cysteine per gram protein, respectively.

fragments

The –SH compounds are also involved in quenching

Concentration

toxic-free radicals.

Whey Proteins Fractions

(g/liter)

⎵-Lactalbumin is a calcium binding protein and

thereby enhances calcium absorption. It is an excel-

N-terminal NL-casein

0.8

lent source of essential amino acids such as tryp-

fragments

tophan and cysteine. Tryptophan regulates appetite,

NL-Lactoglobulin

3.4

sleep-waking rhythm, and pain perception. Cys-

⎵-Lactalbumin

1.3

teine is important in functions of –SH compounds.

Immunoglobulins

0.8

⎵-Lactalbumin interacts with galactosyltransferase

Bovine Serum Albumin

0.4

enzyme to promote transfer of galactose from UDP-

Lactoferrin

0.02–0.2

galactose to glucose to form lactose in the mammary

Lactoperoxidase

0.03

gland.

Lysozyme

130 □g/liter

The immunoglobulins of milk are important for

Adapted from: Chandan, 1999; Schaafsma and Steijns,

imparting immune defense for the host. IgG1 is a

2000.

major component. Milk contains 0.6 g/liter of IgG1,

Table 20.3. *Comparative Nutritional Value of Proteins*

Protein	*PER a*	*AAS b*	*BV c*	*PD d*	*PDCAAS e*

Milk protein

3.1

1.27

91

0.95

1.21

Casein

2.9

1.24

77

0.99

1.23

Whey proteins

3.6

1.16

104

0.99

1.15

Whole egg

3.8

1.21

100

0.98

1.18

Soya

2.1

0.96

–

0.95

0.91

Wheat

1.5

0.47

–

0.91

0.42

a PER (Protein Efficiency ratio). Gain in body weight divided by weight of protein consumed by growing rats fed 10% (w/w) of test or reference protein.

b AAS (Amino Acid Score). Content of the first limiting essential amino acid *of the test protein compared with the content of that essential amino acid in a reference pattern of essential amino acids.*

c BV (Biological value). Proportion of absorbed protein that is retained for body maintenance and/or growth.

d PD (Protein Digestibility). Proportion of food protein absorbed.

e PDCAAS (Protein Digestibility Corrected Amino Acid Score). Ratio of mg of limiting amino acids in 1 g of test protein and mg of the same amino acid in reference requirement pattern multiplied with True Digestibility.

True Digestibility = I (F − f)

I

Where I = nitrogen intake, F = total fecal nitrogen excretion, and f = fecal nitrogen excretion on a protein-free diet.

Adapted from: Schaafsma and Steijns, 2000.

whereas colostrum contains substantially higher level

(which causes ulcer, gastritis). Colostrum stimulates

of 48 g/liter of IgG1. Other fractions *are IgG2, IgA,*

active immune system by enhancing the activity of

IgM, all of which provide passive immunity.

natural killer cells and phagocytes. The colostrum

A number of colostrum products are being mar-

powder is manufactured by drying process to insure

keted to improve functionality of milk. Colostrum *activity. Milk protein concentrate prepared from the*

contains several functional constituents including an-

milk of hyperimmunized cows is now commercially

tibodies, lactoferrin, lactoperoxidase, cytokines, and

available, and is claimed to relieve joint pains of

growth factors. The antibodies act as antimicrobial

arthritis by complementing the body's

naturally oc-

agents against infection from rotavirus (which causes

curring antiinflammatory substances.

diarrhea), Escherichia coli (which causes food poi-

Lactoferrin has a role in nonspecific defense of the

soning), Candida albicans (which causes yeast in-

host against invading pathogens. It is active against *fection), Streptococcus mutans (which causes dental*

several Gram-positive and Gram-negative bacteria,

caries), Clostridium difficile (which causes antibiotic

yeasts, fungi, and viruses. Its iron-binding character-

associated diarrhea), Cryptosporium parvum (which

istic aids in enhancing iron absorption. It stimulates

causes food poisoning), and

Helicobacter pylori

and protects cells involved in host defense mecha-

nism. Furthermore, it controls cytokine response.

Lactoperoxidase is an enzyme that breaks down

***Table 20.4.** Minimum Requirements of*

hydrogen peroxide and exerts an antibacterial effect.

Various Proteins (g/kg body weight) in

Therefore, it is considered to be a

natural preserva-

Humans

tive. It is being incorporated in toothpastes to prevent

cavities. Another suggested use of lactoperoxidase

Protein

Requirement

is to control the acid development in stored yogurt

Lactalbumin

0.480

known as postacidification. Lysozyme has antimicro-

Potato

0.512

bial activity against Gram-positive bacteria and it acts

Potato, 30% + Lactalbumin, 70%

0.374

by lysis of cell walls. Bifidobacteria flora of colon

Cow's milk

0.568

imparts health-promoting properties and healthy gut

Casein

0.699

ecology to the host.

Wheat flour

0.892

Fermented milks are enhanced functional foods

Adapted from Schaafsma and Steijns, 2000.

because of the fact that they contain nutrients of milk,

Table 20.5. *Milk Constituents with Putative Physiological Effects*

Component

Health Effect

Butyric acid

Reduce colon cancer risk

CLA (Conjugated linoleic acid)

Modulate immune function, reduce risk of cancer (stomach, colon,

breast and prostate)

Sphingolipids

May reduce risk of colon cancer

Stearic acid

May modulate blood lipids to reduce risk of cardiovascular and

heart disease

Triglycerides

May enhance long-chain fatty acid and calcium absorption

Whey proteins

May modulate immune system, reduce risk of heart disease and

cancer, lower blood pressure

Glycomacropeptide

Prevent dental caries, gingivitis, antiviral, antibacterial, bifidogenic

Immunoglobulins

Antibodies against diarrhea and GI tract disturbances

Lactoferrin

Toxin binding, antibacterial, immune modulating, anticarcinogenic,

antioxidant, iron absorption

Lactoperoxidase

Antimicrobial

Lysozyme

Antimicrobial, synergistic with immunoglobulins and lactoferrin

Lactose

Calcium absorption

Calcium

Prevent osteoporosis and cancer, control hypertension

Adapted from: Chandan, 1999; Hoolihan, 2004.

as well products of metabolic activities of starter

In general, yogurt contains more protein, calcium,

microorganisms in the product.

Furthermore, they

and other nutrients than milk, reflecting the extra

contain live and active cultures in significant num-

solids-not-fat content. Bacterial mass content and the

bers to effect physiological benefits to the consumer.

products of the lactic fermentation further distinguish

***Table 20.6.** Some Functional Properties of Major Milk Proteins and*

Bioactive Peptides Derived From Them

Protein

Function

Caseins-

Precursors of bioactive peptides,iron carrier (Ca, Fe,

Zn, Cu)

Casomorphins from ⎵- and ␤-caseins

Casoxins from □-casein

Opoid agonists

Casokinins from ␣- and ␤-caseins

Opoid agonists

Casoplatelins from □-casein and transferring

Antihypertensive

Casecidin from ␣- and ␤-caseins

Antithrombotic

Isracidin from ␣-casein

Immunopeptides from ␣- and ␤-caseins

Antimicrobial

Phosphopeptides from ␣- and ␤-caseins

Antimicrobial

Glycomacropeptide from □-casein

Immunostimulants

Mineral carriers

Antistress effects

␣-Lactalbumin

Ca carrier, Lactose synthesis in mammary gland,

␣-Lactorphin

antocarcinogenic and immonomodulatory effects

Opoid agonists

NL*-Lactoglobulin*

Possible antioxidant, retinol carrier, fatty acid binding

NL*-Lactorphin*

Opoid agonists

Immunoglobulis A, M and G

Protectection of immune system, provide antibodies

Lactoferricin from Lactoferrin

Opoid agonists

Adapted from: Saxelin et al., 2003; Aimutis, 2004.

yogurt from milk. Fat content is standardized to com-

this peptide may inhibit binding of toxin in the gas-

mensurate with consumer demand for

low-fat to fat-

trointestinal tract.

free foods.

Some miscellaneous bioactive factors are being

discovered. Specific proteins for binding Vitamin

B

Bioactive Peptides

12, folic acid, and riboflavin may assist in enhancing *bioavailablity from milk and other foods. Fat globule*

Functional peptides are generated during digestive

membrane protein called butyrophilin is a part of the

processes in the body and during the fermentation

immune system. Other growth factors in milk may

processes used in fermented dairy foods. They arise

help gut repair after radiation or

chemotherapy.

from casein as well as from whey proteins (Table

20.6). These peptides are inactive in the native pro-

Lactose

teins but assume activity after they are released from

them. They contain 3 to 64 amino acids and largely

Lactose, the milk sugar stimulates the absorption of *display a hydrophobic character and are resistant to*

calcium and magnesium. It has a relatively lower

hydrolysis in the gastrointestinal tract. They can be

glycemic index as compared to glucose or sucrose,

absorbed in their intact form to exert various phys-

hence making it suitable for diabetics. It is less cario-

iological effects locally in the gut or *may have a*

genic than other sugars. Lactose stimulates bifidobac-

systemic effect after entry into circulatory system.

teria in the colon and thereby prevents infection and

Casomorphins and lactophorins derived from milk

improves intestinal health.

proteins are known to be opoid agonists, whereas

Lactose absorption in humans is catalyzed by the

lactoferroxins and casooxins act as opoid antagonists.

enzyme lactase or NL *-D-galactosidase. Lactase is a*

The opoids have analgesic properties similar to as-

nonpersistent enzyme in certain individuals, resulting

pirin. Casokinins are antihypertensive (lower blood

in distressing symptoms of bloating,

flatulence, and

pressure), casoplatelins are antithrombotic (reduce

diarrhea following milk intake. Most individuals can

blood clotting), immunopeptides are immunostimu-

tolerate two cups of milk spread over a day or with

lants (enhance immune properties), and phosphopep-

meals. In case of lactose malabsorption, the symp-

tides are mineral carriers.

toms are ameliorated by using lactase tablets or by

Casein phosphopeptides may aid in bioavailability

consuming yogurt. Yogurt and some fermented milks

of calcium, phosphorus, and magnesium for optimum

containing live and active cultures furnish the enzyme

bone health. They may also be helpful in preventing *lactase to assist in digesting lactose. Lactose-reduced*

dental caries. They may also have a role in secretion

milk and ice cream products are also available.

of entero-hormones and immune enhancement. The

Heated milk contains up to 0.2% lactulose, a lac-

casein peptides also offer a promising role in reg-

tose derivative. Since lactulose is not a *digestible in-*

ulating blood pressure. Conversion of angiotensin-I

gredient, it acts somewhat like a soluble fiber. Lac-

to angiotensin-II is inhibited by certain hydrolyzates

tulose is generally used for treatment of constipation

of casein and whey proteins. Since Angiotensin-II

and chronic encephalopathy. Some recent data indi-

raises blood pressure by constricting blood vessels,

cates that lactulose may enhance calcium absorption

its inhibition causes lowering of blood pressure. This

in the intestine.

ACE inhibitory activity would therefore make dairy

foods a natural functional food for controlling hy-

Milk Fat

pertension. A commercial ingredient derived by the

hydrolysis of milk protein, has an anxiolytic bioactive

Several positive findings have emerged for the con-

peptide with antistress effects. Psychometric tests and

sumption of milk fat. Milk fat exists in an emulsion

measurement of specific hormonal markers have dis-

form in milk making it highly

digestible. Also, milk

played their antistress effect. The ingredient may be

fat contains 10% short and medium chain fatty acids.

incorporated in milk, cheese, or ice cream.

Their 1:3 positions in the glyceride molecule allow

The glycomacropeptide released from □-casein as

gastric lipase with specificity for these positions to *result of proteolysis may be involved in regulating*

predigest them in the stomach itself. Butyric acid, a

digestion, as well as in modulating platelet function

characteristic fatty acid of milk fat, is absorbed in

and thrombosis in a beneficial way. It is reported to

the stomach and small intestine and provides energy

suppress appetite by stimulating CCK

hormone. Con-

similar to carbohydrates. Medium chain fatty acids

sequently, it may be a significant ingredient of sati-

are transported to the liver for rapid source of en-

ety diets designed for weight reduction. Furthermore,

ergy. The fatty acids lower the pH for facilitating *protein digestion. At the same time, acid barrier for*

ratio for bone growth and maintenance. As a food

pathogenic activity is enhanced. Free fatty acids and

source, milk offers good bioavailability of miner-

monoglycerides are surface tension lowering agents,

als and vitamins. To prevent osteoporosis, continued *thereby exerting an antiinfective effect.*

consumption of milk is cited as important by leading

The flavor of milk fat is unique and it adds to

experts in nutrition and medical science. Other func-

mouth-feel of foods comprised of milk and dairy

tions of calcium involve regulation of blood pressure

foods. Milk fat is a concentrated form of energy. Fat *and prevention of colon cancer.*

protects organs and insulates body from environmen-

The fat-soluble vitamins A, D, E, K and water-

tal temperature effects. It carries vitamins A, D, E,

soluble vitamins are well known for their beneficial

and K and supplies essential fatty acids including

role in human nutrition. Milk is a good source of *arachidonic acid, linolenic acid, omega 3-linoleic,*

B-vitamins.

eicosopentaenoic acid, and docosahexaenoic acid.

The essential fatty acids cannot be synthesized by the

PROBIOTICS

body and must be supplied by our diet. The omega-3

fatty acids have a role in memory development and

Detailed discussion on probiotics is given in Chap-

maintenance.

ter 22. Probiotics may be defined as a food or supple-

Conjugated linoleic acids (CLA) are a class of fatty

ment containing concentrates of defined strains of liv-

acids found in animal products such as milk and yo-

ing microorganisms that on ingestion in certain doses *gurt. Rumen flora synthesizes CLA, which has been*

exert health benefits beyond inherent basic nutrition.

demonstrated to exhibit potent physiological prop-

They are believed to contribute to the well-being

erties. CLA is a strong antioxidant constituent of

of the consumer by improving the host's microbial

milk fat, and may prevent colon cancer *and breast*

balance in the gastrointestinal tract. This definition

cancer. CLA has been shown to enhance immune

stresses upon the importance of ingestion of several

response. Prostaglandin PGE-2 promotes inflamma-

hundred millions of live and active microbial culture.

tion, artery constriction, and blood clotting. CLA may

Recent advances in probiotic research show much

reduce the risk of heart disease by reducing the lev-

promise in new product development of functional

els of prostaglandin PGE-2. Studies have indicated

foods based on milk (Sanders, 1994, Chandan, 1999,

that CLA may increase bone density, reduce chronic

Shah, 2001). There has been marked

proliferation

inflammation, and normalize blood glucose levels by

in the number of probiotic products in the market.

increasing insulin sensitivity.

Probiotics and associated ingredients might add an

Another constituent of milk fat is sphingolipids.

attractive dimension to cultured dairy foods for ef-

They occur at a level of only 160 □g/kg. Recent

fecting special functional attributes.

studies show that they are hydrolyzed in the gas-

Milk is an excellent medium to carry or gener-

trointestinal tract to ceramides and sphingoid bases,

ate live and active cultured dairy products. They add

which help in cell regulation and function. Studies on *an attractive dimension to cultured dairy products*

experimental animal show that sphingolipids inhibit

for augmenting current demand for functional foods.

colon cancer, reduce serum cholesterol, and elevate

The buffering action of the milk proteins keeps the

the good cholesterol HDL. They could protect against

probiotics active during their transit *through the gas-*

bacterial toxins and infections as well.

trointestinal tract. Other potential carriers are fruit

Butyric acid is liberated from milk fat by lipase in

juices, candies, ice cream, and cheese. In general,

the stomach and small intestine. It may exert benefi-

worldwide consumption of fermented milk prod-

cial effect on the gastric and intestinal mucosa cells.

ucts has increased due to their high nutritional pro-

In the colon, butyric acid is formed by fermentation

file, unique flavor, desirable texture, and remarkable

of carbohydrates by the resident microbiota. Butyric

safety against food-borne illness. Concomitantly, it

acid in that location works as a

substrate for colon

translates to a sizeable enhancement in milk utiliza-

cells and confers anticancer properties.

tion and the intake of valuable nutrients contained

therein. Addition of fruit preparations including fruit

flavors and fruit purees has enhanced the versatility

Minerals and Vitamins

of flavor, texture, color, and variety of yogurt con-

Milk and dairy products are, in general, an excellent

taining probiotics. Incorporation of nuts, grains, and

source of calcium, phosphorus, and magnesium in

chocolate syrups gives the fermented milk novel and

diet. High levels of these minerals are in optimum

multiple textures and flavors to attract *its use as a*

snack, breakfast food, or as a dessert item. Probiotic

organisms from the genera Lactobacillu s, Enterobac-

mixtures are also exclusively sold either in the form

ter, Streptococcus, and Bifidobacterium. These gen-

of powders, capsules, or tablets and labeled in the

era are important members of the gastrointestinal mi-

market as natural organic foods/supplements.

croflora and are all relatively beneficial. The strains

of lactic acid bacteria used in probiotics are mostly

intestinal isolates such as Lb. acidophilus, Lb. ca-

Beneficial Microflora

sei, Enterococcus faecium, and Bifidobacterium

Cultures associated with health benefits are yogurt

bifidum.

bacteria (Streptococcus thermophilus and Lacto-

Yogurt starter bacteria, Lb. delbrueckii ssp. bul-

bacillus delbrueckii spp. bulgaricus), other lacto-

garicus and Streptococcus thermophilus, are also in-

bacilli, and bifidobacteria (Nakazawa and Hosono,

cluded as probiotics in this table because yogurt has

1992; Salminen et al., 1998). Table 20.7 gives a list

been associated with several health benefits in the

of various probiotics being used in commercial fer-

past. They are now reported to persist and remain vi-

mented milks.

able throughout the gastrointestinal tract of rats and

Yogurt organisms possess a distinctly high lac-

humans. For sustained benefit, it is necessary to ingest

tase activity, making it easily digestible by individu-

them on continuous basis. Even with intestinal iso-

als with a lactose-maldigestion condition. To bolster

lates such as Lb. acidophilus, it is

necessary to dose

probiotic function, most commercial yogurt is now

regularly rather than to assume that a few doses will

supplemented with Lactobacillus acidophilus and

allow the organisms to colonize the gut permanently.

Bifidobacterium spp.

Currently even Bacillus laterosporus and Bacillus

The probiotic preparations are also available in the

sphaericus and other little-known probiotics are for-

form of tablets, powder, or capsules. They contain

tified with enzymes, antiinflammatory compounds,

specific amino acids, colostrum, and chelated min-

erals in probiotic preparations. Lb. acidophiulus and

***Table 20.7.** Probiotic and Beneficial*

Bifidobacterium bifidum strains are known to differ

Microorganisms in Commercial Products

widely in their ability to grow in the presence of bile

salts (Gilliland, 2003). Both are reported to be stable

Lactobacillus acidophilus group:

at various concentrations of bile salts.

Lactobacillus acidophilus

Lactobacillus johnsoni LA1

Lactobacillus gasseri ADH

Health Benefits of Probiotic

Lactobacillus crispatus

Products

Lactobacillus casei/paracasei

Health benefits of probiotics are enumerated in

Lactobacillus casei subsp. Rhamnosus

Table 20.8.

Lactobacillus reuteri

The belief in the beneficial effects of the probiotic

Lactobacillus brevis

approach is based on the knowledge that the intestinal

Lactobacillus delbrueckii subsp. bulgaricus

microflora provides protection against various dis-

Lactobacillus fermentum

eases. Probiotics have been with us for as long as

Lactobacillus helveticus

people have eaten fermented milks but their associ-

Lactobacillus plantarum

ation with health benefits dates only from the turn

Bifidobacterium adolescentis

of the century when Metchnikoff drew attention to

Bifidobacterium animalis

the adverse effects of the gut microflora on the host

Bifidobacterium bifidum

and suggested that ingestion of fermented milks ame-

Bifidobacterium breve

liorated the so-called autointoxication (Metchnikoff,

Bifidobacterium infantis

1908). It has been shown that germ-free animals are

Bifidobacterium longum

more susceptible to disease than their conventional

Streptococcust thermophilus

counterparts who carry a complete gut flora. This

Enterococcus faecium

difference has been shown for infections caused by

Pediococcus acidilactici

Salmonella enteritidis and Clostrodium botulinum.

Saccharomyces boulardii

Another source of evidence that supports the protec-

Adapted from: Chandan, 2004; Shah, 2001, 2004; Saxelin

tive effect of the gut flora is the finding that antibi-

et al., 2003.

otic treated animals, including humans can become

Table 20.8. *Health Effects of Probiotics*

Effects Corroborated by Scientific

Evidence

Effects of Potential Nature

Assisting lactose digestion

Controlling candida and bacterial infections (vaginitis)

Treatment of rotaviral diarrhea

Alleviating constipation

Treatment of infant gastroenteritis

Antimutagenic/anticarcinogenic effects

Treatment of antibiotic related

diarrhea

Lowering cholesterol and blood pressure

Modulating intestinal (microbiota) ecology

Alleviation of microbial overpopulation in

small intestine

Reducing harmful fecal enzymes, biomarkers

Alleviation of dermatitis and skin allergies *of cancer initiation*

Enhancing/modulating immune system

Prevention and treatment of Crohn disease

Positive effects on cervical and bladder cancer

Treatment of Clostridium difficile diarrhea

Adapted from: Fonden et al., 2003; Shah, 2001, 2004.

more susceptible to disease (Saavedra, 1995). In hu-

for the production of catalase, nitrate reductase, ure-

mans pseudomembranous colitis, a

disease caused by

ase, and for the formation of indole. In addition,

Clostridium difficile, is almost always a consequence

liquefaction of gelatin, gas formation from glucose,

of antibiotic treatment (Shah, 2004).

response to rhamnose, sorbose, glycerol, erythritol,

The third source of the supporting evidence comes *adinotol, and dulcitol should be negative. Commer-*

from experiments in which dosing with fecal suspen-

cial probiotic strains must have verified safety of use

sions has been shown to prevent infection (Schwan

in human diet. They should possess stability to acid

and Sjolin, 1984). In humans it has been shown that

and bile, and exhibit colonization and *adherence in*

C. difficile infection can be reversed by adminis-

the GI tract.

tering fecal enemas derived from a healthy human

adult. Probiotics also deplete the essential nutrients

for the pathogenic organisms thus eliminating their

Production of Enzymes, Vitamins,

growth.

and Bacteriocins

Figure 20.2 illustrates how yogurt and cultured

Other beneficial effect of probiotics includes the im-

dairy products might exert functional benefits to the

provement of lactose utilization in large proportion

consumer (Chandan, 1999).

of the world's population who are unable to effec-

tively digest lactose. The enzyme lactase responsible

for lactose digestion, although present in the suck-

Requirements for Effective

ling infant, disappears after weaning. In areas of the

Probiotics

world where milk is not a staple food, lack of enzyme

Criteria for live and active cultures have been estab-

causes no problems. However, if people from these

lished by the industry with a view to maintain the

regions migrate to Europe or North America, prob-

integrity of refrigerated and frozen yogurts. In addi-

lems arise because ingestion of lactose in some form

tion, the probiotics must implant and multiply rapidly

is difficult to avoid. Lactose

malabsorption refers to

in the gut to avoid them from being expunged en-

incomplete digestion of lactose resulting in a flat or

tirely. They must not only be able to tolerate and pass

low rise in blood sugar following ingestion of lactose

through the high acidity (low pH) of stomach, but

in a clinical lactose intolerance test. The disaccha-

also be able to grow and proliferate at physiological

ride lactose is hydrolyzed to glucose and galactose

levels of bile salts and adhere to the intestinal ep-

by lactase and subsequently absorbed in the small

ithelial cells. Bile salts produced by the gall bladder

intestine. Lactase is a constitutive, membrane-bound

are essential in helping to emulsify fat *before it can*

enzyme located in the brush borders of the epithe-

be digested in the intestine. Probiotics that can colo-

lial cells of the small intestine. The intact residual

nize should also be resistant to several antibiotics and

lactose left over following impaired lactase activity

producer of bacteriocin as natural antimicrobial sub-

enters the colon where it is fermented by inherent

stances. A Bifidobacterium strain should be negative

microflora to generate organic acids, carbon dioxide,

20 Functional Foods and Disease Prevention

321

Fermented milk with

beneficial bacteria

Nutritional

Physiological

attributes

benefits

Cell mass:

Proteins/

probiotic and

Bioactive peptides

beneficial bacteria

Suppression of food

Fats/energy

borne pathogens

Reduction in

Minerals

carcinogenic

compounds

Vitamins

Cholesterol reduction

Improved lactose

digestion

Restore ecological

balance in colon

Immune modulation

Figure 20.2. *Potential mode of health*

attributes of yogurt and fermented milks.

methane, and hydrogen. The fermentation products

symptoms using Lb acidophilus. Bifidobacterium bi-

together with the osmotically driven excessive wa-

fidum effectively kills or controls

Escherichia coli,

ter drawn into the colon are primarily responsible

Staph. aureus and Shigella. Acidophilus is also re-

for abdominal pain, bloating, cramps, diarrhea, and

ported to control viruses such as herpes.

flatulence. These symptoms are associated with lac-

tose maldigestion when lactose is not fully digested

Bioavailability of Calcium

in the small intestine. It has been known for some

time that lactose deficient subjects tolerate lactose

One of the primary functions of calcium is to provide

in yogurt better than the same amount of lactose in

strength and structural properties to bone and teeth.

milk. It is possible to show increased lactase activity

The major source of dietary calcium is dairy products,

in the small intestine of humans that have been fed

supplying 75% of the intake. Milk and dairy products

yogurt.

are excellent sources of bioavailable calcium. Addi-

Probiotics also produce some of the B-vitamins in-

tion of lactic acid to unfermented yogurt, as well as *cluding niacin, pyridoxine, folic acid, and biotin. Pro-*

regular fermented yogurt displays an improved bone

biotics produce antibacterial substances, which have

mineralization as compared to the unfermented yo-

antimicrobial properties against disease-causing bac-

gurt. It is postulated that the acidic pH due to added

teria. Acidophilin produced by Lb.

acidiophilus is

lactic acid or naturally contained in fermented yo-

reported to inactivate 50% of 27 different disease-

gurt converts colloidal calcium to its ionic form and

causing bacteria. Children with Salmonella poi-

allows its transport to the mucosal cells of the intes-

soning and Shigella infections were cleared of all *tine. (Fernandes et al., 1992).*

Reduction in Serum Cholesterol

initiation by various probiotics by reducing fecal pro-

carconogenic enzymes nitroreductase and azoreduc-

Probiotics effectively help to reduce cholesterol lev-

tase (Lee et al., 1996).

els circulating in blood. Some studies have indicated

a modest lowering of serum cholesterol in subjects

consuming milk fermented with Lb. acidophilus, Lb.

Immunomodulatory role

rhamnosus GG and yogurt cultures.

An interesting development in recent years has been

the finding that lactobacili administered by mouth can

Prevention of Diarrhea, Vaginitis

stimulate macrophage activity against several differ-

and Dermatitis

ent species of bacteria (Brassart and Schiffrin, 1997,

Rangavajhyala et al. 1997. For example, Lb. casei

Probiotics improve the efficiency of the digestive

given to mice increased phagocytic activity. Lacto-

tract especially when bowel function is poor. Es-

bacilli injected intravenously are reported to survive

tablishment of probiotics in the GI tract may pro-

in the liver, spleen, and lungs and enhance the natural

vide prophylactic and therapeutic benefits against

killer cell activity.

intestinal infections. Probiotics may have a role in

Probiotics have been reported to be useful in the

circumventing traveler’s diarrhea (Fernandes et al.,

treatment of acne, psoriasis, eczema, allergies, mi-

1992; Elmer et al., 1996). Yogurt supplemented with

graine, gout, rheumatic and arthritic conditions, cys-

probiotic organisms reduces the duration of cer-

titis, candiadiasis, colitis and irritable *bowl syn-*

tain types of diarrhea. Fermented milk with probi-

drome, and some forms of cancer. Recent reports

otics has been recommended to replace milk dur-

suggest that Lb. acidophilus may be able to inhibit

ing the treatment of diarrhea because it is tolerated

HIV, the virus that causes AIDS. It is reported that *well than milk. A double blind study has shown*

certain strains of Lb. acidophilus (and certain species

that only 7% of infants receiving probiotic formula

of Enterococcus) produce large amounts of hydro-

containing Bifidobacterium bifidum and Streptococ-

gen peroxide. Hydrogen peroxide alone, or in com-

cus thermophilus develop diarrhea

against 31% inci-

bination with certain minerals or dietary components,

dence in placebo group (Saavedra et al., 1994). The

can arrest the growth of HIV. More research in this

vaginal microflora changes drastically during bacte-

area is needed to make a definitive validation of these

rial infection. Bacteria of genera Escherichia, Pro-

claims.

teus, Klebsiella, and Pseudomonas along with yeast,

Potential mechanisms by which probiotics may ex-

Candida albican are recognized as etiological agents

ert their beneficial effects are (a), competition with

in urinary tract infection among adult women. It has

other microflora for nutrients, (b) production of acids *been shown that the normal urethral, vaginal, and cer-*

inhibitory to certain enteropathogens, (c) produc-

vical flora of healthy females can competitively block

tion of bacteriocins or inhibitory metabolites, (d) im-

the attachment of uropathogenic bacteria to the sur-

munomodulation, and (e) competition for adhesion

faces of uroepithelial cells.

Lactobacilli strains sup-

to intestinal mucosa.

plemented in the diet or directly applied are reported

Since efficacy of a probiotic is directly related to

to coat the uroepithelial wall and prevent the adher-

the number of live and active cells consumed, it is

ence of uropathogens. Milk fermented with yogurt *important to specify potency or colony forming units*

cultures and Lactobacillus casei influences the in-

(cfu) of the culture per unit weight or volume of the

testinal microflora of infants (Guerrin-Danan et al.,

product. In addition, the culture should be active in

1998).

terms of growth potential (Chandan, 1999).

Anticarcigoenesis

Manufacture of Probiotics for Use

as Food Supplements

Bifidobacteria and lactobacilli, especially Lb. aci-

dophilus have been shown to have powerful anticar-

Various probiotic strains are screened for their ef-

cinogenic features, which are active against certain

fectiveness and formulated for stability *during shelf*

tumors (Goldin and Gorbach, 1992). An epidemio-

life of the product. In general, the process of probi-

logical study reported a positive correlation between

otic manufacture involves growing of probiotic cul-

consumption of probiotic and prevention of colon

tures by a process involving growth in a well-defined *cancer. Several reports suggest prevention of cancer*

nutrient medium. In the manufacturing process, the

microorganisms are concentrated first by removing

magnesium in animal models, and this may be of im-

unspent liquid medium by sedimentation, ultrafil-

portance for humans as well.

tration, reverse osmosis, and/or centrifugation. Cry-

oprotectant is added before freezing to prevent

FORTIFICATION

“freezer damage” to the bacteria. Following freezing,

the mass is freeze-dried. The final product is then sub-

Traditionally, milk has been fortified with vitamins A *jected to fine screening and quality control involving*

and D. Now, popular ingredients of functional signif-

several tests. When the product passes all the rig-

icance are being incorporated to enhance the market

orous tests, it is then mixed with excipient to stan-

value of dairy foods and dairy-based foods. Some

dardize the specific desired count (most *commonly*

of these ingredients designed to enhance consumer

> 10 billion CFU/gram). Following that a natural sta-

appeal are: (a) calcium, claimed to prevent osteo-

bilizer is added to prevent the loss of its viability

porosis and cancer, and control hypertension; (b) an-

during packaging, shipping, storage, marketing, and *tioxidants (vitamins C and E), claimed to prevent*

consumption. The viability of the cells should not

cancer, cardiovascular disease, and cataracts. In ad-

be damaged during the manufacturing and freeze-

dition, dietary fiber (psyllium, guar gum, gum acacia,

drying process. The cultures that can be used alone

oat fiber, soy components) as well as

multivitamin-

or in combination include Lactobacillus acidophilus,

mineral mixes are being incorporated in fat-free milk

Lb. brevis, Lb. delbrueckii ssp. bulgaricus, Lb. casei,

to provide targeted niche consumers meal replace-

Lb. casei ssp. rhanmosus, Lb. helveticus, Lb. lactis,

ments. Such products supply a substantial proportion

Lb. plantarum, Lb. reuteri, Lb. salivarius, Bifidobac-

of daily essential nutrients. In addition to infant for-

terium bifidum, B. breve, B. infantis, B. longum, Ente-

mula line of products based on fat-free milk, there is

rococcus faecium, Str. thermophilus, and Pedicoccus

a proliferation of energy and weight-reduction shake

cerevesiae.

drinks for consumer segments ranging from adults to

Supplementation of probiotics with prebiotics can

geriatric populations. More recently, the food indus-

be a very effective functional food (Shah, 2001).

try has leveraged this area to develop and market a

For example, prebiotic fructooligosaccharide (FOS)

number of drinks and powders targeted

to consumers

is exclusively used by a few strains of Bifidobac-

interested in weight reduction, meal replacement, and

terium bifidum and Lb. acidophilus. Thus a combina-

supplementing their diet with wellness foods (Table

tion of FOS along with these cultures will induce the

20.9). Antioxidants have shown promise, but forti-

proliferation of these cultures in preference to other

fication strategy must include an understanding of

microflora in the gastrointestinal tract. This combina-

their impact on flavor, texture, mouth feel, and shelf

tion is termed as synbiotics. Prebiotic consumption is

life of the product. Also, it is imperative to know a

reported to increase the levels of

bifidobacteria in hu-

meaningful dose-benefit relationship associated with

man volunteers at the expense of less desirable bacte-

the specific fortified dairy food.

rial species. Additionally, prebiotic supplements have

Another ingredient of interest is docosahexaenoic

been shown to improve the absorption of calcium and *acid (DHA). They are long chain polyunsaturated*

Table 20.9. *Various Milk-Based Product Categories Containing Milk Fractions*

Category

Food or Supplement

Clinical nutrition

Total enteral formulas containing casein, milk proteins and their

hydrolyzates for tube or oral administration in hospitalized patients

Health foods or Sports nutrition

Drinks, tablets, energy bars or cookies can deliver easily absorbable

protein hydrolyzates, bioactive peptides and bioavailable milk

minerals; Glutamine peptide supports immune system and facilitates

iron absorption

Infant nutrition

Demineralized whey, lactose, caseinates, milk protein concentrate, and *dairy minerals are constituents of hypoantigenic and hypoallergenic*

humanized infant formulas

Weight-reduction drinks

Meal replacement milk shakes fortified with such supplements as milk

proteins, vitamins and minerals, prebiotics

fatty acids from fish oils and marine algae. They are

Chandan RC. 1999. Enhancing market value of milk

claimed to exert cancer inhibition, antiallergy effects,

by adding cultures. J. Dairy Sci. 82:2245–2256.

and improvement in learning ability. DHA-fortified

Chandan RC. 2004. Yogurt. In: JS Smith, YH Hui

drinks are targeted at school children in some coun-

(Eds), Food Processing, Blackwell

Publishing,

tries.

Ames, IA, pp. 297–318.

Elmer GW, Surawicz CM, McFarland LV. 1996.

Biotherapeutic agents—A neglected modality for

PHYSIOLOGICALLY ACTIVE

the treatment and prevention of selected intestinal

INGREDIENTS

and vaginal infections. JAMA, 275:870–876.

Another possible opportunity to develop functional

Fernandes CF, Chandan RC, Shahani KM. 1992.

foods is to leverage the use of inherent milk con-

Fermented dairy products and health. In: BJB Wood

(Ed), The Lactic Acid Bacteria, Vol. 1. Elsevier,

stituents of known physiological

attributes. Commer-

New York, pp. 279–339.

cially available milk fractions are being used in a

Fonden R, Saarela M, Matto J, Mattila-Sandholm T.

variety of milk-based products (Table 20.9).

2003. Lactic acid bacteria in functional dairy

Besides milk fractions inherently present in nor-

products. In: T Mattils-Sandholm, M Saarela (Eds),

mal milk, a new class of oral therapeutic prepara-

Functional Dairy Products. CRC Press, Boca Raton,

tions is being developed. They constitute a new class

FL, p. 251.

of bovine antibodies or immunoglobulins. They com-

Gilliland SE. 2003. Probiotics. Encyclopedia of Food *prise of antibodies from colostrum of cows. They are*

Sciences and Nutrition, Vol. 8, Academic Press,

designed to attack infections in the GI tract of hu-

London, pp. 4792–4798.

mans. They are consumed orally to provide passive

Goldberg I (Ed). 1994. Functional Foods, Designer

immunotherapy. Regular bovine colostrum contains

Foods, Pharmafoods, Nutraceuticals. Chapman &

antibodies against many human pathogens such as

Hall, New York.

Escherichia coli, Staphylococcus aureus, Staphylo-

Goldin BR, Gorbach SL. 1992. Probiotics for humans.

coccus epidermidis, Streptococcus pyogenes, Strep-

In: R Fuller (Ed). Probiotics—The Scientific Basis.

tococcus faecalis, Streptococcus viridans, Candida

Chapman and Hall, New York, pp. 355–376.

albicans, Salmonella typhimurium, Proteus vulgaris,

Gregory AG. 1997. Method for microfiltration of milk

Klebsiella pneumoniae, and Pseudomonas aerugi-

or colostum whey. US Patent no. 5,670,196.

nosa. Cows are cost effective

bioreactors producing

Guerrin-Danan C, Chabanet C, Pedone C, Popot F,

about 500 g of antibodies in the first 4 days of par-

Vaissade P, Bouley C, Szylit O, Andrieux C. 1998.

turition. During the dry period, pregnant cows are

Milk fermented with yogurt cultures and

immunized against specific antigens derived from

Lactobacillus casei compared with yogurt and

human pathogens. Postpartum milk is collected for

gelled milk: Influence on intestinal microflora in

healthy infants. Am. J. Clin. Nutr. 67:111–117.

4 days and harvested for immunoglobulins, followed

Hoolihan L. 2004. Beyond Calcium. The protective

by formulation for site-specific

delivery. Polyclonal

attributes of dairy products and their constituents.

antibodies contained in the immunoglobulin formu-

Nutrition Today 39(2, March–April): 69—77.

lations may bind multiple target sites.

Hutch PJ, Layman DK, Brown PH. (Eds). 2004. The

Application

of

engineered

immunoglobulins

emerging role of dairy products and bioactive

(Gregory, 1997) to milk as such or in association

peptides in nutrition and health. J. Nutr.

with cultures may be another innovative approach

134(4S):961S–1002S.

to design a product with a distinctive *appeal to cer-*

Lee H, Rangavajhyala N, Gradjean G, Shahani KM.

tain segment of consumers. Certain preparation may

1996. Anticarcinogenic effect of Lactobacillus

contain specific immunoglobulins to combat some

acidophilus on N-nitrosobis(2-oxopropyl) amine

conditions.

induced colon tumor in rats. J. App. Nutr. 48:

59–66.

REFERENCES

Mattila-Sandholm T, Saarela M. 2003. Functional

Dairy Products. CRC Press, Boca Raton, FL.

Aimutis WR. 2004. Bioactive properties of milk

Metchnikoff E. 1908. The prolongation of life. In: PC *proteins with particular focus on anticarcinogenisis.*

Mitchell (Ed), G.P. Putnam's Sons, The

J. Nutr. 134:4S, 989S–995S.

Knickerbocker Press, New York & London.

Brassart D, Schiffrin EJ. 1997. The uses of probiotics

Nakazawa Y, Hosono A. 1992. Functions of Fermented

to reinforce mucosal defence mechanisms. Trends

Milk—Challenges for the Health Services. Elsevier,

Food Sci. Technol. 8:321–326.

New York.

Rangavajhyala N, Shahani KM, Sridevi G, Srikumaran

(Designer Foods, Pharmafoods, Neutraceuticals).

S. 1997. Nonlipopolysaccharide

component(s) of

Chapman and Hall, New York, pp. 295–322.

Lactobacillus acidophilus stimulates the production

Saxelin M, Korpela R, Mayra-Makinen A. 2003.

of interlukin-1 ␣ and tumor necrosis factor- ␣ by

Introduction: classifying functional dairy products.

murine macrophages. Nutrition and Cancer

In: T Mattils-Sandholm, M Saarela (Eds), Functional

28:130–134.

Dairy Products. CRC Press, Boca Raton, FL, p. 6.

Saavedra JM. 1995. Microbes to fight Microbes: A not

Schaafsma G, Steijns JM. 2000. Dairy ingredients as a

so novel approach to controlling diarrheal disease.

source of functional foods. In: MK Schmidl, TP

J. Pediatr. Gastroenterol. 21:125–129.

Labuza (Eds), Essentials of Functional Foods.

Saavedra JM, Bauman NA, Oung I, Perman JA, Yolken

Aspen Publishers, Gaithersberg, MD.

RH. 1994. Feeding of Bifidobacterium bifidum and

Schwan A, Sjolin S. 1984. Clostridium difficile

Streptococcus thermophilus to infants in hospital for *enterocolitis cured by rectal infusion of normal*

prevention of diarrhea and shedding of rotavirus.

faeces. Scand. J. Infect. Diseases 16:211–215.

Lancet, 344:1046–1049.

Shah NP. 2001. Functional foods from probiotics and

Salminen S, Deighton MA, Benno Y, Gorbach SL.

prebiotics. Food Technol. 55(11):46–53.

1998. Lactic acid bacteria in health and disease. In:

Shah NP. 2004. Probiotics and prebiotics. Agro Food

S Salminen, A von Wright (Eds), Lactic Acid

Industry HiTech. 15(1):13–16.

Bacteria, Marcel Dekker, New York, pp. 211–253.

U.S. Department of Agriculture (USDA). October

Sanders ME. 1994. Lactic acid bacteria as promoters of

2002. Nutritive Value of Foods, USDA, Washington,

human health. In: I Goldberg (Ed), Functional Foods

DC, pp. 22–23.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

21

Health Benefits of Yogurt and

Fermented Milks

Nagendra P. Shah

Introduction

Francis I of France was cured of debilitating illness

Yogurt and Other Fermented Milks

by yogurt. Another legend tells that yogurt originated

Cultured Buttermilk

from the Balkans. Peasants of Thrace made soured

Cultured Cream

milks, known as 'Prokish' from sheep milk. Asia con-

Fermented Milks of Eastern Europe

tributed to the early spread of fermented milks by

Fermented Milks of Asia

the Tartars, Huns, and Mongols in their invasions of

Nordic (Scandinavian) Fermented Milks

Russia and European areas. South East

Asia includ-

Fermented Milks from the Middle East

ing Persia (or Iran), Iraq, Syria, and Turkey still re-

Health Benefits of Fermented Milks

Nutritional Value of Fermented Milks

mains a key area for production and consumption of

Nutritional Function

fermented milk. Fermented milk is also a traditional

Physiological Effects

food in the Balkans. Its popularity has now spread to

Antimicrobial Activity and Gastrointestinal Infections

Europe and many other parts of the world. The word

Anticancer Effects

'yogurt' was derived from the Turkish word 'Jugurt'

Reduction in Serum Cholesterol

and Table 21.1 shows the synonyms for

yogurt or

Immune System Stimulation

yogurt-related fermented milks known in different

Health Benefits of Nordic Fermented Milks

countries.

Health Effects of Kefir

A major factor in the evolution of fermented prod-

Health Benefits of Bio-Yogurt

uct is that the Middle East area has a subtropi-

References

cal climate and the temperature may reach around

40◦C. This is the ideal temperature for the growth

INTRODUCTION

of starter bacteria and milk turned sour and coag-

ulated rapidly. However, the souring of milk was

Although there are no records available to trace the

not a uniform process as there was no control

origin of yogurt and other fermented milks, it is

over the starter bacteria in fermentation of milk.

believed that fermentation was the first technique

This gave rise to insipid product, with irregular

employed by humans for preservation

of milk. Fer-

coagulum filled with air (Kosikowski and Mistry,

mented milks are reported to have originated in the

1997).

Middle East before the Phoenician era. The tradi-

Fermented milk plays an important role in the di-

tional Egyptian fermented milks, Laban Rayeb, and *ets of some European communities, particularly in*

Laban Khad, were consumed in Egypt as early as

Bulgaria. Today, fermented milk is manufactured in

7000 bc. Ancient Turkish people in Asia, where

many countries around the world.

they lived as nomads, are believed to have made

Yogurt has played an important role in human nu-

yogurt first. The first Turkish name appeared in the

trition. The fermented milk products vary consider-

eighth century as 'yoghurut.' According to the Per-

ably in composition, flavor and texture, depending on

sian tradition, Abraham owed his longevity to yogurt

the nature of fermenting organisms, the type of milk,

consumption (Prajapati and Nair,

2003). Emperor

and the manufacturing process used.

Table 21.1. *Yogurt and Yogurt-Like Products as Known in Various Countries of the World Traditional Name*

Country

Traditional Name

Country

Jugurt/Eyran

Turkey

Tiaourti

Greece

Busa

Turkestan

Cieddu

Italy

Kissel Mleka

Balkans

Mezzoradu

Sicily

Urgotnic

Balkan mountains

Gioddu

Sardinia

Leben/Leban

Lebanon and some

Filmjolk/Fillbunke/

Scandinavia

Arab countries

Filbunk/Surmelk/

Taettem-jolk/Tettemelk

Zabady

Egypt and Sudan

Tarho

Hungary

Mast/Dough

Iran and Afghanistan

Viili

Finland

Roba

Iraq

Skyr

Iceland

Dahi/Dadhi/ Dahee

India, Bangladesh, Nepal

Yogurt/Yogurt/ Yaort

Rest of the world

Mazun/Matzoon

Armenia

Yourt/Yaourti/ Yahourth/

("Y" is replaced by "J"

Yogur/Yaghourt

in some instances)

Katyk

Transcaucasia

Source: Tamime and Deeth, 1980; Kosikowski and Mistry, 1997.

Although yogurt has many desirable properties,

Prolongation of Life', he hypothesized that yogurt

it is still prone to deterioration. The containers

bacteria, Lactobacillus delbrueckii ssp. bulgaricus

traditionally used by nomads were made from ani-

and Streptoccocus thermophilus, control infections

mal skins. Because of whey evaporation *through the*

caused by enteric pathogens and regulate toxemia,

skin, the solids content and lactic acid concentration

both of which play a major role in ageing and mor-

rose. This gave rise to concentrated or condensed

tality. He linked health and longevity of Bulgarian

yogurt. Such type of product was manufactured in *peasants to their high consumption of fermented*

Armenia, where mazun (Armenian yogurt) is pro-

milks, particularly yogurt. Later, it was found that

cessed to yield concentrated yogurt. Another method

yogurt starter is unable to implant in the intestine.

of concentration of yogurt was by placing the product

Moro in 1900 isolated Lb. acidophilus

from feces of

in an earthenware vessel. Evaporation through pores

infants. Hence, focus was given to Lb. acidophilus as

of earthenware vessels helped increase solids content

a more suitable organism for therapeutic properties.

and lactic acid concentration. This practice also kept

This observation provided a major boost to manu-

the product cool and is still practiced in some parts of

facture and consumption of yogurt (Prajapati and

India and Nepal. Nevertheless, the condensed yogurt

Nair, 2003).

had a limited keeping quality and salting was car-

The first commercial production of yogurt in

ried out to extend the keeping quality. Different types

Europe was undertaken by Danone in 1922 in Madrid,

of concentrated yogurt containing various quantities

Spain. There was a rapid advancement in the tech-

of salt are made in Turkey. Sun drying of salted

nology of yogurt and understanding of its properties

product was another means of extending the keep-

since 1950.

ing quality further. Dried yogurt balls are stored in

glass jars and covered in olive oil. In some countries

YOGURT AND OTHER

including Turkey, Lebanon, Iraq, and Iran, rubbing

FERMENTED MILKS

of wheat flour to dried yogurt is carried out to in-

crease the keeping quality to almost indefinite period.

Yogurt is defined as "a product resulting from milk by

This product is known as "kishk." As refrigeration

fermentation with a mixed starter culture consisting

became widespread, a variety of new generation of

of Str. thermophilus and Lb. delbrueckii ssp. bulgari-

yogurts emerged and the interest in traditional

cus. " However, in some countries

including Australia

products declined.

other suitable lactic acid bacteria in addition to yo-

At the beginning of this century, Nobel Laureate

gurt starter (Str. thermophilus and Lb. delbrueckii ssp.

Elie Metchnikoff at the Pasteur Institute in Paris was

bulgaricus) are permitted for use as starter cultures.

the first to propose a scientific rationale for the bene-

As a result, some yogurt manufacturers use Lac-

ficial effects of bacteria in yogurt. In his treatise 'The

tobacillus helveticus and Lactobacillus jugurti for

manufacturing yogurt. Similarly, yogurt in Australia

1.4% titratable acidity. This fermented milk is popu-

can be made with ABT starter cultures, which in-

lar in Bulgaria.

clude Str. thermophilus, Lactobacillus acidophilus,

and Bifidobacterium spp. In ABT starter cultures, Str.

thermophilus is the main fermenting organism. The

CULTURED BUTTERMILK

first US Federal Standards of Identity for yogurt were

published in 1981. The US standard allows the use

Cultured buttermilk is low-acid fermented milk fer-

of other culture organisms as long as Lb. delbrueckii

mented primarily by mesophilic cultures including

ssp. bulgaricus and Str. thermophilus are used for

Lactococcus lactis ssp. lactis and Lc.

lactis ssp. cremaking yogurt and the titratable acidity, expressed

moris as well diacetyl-producing organisms as shown

as lactic acid, and must be at least 0.9%. The titrat-

in Table 21.2.

able acidity requirement and some other provisions

Lc. lactis ssp. lactis and Lc. lactis ssp. cremoris

of the standard have been stayed and are in limbo for *are acid producers, while Lc. lactis ssp. lactis bio-*

many years. Manufacture of yogurt is discussed in

var diacetylactis and Leuconostoc mesenteroides ssp.

details in Chapter 13.

cremoris produce flavor and aroma compounds such

Recent advances have been supplementation of

as diacetyl. For production of cultured buttermilk, *yogurt starter with probiotic organisms such as Lb.*

pasteurized milk (85◦C for 30 minutes) is fermented

acidophilus and Bifidobacterium spp. to increase the

at 22◦C with starter microorganisms until a titrat-

therapeutic value of the product and use of exo-

able acidity of 0.9% is reached. Incubation at higher

polysaccharide producing starter

cultures to improve

temperatures favors the growth of Lc. lactis ssp. cre-

textural characteristics of yogurt.

moris and Lc. lactis ssp. lactis leading to high acid Bulgarian buttermilk is a high acid product made

product, which limit the aroma production by Lc.

by fermenting pasteurized (85◦C/30 minutes) milk

lactis ssp. lactis biovar diacetylactis and Leu. mesen-with Lb. delbrueckii *ssp. bulgaricus at 42◦C for 10–*

teroides ssp. cremoris. The product has a shelf life of

12 hours. The product is very tart as it contains about

10 days at 5◦C.

***Table 21.2.** Some Fermented Milks and Their Starter Cultures*

Product

Starter Organisms

Butter milk (Bulgarian)

Lactobacillus delbrueckii ssp. bulgaricus

Butter milk (cultured)

Lactococcus lactis ssp . lactis biovar diacetylactis, Leuconostoc mesenteroides ssp. cremoris

Cultured cream

Lc. lactis ssp . lactis, Lc. lactis ssp. cremoris, Lc. lactis ssp . lactis biovar diacetylactis, and Leu. mesenteroides ssp. cremoris

Dahi

Lb. delbrueckii ssp. bulgaricus,

Streptococcus thermophilus or Lc. lactis ssp.

lactis, Lc. lactis ssp. cremoris, Lc. lactis ssp. lactis biovar diacetylactis, and Leu. mesenteroides ssp. cremoris

Filjolk

Lc. lactis ssp. lactis, Lc. lactis ssp. cremoris, Lc. lactis ssp. lactis biovar diacetylactis

Kefir

Lc. lactis ssp. lactis, Lc. lactis ssp . cremoris, Lc. lactis ssp. lactis biovar diacetylactis, and Leu. mesenteroides ssp. dextranicum, Str. thermophilus, *Lb. delbrueckii ssp. bulgaricus, Lb. acidophilus, Lb. helveticus, Lb. kefir, Lb. kefiranofaciens, Kluyveromyces marxianus, Sacchamyces spp.*

Kumys

Lb. acidophilus, Lb. delbrueckii ssp. bulgaricus, Sacchamyces lactis, Torula koumiss

Tatmjolk

Lc. lactis ssp. lactis, Lc. lactis ssp. cremoris, Lc. lactis ssp. lactis biovar diacetylactis

Viilli

Lc. lactis ssp. lactis, Lc. lactis ssp. cremoris, Lc. lactis ssp. lactis biovar diacetylactis, Geotrichum candidum

Yakult

Lb. paracasei ssp. casei

Yogurt

Lb. delbrueckii ssp. bulgaricus, Str. thermophilus

Source: Lee and Wong, 1993.

CULTURED CREAM

teurized or boiled milk, inoculated with dahi as starter

left over from the previous day. Incubation is carried

Cultured cream, also known as sour cream, is low-

out in a warm place usually overnight. The organisms

acid fermented milk with similar flavor as buttermilk.

used as starter cultures are shown in Table 21.2.

The product contains 18% fat. The same starter cul-

The product is claimed to have good nutritional and

ture and incubation temperature are used as cultured

health properties, which make the product very pop-

buttermilk.

ular. Dahi has been used in India since Vedic times.

Lord Krishna (c 5000 bc) had been depicted with eat-

FERMENTED MILKS OF

ing dahi, buttermilk, and ghee. Ayurveda, the tradi-

EASTERN EUROPE

tional Indian medicine, mentions health properties of

dahi including its role in controlling gastrointestinal

Kefir is a refreshing drink of northern slope of

disorders. Dahi is used as a part of daily diet in India

Caucasian mountains of China. Since early times,

and is eaten along with rice and other main meals.

people who lived in the mountains learnt to make

Kumys (also known as kumiss) is traditionally

kefir. Kefir grains are used as starter cultures. Legend

prepared from mare milk and is popular in Eastern

tells that kefir was given to orthodox *people by*

Europe and Asiatic regions. The name kumiss is re-

Prophet Mohammad. Prophet Mohammad kept the

ported to be named after a tribe called Kumanes in the

secret of kefir to himself from the outside world; oth-

Asiatic Steppes. Scythian tribes, which roamed from

erwise the so-called magic strength could be lost.

place to place in South East Asia and Middle Asia,

Kefir was traditionally made in skin bags. Natural

were reported to drink kumiss made from mare's milk

fermentation took place in skin bags under sunlight.

some 2500 years ago (Koroleva, 1988). Kumys has

The finished product contained substantial amount

been mentioned by Marco Polo as

being a pleasant

of lactic acid, alcohol, and carbon dioxide. The sacks

drink. The finished product had high acidity and vary-

were filled with fresh milk and the process repeated

ing amount of alcohol and carbon dioxide. It was

(IDF, 1984; Koroleva, 1988). Russian doctors recom-

consumed as a food as well as weak alcoholic drink.

mended kefir for treatment of intestinal and stomach

Kumys is fermented milk that contains lactic acid

diseases. The first scientific literature about kefir ap-

(0.6–1.0%) and alcohol (0.7–2.5%). The main or-

peared at the end of eighteenth century.

ganisms involved in fermentation are Lb. delbrueckii

Kefir is a product made by fermenting milk with *ssp. bulgaricus and Lb. lactis ssp. lactis and lactose-*

acid and alcohol-fermenting organisms. Kefir grains

fermenting yeasts, e.g., Saccharomyces lactis or

are complex consortium of about 30 species of bac-

Torula spp. Carbon dioxide is produced by the yeast.

teria and yeasts. The microorganisms are embedded

The milk is not heat treated, hence a

high level of

in the matrices made up of polysaccharides. The

starter culture (30%) is used. The incubation is car-

polysaccharide, known as kefiran, is produced by

ried out at 26–28◦C and depending on the fermenta-

Lactobacillus kefiranofaciens. The product contains

tion time the product may contain 0.6% lactic acid

0.9–1.1% lactic acid, 0.3 to 1% alcohol and 1% car-

and 0.2% alcohol, 0.8% lactic acid and 1.5% alcohol,

bon dioxide. The product is very popular in Eastern

or 1.0% lactic acid and 2.5% alcohol.

Europe (IDF, 1984). The microorganisms associated

Yakult is a popular fermented milk in Japan. The

with kefir grains, which are equivalent to starter cul-

product is made with Lb. paracasei ssp. paracasei

tures in other fermented milks, are shown in Table

strain Shirota. The product contains low milk solids

21.2. Incubation is carried out at 18–22∘C for ap-

(3.7%) and high levels of sugar (14%).

proximately 20 hours.

Dadih is a popular fermented milk of Indonesia.

Kumys is another fermented milk of Eastern

The product is equivalent to Indian Dahi and is

Europe. The product is described in the section below.

made by natural fermentation of raw buffalo milk at

28–30◦C. Lb. casei ssp. casei, Leuconostoc mesen-

teroides and Lc. lactis ssp. lactis biovar diacetylactis ***FERMENTED MILKS OF ASIA*** *are usually involved in the fermentation.*

Dahi is a popular fermented milk in India, Africa,

Central Europe, analogous to the western yogurt. In

NORDIC (SCANDINAVIAN)

India, Nepal, and other Asian countries, dahi is still

FERMENTED MILKS

made in every household in villages as well as in *urban areas using traditional method (Prajapati and*

Nordic fermented milks are made from encapsulated

Nair, 2003). The product is typically made from pas-

EPS producing lactococci, primarily L. lactis ssp.

cremoris. The products are characterized by high vis-

Zabady is traditionally made by boiling buffalo

cosity and ropiness and if one lifts the product with a

milk followed by inoculation with previous day's

spoon, long strings will appear. An example of such

product as a starter culture. The product is made in

type of product is "langfil" also known as "tatmjolk,"

uncovered containers and

postprocessing contami-

a popular product in Sweden. Similar fermented milk

nation with yeasts and molds is very common. As a

marketed in Norway is “tettemelk.” Filmjolk is sour

result, the product has a limited shelf life. Organisms

milk popular in Sweden.

commonly found in zabady include Str. thermophilus, *Viili is popular fermented milk of Finland. The*

and Lb. delbrueckii ssp. bulgaricus. However,

product is made primarily with the help of Lc. lac-

Bacillus subtilis, Alcaligenes spp. and Micrococcus

tis ssp. lactis biovar diacetylactis and Leuconostoc

spp. are also found as contaminants.

mesenteroides ssp. cremoris and lactose fermenting

Laban rayeb is an indigenous product of Egypt.

mold Geotrichum candidum. The cream layer is usu-

This product is made in households by milking an-

ally covered with the mold and the product is eaten

imals in earthenware pots and keeping undisturbed

with a spoon. Pasteurized milk is fermented at ap-

until fermented by natural microflora

of milk.

proximately 20◦C until a final acidity of 0.9% is

Laban kad is traditionally made in goatskin bags

reached.

by fermentation with natural flora of milk. The or-

Ymer is Danish fermented milk made from fer-

ganisms isolated from this product include Lc. lactis *mentation of ultrafiltered milk retentate (usually 15%*

ssp. lactis, Leu. mesenteroides ssp. dextranicum, Leu.

solids). The starter cultures used for cultured butter-

mesenteroides ssp. cremoris and Lb. casei.

milk are also used for ymer. Lactofil is a similar prod-

Gariss is an indigenous fermented milk of Sudan.

uct as ymer and is popular in Sweden.

Starter culture

The product is made from camel's milk by natural

used for ymer is similar to cultured buttermilk.

fermentation of milk in leather bags. Lactobacillus

Skyr is produced from skim milk and is popular in

helveticus, Lb. delbrueckii ssp. lactis and yeasts such

Iceland. Lb. delbrueckii ssp. bulgaricus and Lb. casei *as Candida spp. and Kluveromyces spp. are usually*

are used as a starter culture. The product is concen-

involved in fermentation.

trated by separating the whey using a cheese-cloth.

Labneh is a popular product of Lebanon and Syria.

Probiotic fermented milks contain various species

The product is made as full cream zabady (equiva-

of probiotic organisms, particularly Lb. acidophilus,

lent to yogurt) followed by draining of whey using

Bifidobacterium spp. and Lb. casei. Lb. delbrueckii

a cheese-cloth. Laban zeer is a traditional product

ssp. bulgaricus and Str. thermophilus do not survive

of Egypt. Fermented buttermilk (laban kad) obtained

in the gastrointestinal tract. Since

probiotic organ-

from churning of naturally fermented cream is stored

isms grow slowly in milk, the trend is to use Lb.

in earthenware jar (known as "zeer"). The increase

delbrueckii ssp. bulgaricus and Str. thermophilus as

in solids is due to evaporation of moisture through

the primary starter culture and probiotic organisms as *porous pot. Organisms isolated from the product in-*

adjunct organisms. With this approach, the fermenta-

clude Bacillus spp. and Lactobacillus spp. Saccha-

tion time could be short. Some examples of fermented

romyces and yeast is also found.

milks containing probiotics include "Bioghurt,"

Table 21.2 shows the important fermented milks

"Biogarde," and "Bifighurt." These products are

and starter cultures used in production of these prod-

popular in Germany. A similar product popular in

ucts. Table 21.3 shows the origins of some important

Denmark is known as "Cultura." This product con-

fermented milks.

tains Lb. acidophilus and Bifidobacterium bifidum.

HEALTH BENEFITS OF

FERMENTED MILKS FROM THE

FERMENTED MILKS

MIDDLE EAST

Nutritional Value of

Fermented milks in the Middle East are classified

Fermented Milks

based on the total solids content of the product.

Fermented milks with similar solids

content as milk

Health effects are divided into two groups: nutritional

include zabady, laban rayeb, and laban kad. Concen-

function and physiological function. The nutritional

trated fermented milks containing 20–40% solids

attribute is expressed as the function of supplying nu-

include labneh and laban zeer. Dried fermented *trition sufficiently. The physiological function refers*

milks include kishk (Kurmann, and Rasic, 1988).

to prophylactic and therapeutic functions beyond

***Table 21.3.** Origins of Some Important Fermented Milk Products*

Country of

Product

Origin

Period

Characteristics

Airan

Central Asia,

1253–1255 AD

Milk soured by Lb. bulagricus and used

Bulgaria

as refreshing beverages

Bulgarian milk

Bulgaria

500 AD

Very sour milk fermented by Lact.

bulgaricus

Dahi

India

800–300 BC

Milk soured by using previous day soured

milk as starter

Kefir

Caucasusian

–

Milk fermented with kefir grains

China

containing lactobacilli and yeast.
Lactic

acid, alcohol, and CO_2 give sparkling

characteristics

Kishk

Egypt, Arab

Fermented milk mixed with par boiled

world

wheat and dried

Kumys or Kumiss

Central Asia

400 BC

Mare milk is fermented by lactobacilli

Mongol,

and yeast. Lactic acid, alcohol, and

Russia

CO_2 give sparkling characteristics

Laban

Egypt

5000–3000 BC

Soured milk coagulated in earthenware

utensils

Langfil or

Sweden

Milk fermented with slime producing

Tattemjolk

lactococci

Leben

Iraq

3000 BC

Milk soured with yogurt bacteria and

whey is partially drained by hanging

the curd in clothes

Mast

Iran

Natural yogurt with firm consistency and

cooked flavor

Skyr

Iceland

870 AD

Fermented milk made from ewe milk with

the help of rennet and starter

Taette

Norway

–

Viscous fermented milk

Trahana

Greece

–

Fermented milk made by mixing wheat flour followed by drying

Viili

Finland

–

Viscous milk fermented with lactic acid

bacteria and mold

Yakult

Japan

1935 AD

Highly heat-treated milk fermented by L.

casei Shirota strain

Ymer

Denmark

–

Protein fortified milk fermented with

leuconostocs and lactococci

Yogurt or yoghurt

Turkey

800 AD

Custard-like sour fermented milk

Source: Prajapati and Nair, 2003.

nutritional function. Potential nutritional and health *and development. Milk is also a good source of*

benefits of fermented foods are listed in Table 21.4.

micronutrients including calcium, phosphorus, mag-

nesium, and zinc. Milk proteins have high nutri-

tive value due to the favorable balance of essential

Nutritional Function

amino acids (Buttriss, 1997). Milk proteins are defi-

Milk is a complete food for newborn mammals. It

cient only in sulfur-containing amino acids such as

is the sole food during the early stages of rapid de-

cysteine and methionine. Milk also contains antimi-

velopment. Milk contains well-balanced macronutri-

crobial substances, which provide protection against

ents including carbohydrate, fat, and

protein. Milk

infection in neonates. The most important character-

contains approximately 5% lactose, 3% protein, 4%

istics of human milk as compared with cow’s milk are

fat, and 0.7% minerals used for mammalian growth

its low protein, low ash, and high lactose contents.

Table 21.4. *Potential Nutritional and Health Benefits of Fermented Foods*

Beneficial Effect

Possible Causes and Mechanisms

Improved digestibility

Partial breakdown of proteins, fats and carbohydrates

Improved nutritional value

Higher levels of B-vitamins and certain free amino acids, viz.

methionine, lysine and tryptophan

Improved lactose utilization

Reduced lactose in product and further availability of lactase

Antagonistic action toward

Disorders such as diarrhoea, mucous colitis, ulcerated colitis; prevention

enteric pathogens

of adhesion of pathogens

Anticarcinogenic effect

Reduction of carcinogen-promoting

enzymes; inhibitory action toward

cancers of the gastrointestinal tract by degradation of precarcinogens;

stimulation of the immune system

Hypocholesterolemic action

Production of inhibitors of cholesterol synthesis; use of cholesterol by

assimilation and precipitation with deconjugated bile salts

Immune modulation

Enhancement of macrophage formation; stimulation of production of *suppressor cells and □ -interferon*

Source: Gomes and Malcata, 1999.

Nutritionally fermented milks have a similar com-

During fermentation, lactic acid bacteria convert

position to that of the unfermented counterpart from

20–30% of lactose into lactic acid. Consequently, the

which it is made. However, the composition can be *lactose levels in fermented milks can be lower than*

modified by addition of other ingredients such as non-

milk. Fermented milks with lower lactose content

fat dry milk, whey powder, fruit, and sugar. Bacterial

are better tolerated by lactose intolerant individuals.

fermentation results in lowering of lactose and in-

Yogurt in general is supplemented with

2–4% skim

creased level of lactic acid. Fortification with milk

milk powder, so the protein and sugar contents are

solids also results in increased protein and lactose

usually higher than cow's milk. Even after fermen-

contents, although, some lactose is converted to lac-

tation, the product may contain 4–5 g of lactose per *tic acid.*

100 g of the product (Deeth and Tamime, 1981). Nev-

ertheless, yogurts fortified with skim milk powder

and containing higher levels of lactose also appear to

Lactose

be tolerated by lactose malabsorbers (Gurr, 1987).

Lactose is considered as an excellent food for babies *and has a favorable effect in the intestinal tract. Lac-*

Milk Proteins

tose requires longer time for digestion; this provides

a suitable medium for beneficial probiotic bacteria

Milk protein is considered to be of high nutritional

including Lb. acidophilus and bifidobacteria, which

value in terms of its biological value, net protein uti-

in effect dominate the putrefactive bacteria and min-

lization, and protein efficiency ratio. The proteins in

imize the production of gas by them. The beneficial

milk are of excellent quality as caseins and whey

effect of lactose on the absorption of calcium is well

proteins (α-lactalbumin and β-lactoglobulin) contain

established.

high levels of essential amino acids. Protein content

Lactose stimulates gastrointestinal activity. Lac-

of fermented milks such as yogurt is often increased

tose increases the capacity of the body to utilize phos-

due to supplementation with skim milk solids (typi-

phorus and calcium. Polysaccharides such as cellu-

cally, 2–3%). This means that it is an *even more at-*

lose (e.g., carboxy methyl cellulose) are generally

tractive source of protein than its liquid counterpart.

added to yogurt mix as a stabilizer and many of these

The levels of soluble proteins, nonprotein nitrogen

polysaccharides are considered as "bifidus factor"

and free amino acids are higher in yogurt as a result *and may prevent constipation by providing bulk.*

of heat treatment to milk and breakdown of casein

Lactic acid acts as a preservative by reducing pH,

by starter bacteria. Lactic acid bacteria require amino

which inhibits the growth of potentially spoilage and

acids for their growth; they break down milk proteins

harmful bacteria. Lactic acid also

influences physical

due to their proteolytic activity.

properties of casein curd to induce a finer suspension,

Protein in fermented milks is reported to be to-

which appears to promote digestibility.

tally digestible. Fermented milks are more digestible *than milk due to proteolytic activity of starter bacte-*

fat improves consistency and mouthfeel of the prod-

ria resulting in higher levels of peptides and amino

uct. Milk fat has highest value as an energy source

acids (IDF, 1991). Feeding of yogurt resulted in in-

with each gram of fat providing 9 kcal. Milk fat

creased weight gains and increased

feed efficiency in

supplies essential fatty acid including linoleic and

rats compared to that of milk from which it is pre-

linolenic acid and fat-soluble vitamins such as vita-

pared. The substance promoting body weight gain

min A, carotene, vitamin D, E, and K. Choline, a

was found to be of MW ≥ 20,000, possibly related to *constituent of phospholipid, promotes the oxidation*

the cells of Str. thermophilus. Thus, it can be assumed

of lipids in the liver and acts to maintain an equilib-

that yogurt made with Str. thermophilus will have a

rium cholesterol concentration (Deeth and Tamime,

growth promoting effect, possibly due to enhanced

1981). Yogurt is reported to produce

hypocholestero-

bio-availability of minerals, in particular iron. This

laemic effects.

indicates a higher protein value of fermented prod-

ucts compared to unfermented milk. Consumption of

Enhancement in Absorption of Vitamins and

250 g of fermented milks per day can serve an indi-

Minerals.

Milk contains more calcium than other

vidual with the minimum daily requirement of animal

foods. Similarly, absorption of calcium is better from

protein, which is reported to be 15 g (IDF, 1991).

milks than from other forms. The mineral content is

Milk is heat treated (typically 85◦C for 30 min) *hardly altered during fermentation; however, reports*

for making most fermented milks. This results in

suggest that the utilization of Ca, P, and iron in the

soft curd when milk proteins are coagulated by the

body is better for fermented milks than that of milk.

acid produced by yogurt starter bacteria. Milks with

One possible reason could be phospho-

peptides re-

softer curds resulting from such high heat treatment

leased by the hydrolysis of casein that accelerate ab-

show more human milk like characteristics and are

sorption. Animal studies on the amount of calcium

more digestible as a substitute for mother's milk than

in bone and bone weight and strength suggested that *harder curds. Further, the more open nature of the*

lactic acid was involved. These observations suggest

casein aggregates allows the proteolytic enzymes of

that calcium absorption from fermented milk is better

gastrointestinal tract freer access during digestion.

than unfermented counterpart. The utilization of Ca

The soft curd does not give rise to any *feeling of dis-*

and P in the body is known to improve in the pres-

comfort; this is very important in children. The curd

ence of lactose and vitamin D. Calcium is required

formed from milk in the stomach of the young by the

for bone metabolism and prevention of osteoporosis.

action of chymosin and pepsin is less accessible to

Yogurts contain appreciable quantity of sodium and

subsequent enzymatic digestion.

potassium and thus may not be suitable for feeding

The digestibility of milk protein is the highest

babies less than 6 months, unless these minerals are

(> 90%) among proteins. This may be due to decrease

reduced prior to yogurt manufacturing.

in protein particle size and an increase in soluble ni-

Fermented milks are an excellent source of vitamin

trogen, nonprotein nitrogen and free amino acids dur-

B2 and also a good source of vitamin A, vitamins B1,

ing heat processing of milk and proteolysis by starter

B6, B12, and pantothenic acid. The level of fat-soluble

bacteria. In general, yogurt has been

found to be more

vitamins, particularly vitamin A, is dependent on the

digestible than milk.

fat content of the product. Some lactic bacteria are

able to synthesize the B vitamin folic acid (Reddy

et al., 1976). Vitamin content of yogurt in general is

Milk Fat

higher as starter bacteria synthesize

certain B group

Milk fat is highly digestible. Lactic acid in fermented

vitamins during fermentation. Levels of some B vi-

milks has been found to promote peristaltic move-

tamins, particularly vitamin B12, are reduced due

ment, which improves overall digestion and absorp-

to requirement of some lactic acid bacteria for this *tion of food. Traditional yogurt contains 3–4% fat.*

vitamin.

Concentrated yogurt (labneh) or yogurt from sheep

The fortification of fermented milks with vitamins

milk may contain 7–8% fat. The recent trend is to

A and C is possible and losses over 2 weeks in stor-

produce yogurt from skim milk. The overall energy *age are likely to exceed 50%. However, the major-*

(calorie) content of yogurt reflects both the fat content

ity of vitamin C is lost by heat treatment (Bourlioux

of the milk from which it was made and the supple-

and Pochart, 1988). Similarly, vitamin B12 is reported

mentation of ingredients such as cream or sugar. Milk

to be undetectable after storage for 5 days. Low-fat

yogurt is popular in many developed countries; hence

contain substantial quantities of β-D-galactosidase,

fortification with vitamin A should be encouraged.

and it has been suggested that the consumption of *yogurt containing cultures with high levels of lac-*

Alleviation of Lactose Malabsorption.

The aver-

tase may assist in alleviating the symptoms of lac-

age lactose content in yogurt mix is 8.5%, which de-

tose malabsorption. Bacterial enzyme is reported to

creases in yogurt to approximately 5.75% after fer-

auto-digest lactose intracellularly before reaching the

mentation. About 25–30% of lactose is converted to

intestine (Savaiano et al., 1984). Auto-digestion of

lactic acid during fermentation. Lactose content in

lactose intracellularly by bacterial NL-*galactosidase*

other fermented milks varies depending on fortifica-

before reaching the intestine is an

important factor

tion and breakdown of lactose by starter bacteria.

that improves digestibility of lactose. The organisms

Lactose malabsorbers often complain of "gastric

are lysed in the presence of bile salts and the re-

distress" after consuming fresh, unfermented milk

leased lactase causes hydrolysis of ingested lactose.

or milk products. Lactose malabsorption is a condi-

The action of bile increases the cellular permeability

tion in which lactose, the principal carbohydrate of

of yogurt bacteria allowing the release of intracel-

milk, is not completely hydrolyzed into its compo-

lular β-galactosidase activity. Hence, the amount of

nent monosaccharides, glucose, and

galactose. Since

lactose reaching the colon is too small to cause lac-

lactose is cleaved into its constituent monosaccha-

tose malabsorption. Yogurt also has buffering effect

rides with the help of lactase or β-D-galactosidase

and due to this the organisms reach the duodenum

enzyme, lactose malabsorption results from a defi-

and the NL-galactosidase activity is not inactivated. NL-

ciency of this enzyme. Lactase deficiency is a com-

Galactosidase is destroyed in vitro at pH below 3.0,

mon problem in many parts of the world. The preva-

but buffering capacity of yogurt is able to keep the

lence of lactose malabsorption varies depending on

pH above 3.0 (Onwulata et al., 1989).

the ethnic origin of the population. Infants in general

Slower gastric emptying of semisolid fermented

have higher lactase activity than adults. Prevalence of

milk products such as yogurt is another factor respon-

lactose malabsorption is common in China, Thailand,

sible for better absorption of lactose. Delayed gastric

Japan, and Africa and Australian

aborigines, but less

emptying is responsible for hydrolysis of lactose by

common among Caucasians. Temporary deficiency

indigenous β-galactosidase located in the sides and

of β-galactosidase occurs in people suffering from di-

tips of the viili of the jejunum and by bacterial β-

arrhea. The unabsorbed lactose reaches colon, where *galactosidase. Viscous foods such as yogurt or foods*

it is fermented by colonic flora to volatile fatty acids,

with higher solids are reported to delay gastric emp-

lactic acid, CO2, H2, and CH4. The unhydrolyzed

tying and are effective in alleviating lactose intolerant

lactose withdraws water and electrolytes from duo-

symptoms (Shah et al., 1992) As a

result, fermented

denum and jejunum. The lactase deficient people can

milk containing live culture and $^{N}{}_{L}$*-galactosidase is*

suffer from bloat, flatulence, abdominal pain, and di-

better tolerated than unfermented milk. As coagu-

arrhea (Shah, 1993).

lated milk, because of its viscous nature, passes more

Fermented milks, in particular yogurt appears to

slowly through the gut than unfermented milk. Reg-

be well tolerated by lactose malabsorbers and lac-

ular yogurt appears to be more effective than either

tose malabsorbers suffer fewer symptoms with fer-

pasteurized yogurt or buttermilk. Pasteurized yogurt,

mented dairy foods. Reduced levels of

lactose in

in which starter bacteria and enzyme activity are de-

fermented products are due to partial hydrolysis of

stroyed due to heat treatment, is also tolerated well

lactose during fermentation and is partly responsible

due to slower gastric emptying (Shah et al., 1992).

for greater tolerance of yogurt. Factors other than the

Yogurt bacteria hydrolyze lactose into glucose and

presence of yogurt starter are responsible for better

galactose with the help of NL *-galactosidase. Glucose*

tolerance of lactose in lactose maldigesters from fer-

is used directly as a source of energy by the organ-

mented dairy foods. At least three factors appear to

isms. There is often accumulation of

free galactose in

be responsible for better tolerance of lactose from

yogurts. A part of the galactose is converted to glu-

yogurt including (a) yogurt bacteria, (b) lactase en-

cose in the liver. Some of the galactose is used for syn-

zyme or NL*-galactosidase elaborated by these bacte-*

thesis of brain cerebrosides and nerve tissues. Galac-

ria, and most importantly (c) oro-caecal transit time.

tose was reported to cause cataracts of eyes in rats

The traditional cultures used in making yogurt (i.e.,

(Goodenough and Kleyn, 1976). However, the diet in

Lb. delbrueckii ssp. bulgaricus and Str. thermophilus)

rats was composed entirely of yogurt. No such effect *has been reported in humans possibly due to: (i) bet-*

H_2O_2 as an antimicrobial substance. However, it is

ter metabolism of galactose, (ii) lack of the enzyme

believed that lactic acid is the only antimicrobial

responsible for metabolism of galactose in rats, and

agent of any importance. The low pH resulting from *(iii) yogurt is only a small part of the human diet.*

the production of lactic acid during the fermentation

Two types of lactic acid, L (+) and D (−), are pro-

creates an undesirable environment for the growth of

duced during fermentation. Lb. delbrueckii ssp. bul-

spoilage microorganisms (Shah, 2000).

garicus produces only D (−) lactic acid, whereas Str.

Controversies have surrounded the efficacy of

thermophilus produces L (+) lactic acid. D (−) lactic

yogurt as a therapeutic agent. Reports suggest that

acid is not metabolised to pyruvic acid in the body be-

Lb. delbrueckii ssp. bulgaricus do not survive gastric

cause of lack of D2-hydroxy acid dehydrogenase and

(acid) and intestine (bile salt)

conditions. Str. ther-

this results in metabolic acidosis in neonatal infants.

mophilus is susceptible to acidic conditions. How-

The concentration of L (+) will vary with the ratio

ever, Lb. delbrueckii ssp. bulgaricus is acid tolerant.

of Str. thermophilus, and Lb. delbrueckii ssp. bulgar-

Some reports suggest that yogurt bacteria can survive *icus and is usually approximately 50% of the total*

passage through the gastrointestinal tract. However, it

amount as the ratio of the two organisms in the prod-

is agreed that Lb. delbrueckii ssp. bulgaricus is unable

uct is usually 1 : 1. L (+) isomer is easily digested

to implant. Hence, it is unlikely that Lb. delbrueckii

and is completely harmless. Both

isomers are found

ssp. bulgaricus can be used for treating gastrointesti-

to improve the digestibility of the casein and aid in

nal disorders. Nonetheless, yogurt has been used in

retention of calcium in the intestine (Shah, 1999).

treating infantile diarrhea and normalization of gas-

trointestinal flora. The organism is also reported to

PHYSIOLOGICAL EFFECTS

increase the population of Bifidobacterium spp.

Lb. delbrueckii ssp. bulgaricus has been shown to

Many health benefits have been attributed to fer-

produce several bacteriocin including "bulgarican,"

mented milk products as listed in Tables 21.3. A con-

which has shown broad spectrum antibacterial ac-

siderable amount of evidence has been accumulated

tivity. Antimicrobial compounds isolated from skim

for some benefits such as improved lactose tolerance.

milk cultures of Lb. delbrueckii ssp. bulgaricus and

Physiological benefits include antimicrobial activity

Str. thermophilus have shown activity against a range

and gastrointestinal infections,

anticancer effects, re-

of organisms including Salmonella, Shigella, E. coli,

duction in serum cholesterol, and immune system

and Pseudomonas (Dave and Shah, 1997).

stimulation (Holm, 2003).

Fermented milks have shown beneficial effects on

intestinal health. Alleviation of infant diarrhea and *antibiotic associated diarrhea due to consumption of*

Antimicrobial Activity and

fermented milks has been reported (Saavedra et al.,

Gastrointestinal Infections

1994). Consumption of fermented milks has shown

The gastrointestinal tract has a large number of in-

to increase the counts of bifidobacteria and decrease *digenous microflora. There is a balance between use-*

the levels of putrefactive compounds in feces. This is

ful microorganisms and harmful microflora. This bal-

because of enhancement of intestinal immune func-

ance is affected by gastrointestinal illnesses, stress,

tion by lactic acid bacteria in fermented milks and

and use of antibiotics leading to

disturbances of its

antimicrobial substances produced during fermenta-

function. Fermented milks have been used to improve

tion, which have shown improvement in intestinal

intestinal health since ancient times. This includes di-

microflora.

arrhea caused by infection due to pathogenic bacteria.

Fermented foods are reported to improve the compo-

Anticancer Effects

sition and metabolic activity of intestinal microflora.

Starter bacteria used in fermented milks produce

Cancer is one of the main causes of death in western

lactic acid, and bacteriocins as antimicrobial sub-

countries. Epidemiological studies suggest that *stances. These antimicrobial substances are produced*

cancer is caused by environmental factors, partic-

to suppress the multiplication of pathogenic and pu-

ularly diet. The consumption of cooked red meat

trefying bacteria. Lowering of pH due to lactic acid

especially barbequed meat and low consumption of

produced by starter bacteria during

fermentation and

fiber are reported to play a major role. Several factors

in the gut has bactericidal or bacteriostatic effect.

responsible for causes of colorectal cancer including

Many species of lactic acid bacteria also produce

bacteria and metabolic products such as genotoxic

21 Health Benefits of Yogurt and Fermented Milks

337

compounds

(nitrosamine,

heterocyclic

amines,

Antitumor actions of yogurt are claimed to be due

phenolic compounds, and ammonia). Many bacterial

to the stimulation of the immune functions of the *enzymes such as β-glucuronidase generate these*

body, as well as improvement in intestinal microflora

carcinogenic products, except lactic acid bacteria and

population. The anticarcinogenic effect of lactic acid

probiotics, such as Lactobacilli and bifidobacteria.

bacteria is due to the result of removal of sources of

Lactic acid bacteria and fermented

products have

procarcinogens or the enzymes, which lead to their

potential anticarcinogenic activity. An inverse rela-

formation. Short-chain fatty acids produced by lactic

tionship between consumption of fermented dairy

acid bacteria are reported to inhibit the generation

foods and the risk of colorectal cancer has been found.

of carcinogenic products by reducing enzyme activ-

Lactic acid bacteria suppress bacterial enzymes, and

ities. The other mechanism includes improvement in

reduce intestinal pH (Orrhage et al., 1994).

the balance of intestinal microflora, normalized in-

Several studies have shown that fermented dairy

testinal permeability (prevention or

delaying of toxin

products or preparation containing lactic acid bacte-

absorption), and strengthening of intestinal barrier

ria inhibit the growth of tumor cells in experimental

mechanisms.

animals. Animal studies using chemical carcinogen

1, 2-dimethyl hydrazine (DMH) have been carried

Reduction in Serum Cholesterol

out. Rats were given DMH to induce colon cancer

and fed with fermented milks. DMH is activated in

There is a high correlation between dietary satu-

the large intestine by NL*-glucuronidase. Addition of*

rated fat or cholesterol intake and serum cholesterol

Lactobacillus to the diet has been reported to de-

level. Elevated levels of serum cholesterol, partic-

lay tumor formation. The inhibitory effects of fer-

ularly LDL-cholesterol have been linked to an in-

mented milks on colon cancer are either because

creased risk of cardiovascular disease, which is one

of the decrease of mutagenic activity or modifica-

of the main causes of death in

developed countries.

tion of intestinal microflora. Antimutagenic effects of

Cholesterol lowering properties of fermented milks

milk fermented with Lb. delbrueckii ssp. bugaricus

were observed as early as 1960s among Masai tribes

and Str. thermophilus have been reported. Yogurt

of East Africa. Mann and Spoerry (1974) observed a *has been found to reduce the levels of bacterial*

decrease in serum cholesterol levels in men fed large

enzymes, NL-glucuronidase, azoreductase, and ni-

quantities (8.33 L/man/day) of milk fermented with

troreductase. These enzymes are believed to con-

Lactobacillus. Those people had low-blood choles-

tribute to pathogenicity of bowel

cancer as they cat-

terol levels although they consumed a large quantity

alyze conversion of procarcinogens to carcinogens

of meat. Consumption of high quantity of yogurt was

(Lankaputhra and Shah, 1998; Goldin and Gorbach,

found to be responsible for lowering of serum choles-

1977, 1984, Cenci et al., 2002).

terol. Rabbits fed on a high cholesterol diet supple-

Several types of fermented milks including yo-

mented with yogurt showed lower cholesterol levels

gurt, colostrum fermented with Lb. delbrueckii ssp.

as compared to the diet supplemented with nonfer-

bulgaricus, Str. thermophilus, and Lb. acidophilus

mented milk. Cholesterol-lowering

effects of yogurt

or milk fermented with Lb. helveticus are reported

have been reported in human volunteers. The subjects

to suppress cancer cell growth. Studies have shown

consumed 240 mL of yogurt three times per day.

several compounds including supernatants of milk

The role of fermented milks in reducing the *fermented by Lb. delbrueckii ssp. bulgaricus, cells*

serum cholesterol is not completely understood.

of Lb. delbrueckii ssp. bulgaricus, Str. thermophilus,

Cholesterol is an essential component of cell mem-

and Lb. helveticus ssp. jugurti in yogurt, exopolysac-

brane and is required to produce certain hormones

charide in kefir have inhibitory effects *on cancer cell*

and bile acids. It is synthesized by the liver and

growth.

from absorbed foods. The mechanism of control-

Reddy et al. (1973) were the first to report the an-

ling blood cholesterol level is complex. Metabolite

ticancer effect of yogurt in mice. Since then several *of starter cultures in fermented milks is reported*

studies have demonstrated that Lb. delbrueckii ssp.

to produce hydroxymethyl-glutarate, which in-

bulgaricus, and Str. thermophilus strains are able to

hibits hydroxymethylglutaryl-CoA reductase, an en-

slow down the evolution of tumors in mice. Antipro-

zyme required for the synthesis of

cholesterol in

liferative effect of fermented milk on the growth of

the body. This could limit cholesterol synthesis.

human breast cancer line has also been demonstrated.

Calcium, orotic acid, lactose, and casein have been

Only live bacteria appear to have anticancer effect.

suggested as possible hypocholesterolemic factors.

Lactobacillus in fermented milks is reported to

Fermented milks have been reported to inhibit

cause deconjugation of bile acid in the small intestine

infections in mice caused by Klebsiella pneumo-

with consequent fecal excretion of bile acids and a *niae. Mice fed with fermented milks were healthier*

lowering of the body sterol pool (Klaver and Meer,

and lived longer. In a human clinical study, feeding

1993).

yogurt starter bacteria in yogurt increased the serum

Conjugate bile acids are reported to enhance ab-

level of □ -interferon and NK cell count.

sorption of cholesterol. Microorganisms also assimi-

Another potential mechanism of immune system

late or absorb cholesterol. EPS produced by Lc. lactis

stimulation involves the changes in fecal enzymes

ssp. cremoris in fermented milks are reported to in-

such as β-glucuronidase thought to be involved in

terfere with absorption of cholesterol *similar to that*

colon carcinogenesis. Nitrate is metabolized by ni-

with dietary fiber.

trate reductase. Yogurt bacteria are reported to have

Despite several studies, this effect is still not

nitrate reductase activity. Nitrate is an intermediate

considered an established effect and double-blinded *product in the formation of N-nitroso compounds,*

placebo-controlled human clinical trials are needed

which are highly carcinogenic (Goldin and Gorbach,

to substantiate this claim. Similarly, mechanisms in-

1984).

volved in reducing cholesterol level should be clari-

fied. Additional research is needed to substantiate the

HEALTH BENEFITS OF NORDIC

possible hypocholesterolaemic effect of yogurt.

FERMENTED MILKS

Nordic fermented milks are suggested to play im-

Immune System Stimulation

munomodulating role. This is primarily due to anti-

The health benefits of fermented milks are primar-

genic structures of the surface of

lactococci. The pri-

ily because of the ability of starter bacteria to sur-

mary starter culture, Lc. lactis ssp. cremoris in viili

vive in the gastrointestinal tract. Yogurt starter bac-

is reported to stimulate secretion of immunoglobu-

teria are reported to survive in the stomach and are

lins, mainly IgM. Proliferation of T lymphocytes was *also found in feces. The intestinal system defends*

also observed with this strain. This organism has also

the body against bacterial and viral infection and

shown induction of cytotoxicity of peritoneal murine

cancer and allergies. The intestine is body's largest

macrophages against sarcoma cells. Intraperitoneal

immune organ and the intestinal

microflora and the

injection (at a dose of 10 mg/kg) of freeze-dried cell

metabolic activity of intestine is equivalent to that of

preparation was reported to retard the growth of as-

the liver. The intestinal tract works as a peripheral or-

citic and solid sarcomas in mice. This effect has also

gan to protect against intestinal infections and affects *been reported for freeze-dried preparations of langfil*

systemic immunological function. Its function is af-

(at a dose of 50 mg/kg) and ropy yogurt (at a dose of

fected by intestinal microflora. The mechanism for

100 mg/kg). Lc. lactis ssp. cremoris is also reported

immunomodulation is not clearly understood. Lactic

to reduce mutagenic effect of

nitrosated beef extract

acid bacteria (LAB) are likely to, directly or indi-

by 40% as determined by Ames test using Salmonella

rectly (by changing the composition or activity of the

typhimurium. Lc. lactis ssp. cemoris, which is also re-

intestinal microflora), influence the body's immune

ported to lower serum cholesterol in rats. Lactococci *function, but the mechanism is not fully understood.*

isolated from Nordic fermented milks are reported to

LAB can affect function of immune cells and activa-

inhibit common pathogens such as Staphylococcus

tion of macrophages and "natural killer" (NK) cells

aureus and Escherichia coli (Kitazawa et al., 1991)

by LAB have been reported. Yogurt

cultures are re-

ported to produce □ -interferon by T-cells. LAB also

Health Effects of Kefir

stimulate cytokines as represented by TNF- ⎵ (tumor

necrosis factor) and IL-6 and IL-10 (interleukines 6

Kefir is reported to inhibit the growth of pathogenic

or 10). Translocation of small number of ingested *and spoilage microflora including Escherichia coli*

bacteria via M cells to the Peyer's patches of the gut

O-157, Salmonella and Listeria by bacteriocin pro-

associated lymphoid tissue in the small intestine is

duced by LAB isolated from kefir grains. Oral ad-

claimed to be responsible for enhancing immunity.

ministration of water-soluble fraction *of kefir grains*

Ingestion of yogurt has been reported to stimulate

simulated antibody production and reduced tumor

cytokine production in blood cells, and activation of

size in mice. Reduction in lactose-malabsorption re-

macrophages and NK cells has been observed.

lated symptoms is also reported in mini-pigs. The *organisms in kefir grains are reported to assimilate*

Dave R, Shah NP. 1997. Characteristics of bacteriocin

cholesterol (Kitazawa et al., 1991).

produced by L. acidophilus LA-1. Intern. Dairy J.

7:707–715.

Deeth HC, Tamime AY. 1981. Yoghurt:

Nutritive and

Health Benefits of Bio-Yogurt

therapeutic aspects. J. Food Prot. 44(1):78–86.

A number of health benefits are claimed in favor of

Goldin BR, Gorbach SL. 1977. Alterations in faecal

products containing probiotic organisms such as Lb.

microflora enzymes related to diet, age, lactobacillus *acidophilus and Bifidobacterium spp. It is recom-*

supplement and dimethyl hydrazine. Cancer 40:

mended that the probiotic products contain at least

2421–2426.

106 viable cells of Lb. acidophilus and Bifidobac-

Goldin BR, Gorbach SL. 1984. The effect of milk and

terium spp. per gram of product. It is also recom-

Lactobacillus feeding on human intestinal bacterial

mended that the products must be consumed on a reg-

enzyme activity. Amer. J. Clin. Nutr. 39:756–761.

ular basis. The dosage level should be at least 100 g

Gomes AMP, Malcata FX. 1999. Bifidobacterium spp.

and Lactobacillus acidophilus: biological,

so that the level of organisms

consumed would be

biochemical, technological and therapeutical

108 or 109 (Shah, 2000). Health benefits of probiotic

properties relevant for use as probiotics. Trends in

bacteria include antimicrobial properties, improve-

Food Sci. Technol. 10:139–157.

ment in lactose metabolism, antimutagenic proper-

Goodenough ER, Kleyn DH. 1976. Influence of viable

ties, anticarcinogenic properties, reduction in serum

yogurt microflora on digestion of lactose by the rat.

cholesterol, antidiarrhoeal properties, immune sys-

J. Dairy Sci. 59:601.

tem stimulation, improvement in inflammatory bowel

Gurr MI. 1987. Nutritional aspects of fermented milk

disease, and suppression of Helicobacter pylori in-

products. FEMS Microbiology Reviews

fection. There is sufficient evidence to support the

46:337–342.

view that oral administration of Lactobacilli and bi-

Holm F. 2003. Gut health and diet: the benefits of

fidobacteria is able to restore the normal balance of *probiotic and prebiotics on human health. The*

microbial populations in the intestine (Armuzzi et al.,

World of Ingredients. 2:52–55.

2001; Cats et al., 2003).

IDF. 1984. Fermented milks. International Dairy

Federation Bulletin No. 179:16–32.

IDF. 1991. Cultured dairy products in human nutrition.

REFERENCES

Int. Dairy Fed..Bulletin No. 225:1–32.

Armuzzi A, Cremonini F, Bartolozzi F, Canducci F,

Kitazawa H, Toba T, Itoh T, Kumono N, Adachi S,

Candelli M, Ojetti V, Cammarota G, Anti M, De

Yamaguchi T. 1991. Antitumoral activity of

Lorenzo A, Pola P, Gasbarrini G, Gasbarrini A.

slime-forming, ecapsulated Lactococcus lactis

2001. The effect of oral administration of

ssp. cremoris islolated from Scandinavian ropy

Lactobacillus GG on antibiotic-associated

sour milk, 'viili'. Animal Sci. Technol. 62(3):

gastrointestinal side-effects during Helicobacter

277–283.

pylori eradication therapy. Aliment Pharmacol.

Klaver FAM, Meer RVD. 1993. The assumed

Therapy 15(2):163–169.

assimilation of cholesterol by lactobacilli and

Bourlioux P, Pochart P. 1988. Nutritional and health

Bifidobacterium bifidum is due to their bile salt

properties of yogurt. World Reviews of Nutrition

deconjugating activity. Appl. Environ. Microbiol.

and Dietetics 56:217–258.

59:1120–1124.

Buttriss J. 1997. Nutritional properties of fermented

Koroleva NS. 1988. Technology of kefir and kumys.

milk products Int. J. Dairy Technol. 50(1):21–27.

International Dairy Federation Bulletin No. 227,

Cats A, Kulpers EJ, Bosschaert MA, Pot RG, *IDF, pp. 96–100.*

Vandenbroucke-Gauls CM, Kusters JG. 2003. Effect

Kosikowski F, Mistry VV. 1997. Fermented Milk

of frequent consumption of Lactobacillus casei—

Foods—Origins and Principles. Vol. 1. F.V.

containing milk drink in Helicobacter pylori—

Kosikowski-L.L.C., Wesport, CT, USA, pp. 87–108.

colonised subjects. Aliment. Pharmacol. Therapy

Kurmann JA, Rasic JL. 1988. Technology of fermented

17(3):429–35.

special products. Fermented Milks: Science and

Cenci G, Rossi J, Throtta F, Caldini G. 2002. Lactic

Technology, International Dairy Federation Bulletin

acid bacteria isolated from dairy products inhibit *no. 277, IDF, Brussels, pp. 101–109.*

genotoxic effect of 4-nitroquinoline—1 —oxide in

Lankaputhra WEV, Shah NP. 1998. Antimutagenic

SOS-chromotest. Syst. Appl. Microbiol. 25(4):

properties of probiotic bacteria and of organic acids.

483–90.

Mutation Research 397:169–182.

Lee YK, Wong SF. 1993. Stability of lactic acid

Streptococcus thermophilus to infants in hospital for

bacteria in fermented milk. In: S Salminen, von A

prevention of diarrhoea and shedding of rotavirus.

Wright (Eds), Lactic Acid Bacteria Marcel Dekker,

Lancet 344:1046–1049.

New York, pp. 103–114.

Savaiano DA, ElAnouar AA, Smith DJ, Levitt MD.

Mann GV, Spoerry A. 1974. Studies of a surfactant and

1984. Lactose malabsorption from yogurt,

cholesterolemia in the Massai. Amer. J. Clin. Nutr.

pasteurized yogurt, sweet acidophilus milk, and

27:464–469.

cultured milk in lactase-deficient individuals. Amer.

Onwulata CI, Ramkishan Rao D, Vankineni P. 1989.

J. Clin. Nutr. 40:1219.

Relative efficiency of yogurt, sweet acidophilus

Shah NP. 1993. Effectiveness of dairy products in

milk, hydrolysed-lactose milk, and a commercial

alleviation of lactose intolerance. Food Aust.

lactase tablet in alleviating lactose maldigestion.

45:268–271.

Amer. J. Clin. Nutr. 49:1233–1237.

Shah NP. 1999. Probiotic bacteria: Antimicrobial and

Orrhage K, Sillerstrom E, Gustafsson JA, Nord CE,

antimutagenic properties. Probiotica 6:1–3.

Rafter J. 1994. Binding of mutagenic heterocyclic

Shah NP. 2000. Probiotic bacteria: Selective

amines by intestinal and lactic acid bacteria.

enumeration and survival in dairy foods. J. Dairy

Mutation Research 311:239–248.

Sci. 83: 894–907.

Prajapati JB, Nair BM. 2003. History of fermented

Shah NP. 2003. Yogurt: The product and its *foods. Handbook of Fermented Functional Foods.*

manufacture. Encyclopedia of Food Sciences

CRS Press, Boca Raton, New York.

and Nutrition, Academic Press, London, pp.

Reddy GV, Shahani KM, Banerjee MR. 1973. J.

6252–6260.

Natural Cancer Institute. 50:815 (cited in Deeth HC

Shah NP, Fedorak RN, Jelen P. 1992. Food consistency

and AY Tamime, 1981).

effects of quarg in lactose absorption by lactose

Reddy KP, Shahani KM, Kulkarni SM. 1976.

intolerant individuals. Inter. Dairy J. 2:257–269.

B-complex vitamins in culturesd and acidified

Tamime AY, Deeth HC. 1980. Yoghurt: Technology *yogurt. J. Dairy Sci. 59:191.*

and biochemistry. J. Food Prot. 43(2):939–977.

Saavedra JM, Bauman NA, Oung I, Perman JA, Yolken

Tamime AY, Robinson RK. 1999. Yoghurt: Science

RH. 1994. Feeding of Bifidobacterium bifidum and

and Technology, 2nd ed. Cambridge, Woodhead.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

22

Probiotics and Fermented Milks

Nagendra P. Shah

Introduction

casei Shirota, Lactobacillus rhamnosus GG, and Lac-

Taxonomy of Lactic Acid Bacteria

tobacillus reuteri have been developed *in Europe.*

Probiotic Bacteria

However, Lb. acidophilus and Bifidobacterium spp.

Selection Criteria for Probiotics

are most commonly used as probiotics. It is estimated

Genus Lactobacillus

that over 70 products containing Lb. acidophilus and

Genus Bifidobacterium

Bifidobacterium spp. including yogurt, buttermilk,

Health Benefits of Lactobacillus acidophilus and Bifi-

frozen desserts, and milk powder are produced world-

dobacteria

wide. Probiotic organisms are also available as pow-

Antimicrobial Activity and Gastrointestinal Infections

Effectiveness Against Diarrhoea

ders, capsules, and tablets (Mittal and Garg, 1992). A

Improvement in Lactose Metabolism

number of health benefits are claimed in favor of pro-

Antimutagenic Properties

biotic organisms including antimicrobial properties,

Anticarcinogenic Properties

control of gastrointestinal disorders, improvement in

Reduction in Serum Cholesterol

lactose metabolism, anticarcinogenic properties, and

Helicobacter pylori Infection

reduction in serum cholesterol.

Inflammatory Bowel Disease

Immune System Stimulation

Conclusions

TAXONOMY OF LACTIC

References

ACID BACTERIA

Lactic acid bacteria are divided in several genera

INTRODUCTION

based on their ability to ferment specific sugars, tem-

perature for growth, nutrient needs, sensitivity to

Lactic acid bacteria are widely used as starter cul-

salt, and the presence of specific enzymes. Methods

tures in fermentation of milk, vegetables, meats, bev-

for classifying lactic acid bacteria in various gen-

erages, and bakery products. Fermentation with lactic

era, species, or strains have evolved from overall

acid bacteria results in altered composition, improved

morphology of the organisms and growth conditions

flavor, and prolonged shelf life. Lactic acid bacteria

to physiological behavior and

metabolic pathways.

are widespread in nature, and are found primarily

More accurate techniques for the classification of lac-

in the environment with high concentration of car-

tic acid bacteria involve molecular structure and ge-

bohydrates, peptides and amino acids, and vitamins.

netic information such as DNA-DNA and DNA-RNA

Many lactic acid bacteria are normal inhabitants of

homology analyses and sequencing of 16S rRNA

the human body. The use of probiotic organisms such

(Klein et al., 1998; Stiles and Holzapfel, 1997).

as Lactobacillus acidophilus and Bifidobacterium

Lactic acid bacteria can be divided into two gen-

spp. in fermented milks became popular *by the end*

eral categories, according to their metabolic end-

of 1970s as a result of increased knowledge about

products. Homofermentative lactic acid bacteria pro-

these organisms. New fermented products containing

duce lactic acid as their principal end-product,

Lb. acidophilus, Bifidobacterium spp., Lactobacillus *whereas heterofermentative lactic acid bacteria*

341

342

Part IV: Health Benefits

produce acetic acid, CO_2, and ethanol in addition

recently, these organisms are incorporated in drinks

to lactic acid. Mesophilic lactic acid bacteria grow

and marketed as supplements including

tablets, cap-

best at a temperature range of 25–30◦C, whereas

sules, and freeze dried preparations. Today, there are

thermophilic lactic acid bacteria prefer a temperature

over 70 bifidus- and acidophilus-containing products

range of 40–44◦C.

produced worldwide including sour cream, butter-

Lactic acid bacteria are Gram-positive, usually

milk, yogurt, powdered milk, and frozen desserts.

catalase-negative and grow under microaerophilic to

More than 53 different types of milk products that

strictly anaerobic conditions. The most important

contain probiotic organisms are marketed in Japan

genera are: Lactobacillus,

Lactococcus, Enteroco-

alone. The probiotics in Europe are very popular, but

coccus, Streptococcus, Pediococcus, Leuconostoc,

their use is largely restricted to the yogurt sector.

and

Bifidobacterium.

Phylogenetically,

Gram-

A probiotic yogurt may contain Lb. acidophilus

positive bacteria are divided into two major branches.

only or Lb. acidophilus and Bifidobacterium spp.

With the exception of bifidobacteria, all the above-

(known as AB culture) or Lb. acidophilus, Bifidobac-

mentioned genera of lactic acid bacteria have low

terium spp. and Lb. casei (known as

ABC culture)

(<50) %G + C (guanine plus cytosine) content. Nev-

as probiotic organism in addition to the two yogurt

ertheless, Bifidobacterium shares similar physiologi-

starters (Lactobacillus delbrueckii ssp. bulgaricus

cal and biochemical properties as lactic acid bacteria

and Streptococcus thermophilus). The combined use *and some common ecological niches such as the*

of two (e.g., AB culture) or three (e.g., ABC culture)

gastro-intestinal tract. Species of these genera can be

probiotic strains is common in commercial probiotic

found in the gastrointestinal tract of man and animal

foods, as these strains are believed to act synergisti-

as well as in fermented foods. Some

physiological

cally on each other.

characteristics are of interest for their function as pro-

Thus, probiotic yogurts may contain up to five dif-

biotics including survival in the gastrointestinal tract.

ferent groups of bacteria. Unlike yogurt starter bacte-

This is based on their resistance to low pH and bile.

ria, probiotic organisms grow slowly in milk. The fer-

mentation time for making yogurt is approximately

PROBIOTIC BACTERIA

4 hours with yogurt starter bacteria, whereas the fer-

mentation time could be as long as 24 hours with

The word "probiotic" originated from Greek mean-

probiotic bacteria only. Thus the trend is to use yo-

ing “for life”. Probiotics are defined as “live microbial

gurt bacteria as the main starter culture and probiotic

feed supplement, which beneficially affects the host

bacteria as an adjunct starter (Shah, 2000a).

by improving its intestinal microbial balance”. Pro-

biotics have been consumed in foods such as yogurt

for perhaps thousands of years, and

while the “cul-

SELECTION CRITERIA FOR

tures” were thought to have beneficial effects, it was

PROBIOTICS

not until the 1900s that scientists began to investigate

the reasons for those benefits.

There is increasing evidence that probiotics can ben-

A number of genera of bacteria (and yeast) are used *efit the human host by acting as a first line of defence*

as probiotics including Lactobacillus, Streptococcus,

against disease-causing pathogens by improving the

Leuconostoc, Pediococcus, Bifidobacterium, and En-

intestinal microflora.

terococcus; however, the main species believed to

The parameters for screening microorganisms for *have probiotic characteristics are L. acidophilus, Bifi-*

potential valuable probiotic strains should include the

dobacterium spp., and Lb. casei. Members of the gen-

fact that there is a necessity for the strain to be viable

era Lactobacillus and Bifidobacterium have a long

and metabolically active within the gastrointestinal

and safe history in the manufacture of *dairy prod-*

tract. In addition, it is important that viability of the

ucts and are also found as a part of gastrointestinal

organisms and stability of the desirable characteris-

microflora. Probiotic bacteria with desirable proper-

tics of the strain can be maintained during commer-

ties and well-documented clinical effects include Lb.

cial production as well as throughout the shelf life

johnsonii La1, L. rhamnosus GG (ATCC 53103), Lb.

of the product (Gilliland, 2003). To have probiotic

casei Shirota, Lb. acidophilus NCFB 1478, B. ani-

strains with predictable and measurable health bene-

malis Bb12 and Lb. reuteri.

fits, a concerted effort for strain selection is required.

Traditionally, probiotic organisms have been

Common criteria used for selecting probiotic bacteria

added to yogurt and other fermented foods; however,

are shown in Table 22.1.

Table 22.1. *Criteria Used for Selecting Probiotic Bacteria*

Genera of human origin

Nontoxic and nonpathogenic

Resistant to acid, bile, and oxygen

Production of antimicrobial substances and antagonistic toward pathogenic bacteria

Ability to adhere to intestinal mucosa

Colonization potential in the human gastrointestinal tract

Demonstrable efficacy

Immunomodulatory

Able to withstand technological processes and remain viable *throughout the shelf life Viability at high populations, preferably at 106−108*

Source: Adapted from Salminen and Ouwehand, 2003; Gilliland, 2003.

Genus Lactobacillus

In 1909, Moro was the first scientist to isolate fac-

the basis of DNA-DNA homology, six major species

ultative anaerobic rods from the faeces of breast-

have been identified: Lb. acidophilus, *Lb. crispatus,*

fed infants, which he called as Bacillus acidophilus.

Lb. amylovorus, Lb. gallinarum, Lb. gasseri, and Lb.

The name of Lb. acidophilus has been derived from

johnsonii (Gopal, 2003).

"acidus" meaning "acid" and "philus" meaning "lov-

At present, 56 species of the genus Lactobacillus *ing". Lb. acidophilus contains mainly obligately ho-*

have been recognized (Table 22.2).

mofermenters whose major end-product is lactic

Lb. acidophilus is the most commonly suggested

acid, but a few are facultative heterofermenters. They

organism for dietary use. Lb. acidophilus is a Gram-

occur naturally in the gastrointestinal tract of humans *positive rod with rounded ends that occurs as single*

and animals, in the human mouth and vagina, and in

cells, as well as in pairs or in short chains. The typical

some traditional fermented milks, such as kefir. The

size is 0.6–0.9 □m in width and 1.5–6.0 □m in length.

G + C content of their DNA is usually between 32

Lb. acidophilus is nonmotile and

nonspore forming

and 53 mol%. They are either microaerophilic, aero-

organism. Most strains are microaerophilic or aner-

tolerant, or anaerobic and strictly fermentative. Glu-

obic, so the surface growth on solid media is gen-

cose is fermented predominantly to lactic acid in ho-

erally enhanced by anaerobiosis or reduced oxygen *mofermenters, or to equimolar amounts of lactic acid,*

pressure and providing 5–10% CO_2 in anaerobic jars

CO_2 and ethanol in the case of heterofermenters. On

during growth. The organisms require carbohydrates

***Table 22.2.** List of Species (by Alphabetical Order) of the Genera Lactobacillusa Lactobacillus Species*

L. acetotolerans

L. curvatus

L. intestinalis

L. plantaruma

L. acidophilusa

L. delbrueckii

L. jenseniia

L. reuteria

L. alimentarius

L. farciminis

L. johnsonii

L. rhamnosusa

L. amylophilus

L. fermentuma

L. kefir

L. ruminis

L. amylovorus

L. fructivorans

L. kefiranofaciens

L. sake

L. avarius

L. fructosus

L. malefermentans

L. salivarusa

L. bifermentans

L. gallinarum

L. mali

L. sanfrancisco

L. brevisa

L. gasseria

L. minor

L. sharpeae

L. buchneria

L. graminis

L. murinus

L. suebicus

L. casei ssp. caseia

L. halotolerans

L. orisa

L. vaccinostercus

L. collinoides

L. hamsteri

L. parabuchneria

L. vaginalisa

L. confuses

L. helveticus

L. paracaseia

L. viridescens

L. coryniformis

L. hilgardii

L. pentosus

L. crispatusa

L. homohiochii

L. pontis

a Species isolated from human sources

Source: Adapted from Sgorbati et al., 1995; Gomes and Malcata, 1999.

as energy and carbon source as well as nucleotides,

agar can be used as a selective medium in presence *amino acids, and vitamins. Most strains can ferment*

of these organisms. Lb. acidophilus prefers anaero-

cellobiose, fructose, galactose, glucose, lactose, mal-

bic conditions and growth is stimulated in agar un-

tose, mannose, salicin, sucrose, and aesculine. Lb.

der a standard anaerobic environment of 5% oxygen,

acidophilus utilizes sucrose more

effectively than

85% nitrogen, and 10% carbon dioxide. BA-sorbitol

lactose. The glucose moiety is metabolized via the

agar can be used for enumerating L. acidophilus

Embden-Meyerhof-Parnas pathway with lactic acid

from dairy foods containing Lb. delbrueckii ssp.

as essentially the sole end product in homolactics.

bulgaricus, Str. thermophilus, and Bifidobacterium

Supplementation with manganese, oleic acid, esters

spp. For further details on isolation and enumeration

especially Tween 80, are stimulatory or essential for

of Lb. acidophilus, see Dave and Shah (1996) and

most species. Therefore, these compounds are in-

Tharmaraj and Shah (2003).

cluded in MRS medium. Acetaldehyde, a carbonyl

flavoring molecule, also results from metabolism of

Genus BIFIDOBACTERIUM

lactose. Growth of Lb. acidophilus occurs at as high

as 45◦C; however, the optimum growth temperature

Bifidobacteria are normal inhabitants of the human

is between 35◦C and 40◦C. The organisms grow in *gastrointestinal tract. Recent in vivo scientific studies* *slightly acidic media at pH of 6.4–4.5. Growth ceases*

using animals or human volunteers have shown that

when pH of 4.0–3.6 is reached. Acid tolerance of or-

consumption of live bifidobacteria have an effect on

ganisms varies from 0.3% to 1.9% titratable acidity,

the gut microflora. Selected strains survive stomach

with an optimum pH at 5.5–6.0 (Curry

and Crow,

and intestinal transit and reach the colon in abundant

2003; Shah, 1997).

numbers. Newborns are colonized with bifidobacte-

Lb. acidophilus tends to grow slowly in milk, lead-

ria within days after birth and the population appears

ing to the risk of overgrowth of undesirable microor-

to be relatively stable until advanced age, then the

ganisms. Ironically, most strains of Lb. acidophilus

population declines. However, diet, antibiotics, and

do not survive well in fermented milk due to the low

stress are reported to influence the population of bi-

pH, and it is difficult to maintain large numbers in the

fidobacteria in the intestines.

product. Lb. acidophilus grows poorly in milk even

Bifidobacteria were first isolated from feces of

as they show a high level of NL*-galactosidase activity.*

breast fed infants by Tissier in 1899–1900. He de-

This is partly related to low concentration of small

scribed it as rod-shaped, nongas-producing anaero-

peptides and free amino acids in milk, *which would*

bic microorganisms with bifid morphology, which he

be insufficient to support the bacterial growth.

termed Bacillus bifidus. Bifidobacteria are generally

characterized as Gram-positive, nonspore forming,

nonmotile, and catalase-negative anaerobes. They

Isolation and Enumeration

have various shapes including short curved rods,

MRS agar can be used as a nonselective medium for

club-shaped rods, and bifurcated Y-shaped rods. Bi-

isolation of Lb. acidophilus from pure cultures. How-

fidobacteria are anaerobes with a special metabolic

ever, for selection of Lb. acidophilus from a mixed

pathway, which allows them to produce

acetic acid

population of different genera of microorganisms, a

in addition to lactic acid. Acetic acid and lactic acid

selective medium must be employed. MRS medium

are formed primarily in the molar ratio of 3:2. They

supplemented with bile will assist growth of Lb. aci-

are fastidious organisms and have special nutritional *dophilus. MRS agar at pH 5.2 can also be used to sup-*

requirements, thus often these bacteria are difficult

port the growth of Lb. acidophilus. Most media that

to isolate and grow in the laboratory (Shah, 1997;

support the growth of Lb. acidophilus also support the

2002).

growth of Lb. casei and Lb. rhamnosus. Basal agar

The taxonomy of bifidobacteria has changed con-

(BA; 10 g trypton, 10 g Lablemco powder, 5 g yeast

tinuously since they were first isolated. They have

extract, 1 g Tween 80, 2.6 g K_2HPO_4, 5 g sodium

been assigned to the genera Bacillus, Bacteroides,

acetate, 2 g tri-ammonium citrate, 2 g $MgSO_4.7H_2O$,

Nocardia, Lactobacillus, and

Corynebacterium, be-

0.05 g MnSO4.4H2O, 12 g bacteriological agar, and 1

fore being recognized as separate genera in 1974.

liter of distilled water)—sorbitol agar, BA-mannitol

All members of genus Bifidobacterium contain

agar and BA-esculin agar can be used for selective

> 50 mol% G + C, whereas Lactobacilli contain

enumeration of Lb. acidophilus in presence of Lb.

< 50 mol% G + C in DNA. Based on the mol%

casei and Lb. rhamnosus. Similarly, MRS-maltose

G + C contents, all lactic acid producers have been

Table 22.3. *List of Species (by Alphabetical Order) of the Genera Bifidobacteriuma and their mol% G +*

C contents

Bifidobacterium sp.

Mol% G + C

Bifidobacterium sp.

Mol% G + C

B. adolescentisq

58.9

B. indicum

60.0

B. angulatuma

59.0

B. infantisa

60.5

B. animalis

60.0

B. longuma

60.8

B. asteroides

59.0

B. magnum

60.0

B. bifiduma

60.8

B. mericicum

59.0

B. boum

60.0

B. minimum

61.6

B. brevea

58.4

B. pseudocatenulatuma

57.5

B. catenulatuma

54.0

B. pseudolongum

59.5

B. choerinum

66.3

B. pullorum

67.5

B. coryneformes

–

B. ruminatium

57.0

B. cuniculi

64.1

B. saeculare

63.0

B. dentiuma

61.2

B. subtile

61.5

B. gallicum

61.0

B. suis

62.0

B. gallinarum

65.7

B. thermophilum

60.0

B. globosuma

63.8

a Species isolated from human species

Source: Adapted from Sgorbati et al., 1995; Gomes & Malcata, 1999.

allocated into two divisions: Clostridium and Acti-

or below or at pH 8.0–8.5. Optimum growth occurs

nomycetes. The Actinomycetaceae family consists *at a temperature of 37–41◦C, maximum growth is*

of five genera: Bifidobacterium, Propionibacterium,

at 43–45◦C, while minimum growth temperature is

Microbacterium, Corynebacterium, and Brevibac-

25–28◦C.

terium. Presently, there are 29 species in the genus Bi-

The main probiotic organisms that are currently *fidobacterium (Table 22.3), 14 of which are isolated*

used worldwide belong to the genera Lactobacillus

from human sources (i.e., dental caries, faeces, and

and Bifidobacterium and are shown in Tables 22.4 and

vagina), 12 from animal intestinal tracts or rumen,

22.5, whereas the leading commercial probiotic lac-

and three from honeybees.

Bifidobacterium species

tobacilli and bifidobacteria are shown in Table 22.6.

found in humans are: B. adolescentis, B. angulatum,

Strains with peer reviewed published evidence

B. bifidum, B. breve, B. catenulatum, B. dentium,

from human clinical trials are shown in Table 22. 7.

B. infantis, B. longum, and B. pseudocatenulatum.

A limited number of investigations have also been

B. breve, B. infantis, and B. longum are found in hu-

carried out into the potential properties of genera in-

man infants. B. adolescentis, and B. longum are found

cluding Pediococcus, Leuconostocs, and Propioni-

in human adults (Shah and Lankaputhra, 2002).

bacterium and Enterococcus faecium.

E. faecium is

Bifidobacteria are saccharolytic organisms and

more pH stable than L. acidophilus and produces bac-

produce acetic acid and lactic acid without generation

teriocins against some enteropathogens. These prop-

of CO2. All bifidobacteria from human origin are able

erties make this organism attractive as a probiotic.

to utilize glucose as well as galactose, lactose and,

It is obvious from published reviews that four

usually, fructose as carbon sources. Bifidobacterium

strains with the most published clinical data are Lb.

spp. are also able to ferment complex carbohydrates.

rhamnosus GG, Lb. casei Shirota, B. animalis Bb-12,

The substrates fermented by the largest *number of*

and Saccharomyces cerevisiae Boulardii.

species are: D-galactosamine, D-glucosamine, amy-

lose and amylopectin. Fructose-6-phosphate phos-

Isolation and Enumeration

phoketolase is the characteristic key enzyme, which

is the most direct and reliable test for assigning an

Bifidobacteria are fastidious organisms. MRS agar

organism to the genus Bifidobacterium.

can be used as a nonselective medium for isola-

The optimum pH for the growth of bifidobacteria

tion of Bifidobacterium spp. MRS-NNLP (nalidixic

is 6.0–7.0, with virtually no growth at pH 4.5–5.0

acid, neomycin sulfate, lithium chloride, and

Table 22.4. *Lactobacilli Used as Probiotic Cultures*

Species	*Strains*
L. acidophilus	*LA-1/LA-5 (Chr. Hansen)*
L. acidophilus	

NCFM

(Rhodia)

L. acidophilus Johsonii

La1

(Nestle)

L. acidophilus

DDS-1

(Nebraska Cultures)

L. acidophilus

SBT-2062

(Snow Brand Milk Products)

L. bulgaricus

Lb12

L. lactis

L1A

(Essum AB)

L. casei Immunitas

(Danone)

L. plantarum

299v, Lp01

L. rhamnosus

GG

(Valio)

L. rhamnosus

GR-1

(Urex Biotech)

L. rhamnosus

LB21

(Essum AB)

L. reuteri

SD2112/MM2)

(Biogaia)

L. rhamnosus

271

(Probi AB)

L. plantarum

(Probi AB)

L. reuteri (also known as MM2)

SD2112

L. casei

Shirota

(Yakult)

L. paracasei

CRL 431

(Chr. Hansen)

L. fermentum

RC-14

(Urex Biotech)

L. helveticus

B02

Source: Adapted from Krishnakumar and Gordon, 2001; Holm, 2003.

paramomycin sulfate) agar is selective medium for

vides essential nutrient and lowers redox-potential.

counting bifidobacteria. Bifidobacteria can be selec-

Incubation conditions are anaerobic environment at

tively enumerated from dairy foods containing Lb.

37∘C for 72 hours. When L-cysteine is

not present in

delbrueckii ssp. bulgaricus, Str. Thermophilus, and

the media, bifidobacteria either do not grow or form

Lb. acidophilus using MRS-NNLP agar. Cysteine

pin-point colonies. Bifidobacteria do not grow under

(0.05%) must be added to the medium. Cysteine pro-

aerobic conditions. For further details on isolation

Table 22.5. *Bifidobacteria Cultures Used as Probiotic Cultures*

Species

Strains

B. adolescentis

B. longum

BB536

(Morinaga Milk Industry)

B. longum

SBT-2928

Snow Brand Milk Products)

B. breve

Yakult

B. bifidus

Bb-11

B. lactis (reclassified as B. animalis)

Bb-12

(Chr. Hansen)

B. essensis

Danone

(Bioactivia)

B. lactis

Bb-02

B. infantis

Shirota

B. infantis

Immunitas

(Danone)

B. infantis

744

B. infantis

01

B. laterosporus

CRL 431

B. lactis

LaftiTM, B94

(DSM)

B. longum

UCC 35624

(UCCork)

B. lactis

DR10/HOWARU

Danisco

Source: Adapted from Krishnakumar and Gordon, 2001; Holm, 2003; Playne et al., 2003.

Table 22.6. *Leading Commercial Probiotic Lactobacilli and Bifidobacteria.*

Lactobacillus

Strain

Manufacturer

L. acidophilus

La-5

(Chr. Hansen, Denmark)

L. acidophilus

NCFM

(Rhodia, USA)

L. casei

Shirota

(Yakult, Japan)

L. acidophilus

Johsonii La1

(Nestle, Switzerland)

L. plantarum

299v

(Probi, Sweden)

L. reuteri

MM2

(Biogaia, Sweden and USA)

L. rhamnosus

GG

(Valio, Finland)

Bifidobacterium

B. lactis (reclassified as

Bb-12

(Chr. Hansen, Denmark)

B. animalis)

B. longum

BB536

(Morinaga Milk Industry, Japan)

B. longum

SBT-2928

(Snow Brand Milk Products, Japan)

B. breve

(Yakult, Japan)

B. lactis LaftiTM,

B94

(DSM, Australia)

B. longum

UCC 35624

(UCCork, Ireland)

B. lactis

DR10/HOWARU

(Danisco, Denmark)

Source: Adapted from Krishnakumar and Gordon, 2001; Holm, 2003; Playne et al., 2003.

and enumeration of bifidobacteria, see Dave and Shah

benefits, not even strains of the same species. Not all

(1996) and Tharmaraj and Shah (2003).

strains of the same species will be effective against

defined health conditions. The strains Lb. rhamnosus

GG (Valio), Sacch. cerevisiae Boulardii (Biocodex),

Health Benefits of LACTOBACILLUS

Lb. casei Shirota (Yakult), and B. animalis Bb-12

ACIDOPHILUS and Bifidobacteria

(Chr. Hansen) have the strongest

human health

A number of health benefits are claimed in favor

efficacy data against management of lactose malab-

of products containing probiotic organisms. Some

sorption, rotaviral diarrhoea, antibiotic-associated di-

of the health benefits are well established, while

arrhoea, and Clostridium difficile diarrhoea (Playne *other benefits have shown promising results in animal*

et al., 2003) (Table 22.8).

models. However, additional studies are required in

Health benefits of probiotic bacteria include an-

humans to substantiate these claims. Health bene-

timicrobial activity and gastrointestinal infections,

fits imparted by probiotic bacteria are strain specific, *improvement in lactose metabolism, antimutagenic*

and not species- or genus-specific. It is important to

properties, anticarcinogenic properties, reduction in

understand that no strain will provide all proposed

serum cholesterol, antidiarrhoeal properties, immune

***Table 22.7.** Strains with Peer Review Published Evidence from Human Clinical Trials.*

Lactobacillus rhamnosus

GG

(Valio)

Lactobacillus casei

Shirota

(Yakult)

Lactobacillus acidophilus

NCFM

(Rhodia)

Lactobacillus plantarum

299v

(ProViva)

Lactobacillus reuteri

(Biogaia)

Lactobacillus acidophilus

Johnsonii La1

(Nestle)

Lactobacillus acidophilus

La5

(Chr. Hansen)

Bifidobacterium animalis

Bb 12

(Chr. Hansen)

Bifidobacterium longum

BB536

(Morinaga)

Bifidobacterium breve

(Yakult)

Enterococcus faecium

SF68

(Cemelle)

Saccharaomyces cerevisiae

Boulardii

(Biocodex)

Source: Adapted from Krishnakumar and Gordon, 2001; Holm, 2003; Playne et al., 2003.

Table 22.8. *Reported Studies and Proven Effects of Some Currently Available Probiotics Strains*

Reported Effects in Clinical Studies

Scientifically Established Effects

L. johnsonii LJ1

Adherence to human intestinal cells,

Mucosal adherence, immune enhancement

balances intestinal flora

L. acidophilus

Lowering of fecal enzyme activity,

Alleviation of lactose malabsorption

NCFM

improvement in lactose absorption,

production of bacteriocin

L. rhamnosus GG

Prevention of antibiotic associated

Management of Clostridium difficile

diarrhea and rotavirus diarrhea,

diarrhea, prevention of acute diarrhea,

Shortening of duration of rotavirus

prevention of antibiotic diarrhea,

reduction

in fecal enzyme associated diarrhea

L. casei Shirota

Prevention of intestinal disturbance;

balancing intestinal flora; lowering

of fecal enzyme activity

B. animalis Bb12

Treatment of rotavirus diarrhea;

Shortening of duration of rotavirus

balancing intestinal flora

L. reuteri

Colonizing the intestinal tract in

Shortening of duration of rotavirus

animal studies Shortening of

duration of rotavirus diarrhoea,

immune enhancement

S. cerevisiae

Prevention of antibiotic associated

Prevention of antibiotic associated

(boulardii)

diarrhoea; treatment of C. difficile

diarrhoea

colitis

E. faecium (Gaio)

Reduction in cholesterol

Reduction in cholesterol

Source: Adapted from Fonden et al., 2000; Salminen and Ouwehand, 2003; Plyne et al., 2003.

system stimulation, improvement in inflammatory *ward enteropathogenic Escherichia coli, Salmonella*

bowel disease, and suppression of Helicobacter py-

typhimurium, Staphylococcus aureus, and Clostrid-

lori infection (Kurmann and Rasic, 1991). There

ium perfringens. Lb. acidophilus produces various

is sufficient evidence to support the view that oral

bacteriocins and antibacterial

substances such as Lac-

administration of Lactobacilli and bifidobacteria

tocidin, Acidolin, Acidophilin, Lactacium-B, and in-

is able to restore the normal balance of micro-

hibitory protein (known as bacteriocin-like inhibitory

bial populations in the intestine (Ouwehand et al.,

substances; BLIS). Similarly, Bifidobacterium pro-

1999).

duces Bifidolin and Bifilong, which inhibit several

pathogenic bacteria. Hydrogen peroxide produced

by Lb. acidophilus is inhibitory to many pathogens.

Antimicrobial Activity and

Preparations containing Enterococcus faecium have

Gastrointestinal Infections

been used for treatment of acute

enteritis and other

Probiotic bacteria produce lactic acid and acetic acid,

gut disorders. Ent. faecium is found in the feces of

hydrogen peroxide, and bacteriocins as antimicrobial

healthy adults.

substances. The antimicrobial substances are pro-

Two types of lactic acid, L(+) and D(−), are pro-

duced to suppress the multiplication of pathogenic

duced during fermentation by lactic acid bacteria.

and putrefying bacteria. Lactic acid and acetic acid

Some species of bacteria including Lb. delbrueckii

are the main organic acid produced. Other acids pro-

ssp. bulgaricus and Lactococcus lactis produce only

duced in small quantities include citric *acid, hippuric*

D(−) lactic acid, whereas some lactic streptococci

acid, orotic acid, and uric acid. Lactic and acetic

and Lb. casei produce L(+) lactic acid. Lb. helveti-

acids account for over 90% of the acids produced.

cus and Lb. acidophilus produce a racemic mixture

Lowering of pH due to lactic acid or acetic acid *of L(+) and D(−) lactic acid. D(−) lactic acid is*

produced by these bacteria in the gut has a bacte-

not metabolised to pyruvic acid in the body due to

riocidal or bacteriostatic effect. Both bifidobacteria

a lack of D2-hydroxy acid dehydrogenase and this

and Lb. acidophilus show antagonistic effects to-

results in acidosis in neonatal infants.

L(+) isomer

is completely harmless. Bifidobacteria and Lb. ca-

Lb. rhamnosus GG has been reported to be more ef-

sei produce L(+) lactic acid. Thus the lactic acid

fective in the treatment of rotavirus diarrhea as com-

produced by bifidobacteria and Lb.

casei is easily

pared with preparations containing Str. thermophilus

metabolised, while providing antimicrobial proper-

and Lb. delbrueckii ssp. bulgaricus. Lb. reuteri has

ties (Shah, 1999).

also been effective in shortening the duration of

rotavirus diarrhea. It reduces the duration of diarrhea *in children suffering from rotavirus diarrhea. Treat-*

ment with Lactobacillus GG was associated with en-

Effectiveness Against Diarrhoea

hancement of IgA- specific antibody-secreting cells

One of the main applications of probiotics has been

to rotavirus and serum IgA antibody level.

treatment and prevention of diarrhoea. A major prob-

The mechanisms by which fermented dairy foods

lem associated with antibiotic treatment is appear-

containing probiotics or culture containing milks re-

ance of diarrhoea, often caused by Clostridium dif-

duce the duration of diarrhea are unclear. One possi-

ficile. This organism is found in small numbers in

ble mechanism is that probiotic

bacteria may prevent

the healthy intestine; however, disruption of indige-

the growth of pathogens by competing for the attach-

nous microflora due to antibiotic treatment leads to

ment sites by producing specific binding inhibitor or

an increase in their number and toxin production,

by production of antimicrobial substances. Probiotic *which causes symptoms of diarrhoea. Treatment with*

bacteria can also potentiate the immune response to

metonidazole or vancomycin is usually effective but

intestinal pathogens.

recurrences are common. Administration of exoge-

There is also strong evidence that probiotic strains

nous probiotic is required to restore the balance of *can prevent traveller's diarrhea (Hilton et al., 1997).*

flora. Probiotics have proved to be useful as a prophy-

Traveller's diarrhea is caused by bacteria, particularly

lactic regimen with antibiotic-associated diarrhea, as

enterotoxigenic E. coli. Several studies have been

well as for treatment after onset of antibiotic induced

carried out to assess the effects of

probiotic prepa-

diarrhea. A daily dose of Lactobacillus GG has been

rations as prophylaxis for traveller's diarrhea; how-

found to be effective in termination of diarrhea. Stud-

ever, the results have been conflicting. In one study,

ies with a yeast preparation containing Sacch. cere-

Danish tourists on a 2-week trip to Egypt, were given *visiae Boulardii has also been effective in treatment*

a mixture of live freeze-dried preparation of Lb. aci-

of Clost. difficile related colitis.

dophilus, B. animalis, Lb. delbrueckii ssp. bulgari-

Rotavirus is one of the most common causes of

cus and Str. thermophilus at a daily dose of 109 cfu.

acute diarrhea in children worldwide. During diar-

The administration of probiotic preparation reduced

rheal stage of infection, the permeability of gut ep-

the frequency of diarrhea. A similar study conducted

ithelial cells is increased to intact proteins. Probiotics

with Finnish tourists using lyophilized preparation

are claimed to shorten duration of rotavirus diarrhea

of Lactobacillus GG has shown to

reduce the occur-

in children (Saavedra et al., 1994). The strongest

rence of traveler's diarrhea.

evidence of a beneficial effect of defined strains of

Yogurt containing B. longum was found to be effec-

probiotics has been established using Lb. rhamno-

tive in reducing the course of erythromycin induced *sus GG and B. lactis Bb-12 (now reclassified as B.*

diarrhea. Antibiotic treatment disturbs the balance of

animalis Bb-12) for prevention and treatment of di-

gastrointestinal flora leading to diarrhea. Fecal counts

arrhea and acute diarrhea in children mainly caused

of Lactobacillus GG indicated that the organisms col-

by rotaviruses. Selected probiotic

strains are also ef-

onized the intestine despite erythromycin treatment.

fective against antibiotic-associated diarrhea. Certain

Probiotic reparations containing 4 × 109 B. animalis

probiotic strains can inhibit the growth and adhe-

Bb-12 and Lb. acidophilus La-5 has shown similar

sion of a range of enteropathogens. Studies have *results when volunteers received ampicillin along*

indicated beneficial effects against pathogens such

with probiotic preparation. Recolonization with bi-

as Salmonella enteriditis and Salm. typhimurium. B.

fidobacteria as shown by an increase in their counts

longum SBT-2828 has shown inhibition of entero-

is reported with treatment with Lb.

acidophilus La-

toxigenic Escherichia coli. Mix of pediatric bev-

5 and B. animalis Bb-12. A lower degree of colo-

erage containing B. animalis, Lb. acidophilus, and

nization by Clost. difficile was also observed. Several

Lb. reuteri has been found to be useful in the pre-

studies have shown reduction in diarrhea in subjects *vention of rotavirus diarrhoea (Guandalini et al.,*

taking Sacch. cerevisiae Boulardii during the period

2000).

of antibiotic treatment.

Improvement in Lactose Metabolism

NL-galactosidase located in the sides and tips of the vi-

ili of the jejunum. Regular yogurt appears to be more

Relief of lactose maldigestion symptoms by probi-

effective than either pasteurized yogurt or buttermilk.

otics is probably the most widely accepted health

Pasteurized yogurt is also tolerated well due to slower

benefits of probiotic organisms. Lactose malabsorp-

gastric emptying as the enzyme activity *and starter*

tion is a condition in which lactose, the principal

bacteria are destroyed due to heat treatment (Shah

carbohydrate of milk, is not completely hydrolysed

et al., 1992).

into its component monosaccharides, glucose and

McDonough et al. (1987) reported that the pres-

galactose. Since lactose is cleaved into its constituent

ence of bacterial-derived NL*-galactosidase in yogurt*

monosaccharides by the enzyme NL*-D-galactosidase,*

contributes to the in vivo degradation of lactose. Sig-

lactose malabsorption results from a deficiency of

nificantly lower breath hydrogen levels were reported

this enzyme. Lactose malabsorbers

often complain of

to produce following consumption of yogurt com-

"gastric distress" after consuming fresh, unfermented

pared with milk or heated yogurt (Savaiano et al.,

milk or milk products due to the formation of hydro-

1984). A French group confirmed that viable cul-

gen gas by microbial action on undigested lactose *tures reached the duodenum and contained active -*

in the gut. The prevalence of lactose malabsorption

galactosidase. The group confirmed the role of slow

varies depending on the ethnic origin of the popu-

gastric emptying of semisolid milk foods in digestion

lation. It is common in China, Thailand, Japan, and

of lactose in milk (Vesa et al., 1996).

African and Australian aborigines, but less common

Although, there are limited studies conducted on

among Caucasians. Temporary deficiency of NL *-D-*

the efficacy of bifidus products in management of lac-

galactosidase occurs in people suffering from diar-

tose malabsorption, the effects of acidophilus milk in

rhea (Shah, 1993; Shah et al., 1992).

alleviation of lactose malabsorption have been thor-

The traditional cultures used in making yogurt (i.e.,

oughly researched (Gilliland, 1989; 1991).

Lb. delbrueckii ssp. bulgaricus and Str. thermophilus)

contain substantial quantities of NL *-D-galactosidase*

Antimutagenic Properties

as compared with probiotic organisms, and the con-

sumption of yogurt has been found to assist in allevi-

Antimutagenic effect of fermented milks has

ating the symptoms of lactose malabsorption (Shah,

been detected against a range of mutagens and

2000b). β-D-galactosidase is affected by bile. Be-

promutagens including 4-nitroquinoline-N’-oxide,

cause bifidobacteria are resistant to

bile, they may

2-nitrofluorene, and benzopyrene in various test

have a better chance of colonizing the gut and deliv-

systems based on microbial and mammalian cells.

ering this enzyme to its site of action over an extended

However, antimutagenic effect might depend on an

period of time.

interaction between milk components and the lac-

There is convincing evidence that lactose malab-

tic acid bacteria. The mechanism of antimutagenic-

sorbers suffer fewer symptoms with fermented dairy

ity of probiotic bacteria has not been clearly under-

products. Yogurt or probiotic yogurt is tolerated well

stood. It has been suggested that

microbial binding

by lactose malabsorbers. Factors other than the pres-

of mutagens to the cell surface could be a possi-

ence of yogurt starter or probiotic bacteria are re-

ble mechanism of antimutagenicity (Orrhage et al.,

sponsible for better tolerance of lactose in lactose

1994). Probiotic strains have been associated with a *maldigesters from fermented dairy foods. Reduced*

reduction in fecal enzymatic activities. A decrease

levels of lactose in fermented products due to partial

in fecal and urinary mutagenicity as a result of con-

hydrolysis of lactose during fermentation is partly

sumption of Lb. acidophilus NCFB 1748 has been re-

responsible for greater tolerance of

yogurt. Auto-

ported. Lactococcus spp. was ineffective. Similarly,

digestion of lactose intracellularly by bacterial NL*-D-*

reduction in fecal enzymatic activities including NL*-*

galactosidase before reaching the intestine is an im-

glucuronidase, azoreductase, and nitroreductase in-

portant factor that improves digestibility of lactose *volved in mutagens activation with strains of probi-*

(Onwulata et al., 1989). Slower gastric emptying of

otics has been reported (Goldin and Gorbach, 1977;

semisolid milk products such as yogurt is another

1984).

factor responsible for better absorption of lactose.

Lankaputhra and Shah (1998) studied the an-

Because of slower gastric emptying, small quantity

timutagenic activity of organic acids produced

of lactose is reached in the jejunum at a time and there

by probiotic bacteria against eight mutagens

is more effective hydrolysis of lactose by indigenous

and promutagens including 2-nitroflourene (NF), *Aflatoxin-B (AFTB), and 2-amino-3-methyl-3H-*

cinogens and consequently decrease the risk of tu-

imidazoquinoline (AMIQ). AFTB is a diet-related

mor development. Several studies have shown that

potent mutagen produced by a fungal strain of As-

preparation containing lactic acid bacteria inhibit *pergillus flavus, which is a major food contaminant*

the growth of tumor cells in experimental animals

species prevalent in most Asian countries. AMIQ is a

or indirectly lower carcinogenicity by decreasing

heterocyclic amine mutagen. This is a major mutagen

bacterial enzymes that activate carcinogenesis (Yoon

formed in heat-processed beef in

Western diets. The

et al., 2000). Animal studies using chemical car-

TA-100 mutant of Salmonella typhimurium (His−)

cinogen 1,2-dimethyl hydrazine (DMH) have been

strain is used as a mutagenicity indicator organism.

carried out. DMH is activated in the large intestine

The mutagenicity test is carried out using the Ames *by β-glucuronidase. Addition of Lactobacillus to the*

Salmonella test. Among the organic acids, butyric

diet has been reported to delay tumor formation. In

acid showed a broad-spectrum antimutagenic activ-

human studies indirect evidence of potential benefits

ity against all mutagens or promutagens studied. Live

of probiotics have been obtained by

monitoring muta-

bacterial cells showed higher antimutagenicity than

genic activity of human intestinal contents and feces.

killed cells against the mutagens studied. This sug-

Lb. acidophilus 1748 and Lb. casei are reported to

gests that live bacterial cells are likely to metabolise

decrease mutagenic activity in feces caused by fried *mutagens. Inhibition of mutagens and promutagens*

beef (Lidbeck et al., 1991).

by probiotic bacteria appeared to be permanent for

Short chain fatty acids produced by Lb. aci-

live cells and temporary for killed cells. Killed cells

dophilus and bifidobacteria are reported to inhibit

released mutagens and promutagens when extracted *the generation of carcinogenic products by reduc-*

with dimethyl-sulfoxide suggesting binding of mu-

ing enzyme activities. When incubated in vitro with

tagens to bacterial cells. The results emphasized the

4-nitroquinoline-1-oxide (4NQO), some probiotic

importance of consuming live probiotic bacteria and

strains inhibited the genotoxic activity *of 4NQO. Lb.*

of maintaining their viability in the intestine to pro-

casei was most effective, followed by Lb. plantarum

vide efficient inhibition of mutagens.

and Lb. rhamnosus. Some strains of Lb. acidophilus

and Lb. delbrueckii ssp. bulgaricus were not as effec-

tive (Cenci et al., 2002).

Anticarcinogenic Properties

The anticarcinogenic effect of probiotic bacteria

There are several factors responsible for causes of

is reported to be due to the result of removal of

colorectal cancer including bacteria and metabolic

sources of procarcinogens or the enzymes, which

products such as genotoxic compounds (nitrosamine,

lead to their formation. The proposed

mechanisms

heterocyclic amines, phenolic compounds, and am-

include improvement in the balance of intestinal mi-

monia). The consumption of cooked red meat espe-

croflora, normalized intestinal permeability (lead-

cially barbequed meat and low consumption of fiber

ing to prevention or delaying of toxin absorption), *are reported to play a major role in causing colorec-*

and strengthening of intestinal barrier mechanisms.

tal cancer. The colonic flora has been shown to be in-

Mechanism of anticarcinogenicity also involves ac-

volved in colonic carcinogenesis. This effect is medi-

tivation of nonspecific cellular factors such as

ated by microbial enzymes such as NL -

glucuronidase,

macrophages and natural killer cells via regulation

azoreductase, and nitroreductase, which convert pro-

of □ -interferon production. Orally administered bi-

carcinogens into carcinogens. Lactic acid bacteria

fidobacteria are also reported to play a role in the

and fermented products have potential anticarcino-

increasing of production of IgA antibodies and func-

genic activity and an inverse relationship between

tions of Peyer's patch cells (Singh et al., 1997).

consumption of fermented dairy foods and the risk

of colorectal cancer has been found. Lactic acid

Reduction in Serum Cholesterol

bacteria suppress bacterial enzymes such as beta-

glucuronidase, azoreductase, and nitroreductase, and

There is a high correlation between dietary saturated

reduce intestinal pH.

fat or cholesterol intake and serum cholesterol level.

Experiments carried out in animal models showed

The level of serum cholesterol is a major factor for

that certain strains of Lb. acidophilus and Bifidobc-

coronary heart diseases. Elevated levels of serum

terium spp. are able to decrease the levels of en-

cholesterol, particularly LDL-cholesterol have been

zymes such as $^{N}{}_{L}$-glucuronidase, azoreductase, and

linked to an increased risk for cardiovascular disease.

nitroreductase responsible for activation of procar-

Feeding of fermented milks containing

very large

numbers of probiotic bacteria (~109 bacteria/g) to

consumed fermented products containing probiotics,

hypercholesterolemic human subjects has resulted in

compared to 33% of the control group (Cats et al.,

lowering cholesterol from 3.0 to 1.5

g/liter. The role

2003).

of probiotic bacteria in reducing the serum choles-

terol is not completely understood. Mann and Spoerry

Inflammatory Bowel Disease

(1974) observed a decrease in serum cholesterol lev-

els in men fed large quantities (8.33 liter/man/day)

Inflammatory bowel disease (ulcerative *colitis and*

of milk fermented with Lactobacillus, possibly be-

Crohn’s disease) is related to the intestinal microflora.

cause of the production of hydroxymethyl-glutarate

Inflammatory bowel disease affects up to 2 million

by probiotic bacteria, which is reported to inhibit

people worldwide. Symptoms of inflammatory bowel *hydroxymethylglutaryl-CoA reductases required for*

disease include a disturbance in bowel habits and mu-

the synthesis of cholesterol.

cosal inflammation. In the intestine of people with

Probiotic bacteria are reported to deconjugate bile

inflammatory bowel disease, the number of Lacto-

salts. The deconjugated bile acid does not absorb *bacillus and Bifidobacterium is lower, and that of*

lipid as readily as conjugated counterpart, leading

coccoids and anaerobes are higher. Probiotics do not

to a reduction in cholesterol level. Lb. acidophilus

cure the disease. However, once patients are in re-

is also reported to take up cholesterol during growth

mission through treatment with

corticosteroids, some

and this makes it unavailable for absorption into the

probiotics can prolong the remission, thus reducing

blood stream (Klaver and Meer, 1993). A lower serum

the relapses and the use of corticosteroids. This im-

cholesterol concentration in rats fed with fermented

proves the quality of life of patients.

milk containing Lb. acidophilus and bifidobacteria

has been observed.

Immune System Stimulation

Despite several studies, the reduction in serum

cholesterol effect is still not considered an established

The intestine is body's largest immune organ and the

effect and double-blinded placebo-controlled human *intestinal microflora and the metabolic activity of in-*

clinical trials are needed to substantiate this claim.

testine is equivalent to that of the liver. Probiotics

Similarly, mechanisms involved in reducing choles-

may directly or indirectly (by changing the composi-

terol level need to be clarified.

tion or activity of the intestinal microflora) influence *the body's immune function (Marteau et al., 1997).*

Yogurt and probiotic cultures produce
□ -interferon

H

by T-cells. Probiotics also stimulate cytokines as rep-

ELICOBACTER PYLORI INFECTION

resented by TNF-⎵ (tumor necrosis factor), and IL-6

Helicobacter pylori is a pathogenic bacterium, which *and IL-10 (interleukines 6 or 10). Immunomodula-*

causes peptic ulcers, type B gastritis, and chronic

tion by L. acidophilus and bifidobacteria, in particular

gastritis. H. pylori is present in the stomach as an op-

IgA levels and the nonspecific immunity has been ob-

portunistic pathogen without causing any symptoms

served. It is important to note that

probiotics may not

(Armuzzi et al., 2001; Sakamato et al., 2001).

necessarily provide changes to immune system of

Antibiotic treatments can successfully eradicate

healthy subjects. The mechanism for immunomod-

H. pylori. However, antibiotics often cause side ef-

ulation is not clearly understood. Translocation of *fects and make the bacteria more antibiotic resis-*

small number of ingested bacteria via M cells to the

tant. Probiotic organisms do not appear to eradicate

Peyer's patches of the gut associated lymphoid tis-

H. pylori, but they are able to reduce the bacterial

sue in the small intestine is claimed to be responsi-

load in patients infected with H. pylori.

Lb. john-

ble for enhancing immunity. Ingestion of probiotic

sonii La1 and Lb. gasseri OLL2716 have been found

yogurt has been reported to stimulate cytokine pro-

to reduce H. pylori colonization and inflammation

duction in blood cells and enhance the activities of

(Felley et al., 2001). Similarly, Lb. casei Shirota, and

macrophages.

Lb. acidophilus are able to inhibit the growth of H.

pylori. In an intervention study, 14 patients infected

CONCLUSIONS

with H. pylori received Lb. casei Shirota (2 × 1010

cfu/day) fermented milk for 6 weeks. H. pylori bac-

Probiotic products containing Lb. acidophilus, Bifi-

terial load was assessed by the breath urea test. Ure-

dobacterium spp. and Lb. casei are becoming increas-

olytic activity was reduced in 64% of the patients that

ingly popular. Other probiotic organisms including

Ent. faecium, Sacch. cerevisiae Boulardii and Pro-

Gilliland SE. 1991. Therapeutic properties of yogurt.

pionibacterium have a potential to be used in pro-

In: RK Robinson (Ed), Therapeutic Properties of

biotic products. Several health benefits have been

Fermented Milks. Elsevier, London, pp. 65–80.

claimed for probiotic bacteria; however, not all probi-

Gilliland SE. 2003. Probiotics.

Encyclopedia of Food

otic bacteria are effective in providing health benefits.

Science and Nutrition, Vol. 8, Elsevier, London .

Proper strain selection and assessment of health ben-

Goldin BR, Gorbach SL. 1977. Alterations in faecal

efits should be carried out before incorporating these

microflora enzymes related to diet, age,

strains for providing health benefits.

Lactobacillus supplement and dimethyl hydrazine.

Cancer 40:2421–2426.

Goldin BR, Gorbach SL. 1984. The effect of milk and

REFERENCES

Lactobacillus feeding on human intestinal bacterial

enzyme activity. Amer. J. Clin. Nutr. 39:756–761.

Armuzzi A, Cremonini F, Bartolozzi F,

Canducci F,

Gomes AMP, Malcata FX. 1999. Bifidobacterium spp.

Candelli M, Ojetti V, Cammarota G, Anti M, De

and Lactobacillus acidophilus: Biological,

Lorenzo A, Pola P, Gasbarrini G, Gasbarrini A.

biochemical, technological and therapeutical

2001. The effect of oral administration of *properties relevant for use as probiotics. Trends in*

Lactobacillus GG on antibiotic-associated

Food Sci. Technol. 10:139–157.

gastrointestinal side-effects during Helicobacter

Gopal PK. 2003. Lactobacillus acidophilus.

pylori eradication therapy. Aliment Pharmacol.

Encyclopedia of Dairy Sciences, 3:1484–1488.

Therapy 15(2):163–169.

Guandalini S, Pensabene L, Zikri MA, Dias JA, Casali

Cats A, Kulpers EJ, Bosschaert MA, Pot RG,

LG, Hoekstra H, Kolacek S, Massar K, Micetic-Turk

Vandenbroucke-Gauls CM, Kusters JG. 2003.

D, Papadopoulou A, de Sousa JS, Sandhu B,

Effect of frequent consumption of Lactobacillus

Szajewska H, Weizman Z. 2000. Lactobacillus GG

casei—containing milk drink in Helicobacter

administered in oral rehydration solution to children

pylori—colonised subjects. Aliment. Pharmacol.

with acute diarrhoea: A multicenter European trail.

Therapy 17(3):429–35.

J. Pediatr. Gastroenterol. Nutr. 30:54–60.

Cenci G, Rossi J, Throtta F, Caldini G. 2002. Lactic

Hilton E, Kolakowski P, Singer C, Smith M. 1997.

acid bacteria isolated from dairy products inhibit

Efficacy of Lactobacillus GG as a diarrhoeal

genotoxic effect of 4-nitroquinoline-1—oxide in

preventive in Travellers. J. Travel. Med. 4:41–43.

SOS-chromotest. Syst. Appl. Microbiol.

25(4):

Holm F. 2003. Gut health and diet: The benefits of

483–90.

probiotic and prebiotics on human health. The

Curry B, Crow V. 2003. Lactobacillus spp.: General

World of Ingredients. 2:52–55.

characteristics. Encyclopedia of Dairy Sciences.

Klaver, FAM, Meer RVD. 1993. The

assumed

Vol. 3. Academic Press, London, pp. 1479–1484.

assimilation of cholesterol by lactobacilli and

Dave R, Shah NP. 1996. Evaluation of media for

Bifidobacterium bifidum is due to their bile salt

selective enumeration of S. thermophilus, L.

deconjugating activity. Appl. Environ. Microbiol.

delbrueckii ssp. bulgaricus, Lactobacillus

59:1120–1124.

acidophilus and Bifidobacterium species. J. Dairy

Klein G, Pack A, Bonaparte C, Reuter G. 1998.

Sci. 79:1529–1536.

Taxonomy and physiology of probiotic lactic acid

Felley CP, Corthesy-Theulaz I, Rivero JL, Sipponen P, *bacteria. Intern. J. Food Microbiol. 41:103–125.*

Kaufmann M, Bauerfeind P, Wiesel PH, Brassart D,

Krishnakumar V, Gordon IR. 2001. Probiotics:

Pfeifer A, Blum AL, Michetti P. 2001. Favourable

Challenges and opportunities. Dairy Ind. Inter.

effect of an acidified milk (LC-1) on Helicobacter

66(2):38–40.

pylori gastritis in man. Eur. J. Gastroenterol.

Kurmann JA, Rasic JL. 1991. The health potential of

Hepatol. 13:25–29.

products containing bifidobacteria. In: RK Robinson

Fonden R, Mogensen G, Tanaka R, Salminen S. 2000.

(Ed), Therapeutic Properties of Fermented Milks.

Effects of culture containing dairy products on

Elsevier Applied Science Publishers, London,

intestinal microflora, human nutrition, and

pp. 117–157.

health—current knowledge and future perspective.

Lankaputhra WEV, Shah NP. 1998. Antimutagenic

Bulletin of the International Dairy Federation, No.

properties of probiotic bacteria and of organic acids.

352. IDF, Brussels, Belgium.

Mutation Research 397:169–182.

Gilliland SE. 1989. Acidophilus milk products: A

Lidbeck A, Geltner Allinger U, Orrhage KM, Ottova

review of potential benefits to consumers. J. Dairy

L, Brismar B, Gustaffson JAS, Rafter JJ, Nord CE.

Sci. 72:2483–2494.

1991. Impact of L. acidophilus

supplements on the

fecal microflora and solublefecal bile acids in colon

lactic acid bacteria. pp. 279–306, Blackie Academic,

cancer patients. Ecol. Health Dis. 4:81–88.

London.

Mann GV, Spoerry A. 1974. Studies of a surfactant and

Shah NP. 1993. Effectiveness of dairy products in

cholesterolemia in the Massai. Amer. J. Clin. Nutr.

alleviation of lactose intolerance. Food Aust.

27:464–469.

45:268–271.

Marteau P, Vaerman JP, Bord JP, Brassart D, Pochart P,

Shah NP. 1997. Bifidobacteria: Characteristics and

Desjeux JF, Rambaud JC. 1997. Effects of

potential for application in fermented milk products.

intrajejunal perfusion and chronic ingestion of

Milchwissenschaft 52(1):16–21.

Lactobacillus johnsonii strain LA1 on serum

Shah NP. 1999. Probiotic bacteria: Antimicrobial and

concentrations and jejunal secretions of *antimutagenic properties. Probiotica 6:1–3.*

immunoglobulins and serum proteins in

Shah NP. 2000a. Probiotic bacteria: Selective

healthy humans. Gastroenterol. Clin. Biol.

enumeration and survival in dairy foods. J. Dairy

21:293–298.

Sci. 83:894–907.

McDonough FE, Wong NP, Hitchins A,

Bodwell CE.

Shah NP. 2000b. Some beneficial effects of probiotic

1987. Alleviation of lactose malabsorption from

bacteria. Biosci. Micro. 19(2):99–106.

sweet acidophilus milk. Amer. J. Clin. Nutr.

Shah NP. 2002. Bifidobacterium spp.: Applications in

42:345–346.

fermented milks. Encyclopedia of Dairy

Science,

Mittal BJ, Garg SK. 1992. Acidophilus milk products:

Academic Press, London, pp. 147–151.

Manufacture and therapeutics. Food Reviews Intern.

Shah NP, Fedorak RN, Jelen P. 1992. Food

8(3):347–389.

consistency effects of quarg in lactose absorption

Onwulata CI, Ramkishan Rao D,

Vankineni P. 1989.

by lactose intolerant individuals. Inter. Dairy J.

Relative efficiency of yogurt, sweet acidophilus

2:257–269.

milk, hydrolysed-lactose milk, and a commercial

Shah NP, Lankaputhra WEV. 2002. Bifidobacterium

lactase tablet in alleviating lactose maldigestion.

spp.: Morphology and Physiology. Encyclopedia of

Amer. J. Clin. Nutr. 49:1233–1237.

Dairy Science, Academic Press, London, pp.

Orrhage K, Sillerstrom E, Gustafsson JA, Nord CE,

141–146.

Rafter J. 1994. Binding of mutagenic heterocyclic

Singh J, Rivenson A, Tomita M, Shimamura S, *amines by intestinal and lactic acid bacteria.*

Ishibashi N, Reddy BS. 1997. Bifidobacterium

Mutation Research. 311:239–248.

longum and Lactobacillus acidophilus

Ouwehand AC, Kirjavainen PV, Shortt C, Salminen S.

producing intestinal bacteria inhibits colon

1999. Probiotics: Mechanisms and established *cancer and modulates the intermediate biomarkers*

effects. Intern. Dairy J. 9:43–52.

of colon carcinogenesis. Carcinogenesis

Playne MJ, Bennet LE, Smithers GW. 2003.

18(4):833–841.

Functional dairy foods and ingredients. Aust. J.

Stiles ME, Holzapfel WH. 1997. Lactic acid bacteria

Dairy Technol. 58(3):242–264.

of foods and their current taxonomy. Intern. J. Food

Saavedra JM, Bauman NA, Oung I, Perman JA, Yolken

Microbiol. 36:1–29.

RH. 1994. Feeding of Bifidobacterium bifidum and

Tharmaraj N, Shah NP. 2003. Selective enumeration of

Streptococcus thermophilus to infants in hospital for

Lactobacillus delbrueckii ssp. bulgaricus,

prevention of diarrhoea and shedding of rotavirus.

Streptococcus thermophilus, Lactobacillus

Lancet 344:1046–1049.

acidophilus, bifidobacteria, Lactobacillus casei,

Sakamato I, Igarashi M, Kimura T, Takagi A, Miwa

Lactobacillus rhamnosus and Propionibacteria.

T, Koga Y. 2001. Helicobacter pylori infections in

J. Dairy Sci. 86:2288–2296.

humans. J. Antimicrobiol. Chemother. 47:709–710.

Vesa TH, Marteau P, Zidi S, Pochart P, Rambaud JC.

Salminen S, Ouwehand AC. 2003. Probiotics,

1996. Digestion and tolerance of lactose from

applications in dairy products. Encyclopedia of *yoghurt and different semi-solid fermented dairy*

Dairy Sciences, Vol. 4, pp. 2315–2322.

products containing L. acidophilus and

Savaiano DA, ElAnouar AA, Smith DJ, Levitt MD.

bifidobacteria in lactose maldigesters. Is Bacterial

1984. Lactose malabsorption from yogurt,

Lactase Important? Eur. J. Clin. Nutr. 50:730–

pasteurized yogurt, sweet acidophilus milk, and

733.

cultured milk in lactase-deficient individuals. Amer.

Yoon H, Benamouzig R, Little J, Francois-Collange

J. Clin. Nutr. 40:1219–1223.

M, Tome D. 2000. Systematic review of

Sgorbati B, Biavati B, Palenzona D. 1995. 'The genus

epidemiological studies on meat, dairy

products, and

Bifidobacterium'. In: BJB Wood, Holzapfel (Eds),

egg consumption and risk of colorectal adenomas.

The Lactic Acid Bacteria, Vol. 2: The genera of

Eur. J. Cancer Prev. 9:151–164.

Manufacturing Yogurt and Fermented Milks

Edited by Ramesh C. Chandan

Publishing

Index

acceptance testing, 126

resistance mechanisms, 97–98

"just right" scaling, 126

starters, 90, 95

hedonic scale, 126

types of, 96

Acetobacter spp. 301

balance tank, 20

acidity, 121. See also pH

basic dairy processing principles, 73–88

apparent, 121

batch blending system, 8

developed, 121

batch pasteurization, 8

real, 121

batch processes, 19

titratable, 121, 182, 198,

beneficial microflora, 319

total, 121

bifidobacerium, 203, 344

acidophilus milk, 295, 296, 303, 304

isolation and enumeration, 344

history, 303

Bifidobacterium spp. 296, 305

microbiology, 305

bioactive dairy ingredients, 312

production of sweet acidophilus milk,

bioactive peptides, 316, 317

304

boiling point, 38

acidulants for fruit preparations, 159

booster pump, 21

adulteration, 14

brix, 159, 160, 165

affective test, 268, 269

buffering capacity, 32

focus group, 269, 270

bulgarian milk/buttermilk, 296, 306

just right intensity, 274

buttermilk, 329

nine-point hedonic scale, 270

buttermilk, cultured, 279–284

agitation, 15

buttermilk powder, 172

agitation of mix, 288

buttermilk sales trend, 11

analysis, 117

antimicrobial substances, 125

Candida spp. 301

brilliant black reduction test, 125

casein fractions, 23, 314

delvotest, 125

caseinates, 174

immunoassays, 125

catalase, 89

reference method, 125

category scale, 270

analytical tests, 268

cavitation, 3

anticarcinogenesis, 322

centrifugal, 4

antimicrobial substances, 125

chakka, 14

aseptic packaging, 146–147

chemical tests, 122

flavorful substances, 122

Bacillus stearothermophilus, 125

free fatty acids, 122

bactofugation, 9, 10

cholesterol, 20

bacteriophages, 90

cirtate-fermenting bacteria, 125

characteristics, 96

clarification, 9

control of, 96–98

cleaning, 43, 45

effect on cultured product, 90

code dating, 68

Code of Federal Regulations, 57

dahi, 7, 14, 90, 99, 295, 329

State preemption, 62

history, 297

Codex standards, 68

microbiology, 299–300

fermented milks, 68

production, 298

additives, 70

quality, 299

composition, 69

dairy foods production, United States, 5

cultures, 69

dairy ingredients, 167, 179

cold separation, 18

composition, 167, 180

coliform bacteria, 124

origin, 179

colligative properties, 38

performance in yogurt formulation, 168

boiling point, 38

dairy processing principles, 73–87

freezing point, 38

overview of dairy processing equipment, 73 *osmotic pressure, 38*

centrifugal operations, 81

color, milk, 31

centrifugal pump, 74

colors, 158, 165

from farm to factory, 78

Committee on Sensory Evaluation of Dairy Products of

heat transfer operations, 75

ADSA, 127

homogenization, 84–86

composition and specifications of dairy ingredients,

membrane technology, 86–87

167–168

microbial transformation, 78

compositional, 117

mixing operations, 76

acidity, titratable, 121

positive displacement pump, 74–75

fat, 118

separation, 77

lactose, 120

storage, raw milk, 79–80

moisture, 119

thermal processing systems, 82–84

protein, 120

density, 36, 122

solids, 119

dermatitis, 322

concurrent, 7

descriptive, 269

condensed milk, 172, 181

flavor profile, 269

contents, v

panelist selection, 269

continuous mixing systems, 9

quantitative, 269

continuous pasteurization, 19

scale usage, 269

contributors, vii

spectrum technique, 269

cooling, 6, 43, 44, 46, 286

texture profiling, 274

countercurrent, 7

training, 269

cream, 170

descriptive analysis, 126

cream separation, 9

quantitative, 127

culture bacteria, 125

diacetyl, 92, 103–105

culture containing milks, 295–310

diarrhea, prevention, 322

cultured buttermilk, 279–284, 329

difference, 269

key steps in manufacture, 280

attribute, 269

breaking, cooling and distribution, 282

paired comparison, 269

buttermilk starter culture, 281

ranking, 269

flavor, body and texture, 283

direct acidification, 287

milk supply, 280

discrimination tests, 268

processing of milk, 281

duo-trio, 268

sensory evaluation, 283

triangle, 268

cultured cream sales trend, 11

drinkable yogurt, 270

cultured/sour cream, 285–294, 330

dual-stage, 23

body and texture, 289

dye-binding, 120

early history, 285

filled sour cream, 291

electrical conductivity, 34

flavor defects, 290

electrochemical properties, 33

manufacturing procedure, 288

Elliker's lactic agar, 125

present standards, 287

Enterobacteriaceae, 124

problems and corrections, 289

equipment, 51

sour cream products, 290

3A sanitary standards, 52

curd tension, 37

exoplysaccharide, 96, 106

farm requirements, 43

high intensity sweeteners, 155

barns, 43

organic, 154, 160

milking, 43

packaging, 164

milking equipment, 43

peaches, 153

fat free sour cream, 291

pectin, 157

fat globule size, 24

preservatives, 159

fat globules, 170

processing, 160

fat, tests for,

aseptic process, 163

Babcock, 118

hot kettle process, 162

ether extraction, 118

quality checks, 165

Gerber, 118

raspberries, 153

Mojonnier, 118

raw materials, 152

Roese-Gottlieb, 118

specifications, 155

fermentation, 10, 89

stabilizers, 156

fermentation vessels, 285–288

strawberries, 153

fermented dairy packaging materials, 129–150

sweeteners, 155

fermented milks, 68, 271, 327, 295–310, 328

functional foods/disease prevention, 311–326

additives, 70

beneficial microflora, 319

composition, 69

bioactive dairy ingredients, 312, 316

consumption, 8

bioactive peptides, 317

culture containing milks, 295–310

casein fractions, 314

cultures, 7, 9, 69, 329

lactose, 317, 333

forms, 7

lactose malabsorption, 335

middle east, 1, 331

milk fat, 317, 334

origin, 332

milk proteins, 313, 333

packaging, 143–145

nutritional value, 315

Russia/eastern europe, 13, 330

nutritional profile of yogurt, 314

Scandinavia, 12, 330

physiological effects, 316, 336

South Asia, 13, 330

probiotics, 318

world production, 6, 7

anticarcinogenesis, 322, 336

filled sour cream, 291

calcium, 321

flavor defects, 290

fortification, 323

flavor, milk, 31

health benefits, 319

flavor profile, 127

immunomodulatory role, 322, 338

flavorful substances, 122

manufacture, 322

flavoring, 58, 59, 60, 63, 68

mode of action, 321

flavors

physiological effects, 336

fruit, 158

physiologically active ingredients, 324

preparation, 158

prevention of diarrhea, vaginitis, dermatitis,

vanilla, 158

322

flow controller, 20

production of enzymes and vitamins, 320

flow diversion valve, 21

reduction in serum cholesterol, 337

foaming, 37

whey proteins, 314

food additives, 62, 70

functional properties of milk constituents, 316

Food and Drug Administration, 155, 159–160, 162, 190,

229, 230, 235, 247–248

gelatin, 190

fortification, 323

Geotrichum candidum, 92, 301, 306

free-choice profile, 127

Grade "A" PMO, 42, 57

free fatty acids, 122

labeling, 48

freezing point, 14, 38

standards, 49, 50, 51

fruit preparation, 151–166

grading, 265

acidulants, 159

USDA quality approval rating, 265,

266

banana, 154

blueberries, 153

HACCP, 47

cherry, 154

prerequisite program, 47

flavors, 161

Health Attributes of Yogurt and Fermented Milks,

formulation, 154

327–340. See also health benefits

health benefits, 309, 319, 331, 347, 311–354

judging, 265, 266

anticarcinogenic, 351

antimutagenic, 350

kefir, 9, 13, 92, 113, 295–296, 330

beneficial effects, 333

description, 301

bioyogurt, 339

grains, 296, 301–302

Heliobacter pylori infection, 352

history, 300

immune system stimulation, 352

microbiology, 301, 302

irritable bowel disease, 352

production, 298–300

kefir, 338

quality, 301

lactose metabolism, 333, 350

keldermilk, 12

nordic fermented milks, 338

kishk, 13

nutritional value, 331

kosher, 67

reduction in serum cholesterol, 351

koumiss, 9, 13, 92, 93, 295–296, 330

heat effects/stability, 34, 35

description, 303

heat exchanger, 7

history, 302

heating, 6

microbiology, 303

heterofermentative, 11

production, 303

High Temperature Short Time Pasteurization (HTST),

quality, 305

19

history and consumption trends, 3

laban, 331

holding tube, 21

laban rayeb, 13

homofermentative, 11

labeling, 62, 249

homogenization, 16, 171, 221, 287–289

flavors, 63

homogenizer, 23

information panel, 63

homogenizer valve, 24

ingredients, 64

HPLC method, 121

nomenclature, 58–61

nutrient claims, 251

imitation sour cream, 290

nutrition, 65

immunomodulatory role, 322

daily reference values, 65, 250

index, 355

format, 67

infrared method, 118

principal display panel, 62

ingredients, 179

serving size, 65

acesulfame-K, 189

standard of identity, 63

aspartame, 156, 188

labneh, 7, 13, 270, 271

condensed skim milk, 181

laboratory analysis of fermented milks, 117–128

dairy, 167, 179

lactic acid bacteria, 10

composition, 180

lactic acid bacteria, 125

gelatin, 190

lactic acid bacteria, taxonomy, 341

gums and pectins, 192

Lactobacillus, 108, 125, 296, 301, 305, 344

milk protein concentrate/ultrafiltered milk, 183

acidophilus, 109, 110, 296, 303, 304, 305

neotame, 189

brevis, 301

nonfat dry milk, 181

casei subsp . casei, 99

saccharin, 189

delbrueckii subsp . bulgaricus, 94, 99, 108,

stabilizers, 190, 191

109

starch, 191

subsp . lactis, 99

sucralose, 189

helveticus, 99, 306

sweeteners

kefir, 301

corn, 184

kefiranfaciens, 301

high intensity, 156, 188

Lactococcus, 99, 121, 125, 301

nutritive, 184

lactis, 92

whey solids, 182

subsp. cremoris, 94, 99, 307

yogurt manufacture, 179–194

subsp . lactis, 94, 99

in-line standardization, 18

subsp . lactis (Cit+), 92, 93, 99, 106

international dairy federation, 119, 125

lactose, 27, 28, 29, 317, 333

international standards, 68

␣-lactose, 28

interstate commerce, 62

NL-lactose, 28

359

lactose, tests for, 120

plasmin, 26

HPLC method, 121

protease, 26

polarimetric method, 12

milk fat, 19, 317

langfil, 12

fatty acid profile, 20

lassi, 14

milk fat globule, 20, 21

Leuconostoc, 106, 125, 301

membrane, 21, 22

line scale, 270

size distribution, 21

lipolysis, 15

milk powder, 167

Listeria monocytogenes, 94

composition, 167

Long Time Low Temperature (LTLT),

19

high heat, 168

low fat sour cream, 290

low heat, 168

medium heat, 168

MacConkey glucose agar, 124

whey protein nitrogen index, 167

manufacture of various types of yogurt, 211–236. See also

milk pricing, 52

yogurt, manufacture

classification, 54

mastitis, 14

component, 52

membrane fouling, 26

producer, 53

membrane technology, 25

milk production, 3

mesophilic microorganisms, 12

United States, 3, 4

microbiological tests, 124, 165. See also analysis

world, 3, 4, 8

microfiltration (MF), 25

milk protein concentrates, 172, 183

microorganisms, 10

milk proteins, 22, 23, 313, 314, 333, 334

microscope view of cultures, 108, 109, 110,

biologically active, 26

bifidobacteria, 203

caseins, 23, 313

Lactobacillus acidophilus, 110, 202

composition, 23, 313

Lactobacillus delbrueckii spp. bulgaricus, 109,

functional aspects, 27

201

isoelectric point, 24

Streptococcus thermophilus, 108, 200

nutritional value, 315

yogurt culture, 109, 197

milk safety, 41

milk, 2, 167

history, 41

composition, 8, 18, 168, 170

imports, 48

breed, 170

inspections, 42

camel, 8

check rating, 43

constituents, 19

compliance ratings, 43

donkey, 8

milk transportation, 43, 47

genetic variant, 17

delivery, 46

goat, 8

hauler, 43

mare, 8

shipping information, 43

season, 170

trucks, 43

sheep, 8

minerals, 29, 318

species, 168

partition in milk, 30

yak, 8

mishti doi (dahi), 14

composition, physical and processing

characteristics,

mixing, 7

17

Mycoderma spp. 303

definition, 17

functional properties, 316

nanofiltration (NF), 25

minor constituents, 30

National Conference on Interstate Milk Shipments, 42, 47, *nutritional composition, 313*

49

physical characteristics, 31

National Yogurt Association, 61, 67

physical structure, 18–19

Newtonian fluids, 123

milk and milk based dairy ingredients, 167–178

nonfat dry milk, 181

milk enzymes, 26

composition, grade a, 182

alkaline phosphates, 26

heat treatment classification, 183

lactoperoxidase, 26

standards, 169, 182

lipoprotein lipase, 26

nonfat milk solids, 120

lysozyme, 26

nuclear magnetic resonance (NMR), 119

nutritional function, 332

phage inhibitory media, 97

nutritional profile of yogurt, 314

phosphatase, 20

nutritional value, 331, 333

phospholipids, 20

physical properties of milk, 31, 122

official methods of analysis, 119

acidity, titratable, 32

optical properties, 31

buffering capacity, 32

organic, 160

color, 31

organoleptic, 165

density, 36, 122

osmotic pressure, 38

electrical conductivity, 34

oxidation-reduction potential, 33

electrochemical, 33

flavor/off flavor, 31, 32, 33

package in product distribution, 139–140

oxidation-reduction potential, 33

packaging, 45, 47, 62, 129–150

refractivity, 31

biodegradability, 143

rheological, 123

definition, 130

specific gravity, 122

distribution, 130

tests, 122–124

economics, 140

thermal, 34

environment, 142

water-holding capacity, 123

fundamentals, 130

physiological effects, 309, 316, 336, 338, 351 *future trends, 147–148*

anticancer effects, 336, 351

graphic design assessment, 140

antimutagenic, 350

graphics, 130

diarrhea, 320, 349

interactions with product, 137–139

Heliobacter pylori infection, 352

primary, 130

immune system stimulation, 338, 352

recycling, 143

irritable bowel disease, 352

regulation, 141

lactose metabolism, 350

secondary, 130

reduction in serum cholesterol, 337, 351

structural design, 130

physiologically active ingredients, 324

technology, 130

plasmids, 93–94

packaging for yogurt and fermented milks, 143

plate heat exchangers, 12, 20

packaging levels, 133

Podoviridae, 96

converters, 133

polarimetric method, 121

distributors, 134

positive displacement, 4

equipment, 134

positive lobe, 5

packagers, 134

precipitation, 24

packaging developments, 134–136

alcohol, 24

raw material suppliers, 133

heat, 24

resources available, 136–137

polyvalent ion, 24

packaging materials, 130

preface, ix

glass, 131

preference mapping, 270

metal, 131

preference testing, 126

oxygen-barrier materials, 133

preservatives, 60, 62, 70, 159

paper and paperboard, 131

pressure differential meter, 22

plastic, 132, 212

principles of yogurt processing, 195–210

polyester, 132

probiotic milks, 295, 305, 318, 341

polyethylene, 132

history, 305

packaging sour cream, 286, 292

production, 305

containers, 286, 288

quality, 305

hot packaging, 286

probiotics, 318, 319, 341, 343

paring disc, 17

health benefits, 319, 320, 347

pasteurization, 19, 46, 59, 61

manufacture, 322

Petrifilm®, 124

mode of health benefits, 321

pH, 32, 121, 196, 204–206, 222, 227,

228, 223, 231, 233,

requirements for effective, 320

234

probiotics and fermented milks, 341–354

indicator, 121

beneficial effects of probiotics, 348. See also probiotics,

phage infection protein, 97

health benefits

Index

361

anticarcinogenic, 351

quality-based method, 267

antimicrobial activity, 348

quality control, sensory tests for, 127

antimutagenic, 350

diarrhea, effective against, 349

raw milk, 6

commercial probiotic strains, 347

reagents

genus bifidobacterium, 344–346

ammonium hydroxide, 118

isolation and enumeration, 345

ethanol, 118

genus lactobacillus, 343, 346

isoamyl alcohol, 118

isolation and enumeration, 344

phenolphthalein, 121

immune system stimulation, 352

sulfuric acid, 118

inflammatory bowel disease, 352

Real Seal, 67

lactose intolerance, 350

reference method, 118

Heliobacter pylori infection, 352

reference samples/standards, 118, 120, 121, 127

physiological effects, 336

refractivity, 31

probiotic bacteria, 342

refrigeration, 7, 21

reduction in serum cholesterol, 351

regulations for product standards and labeling,

selection criteria, 342–343

57

strains with peer reviewed clinical trials, 347

regulatory requirements for milk production, transportation

processing plants, 44

and processing, 41

construction, 44

rennet coagulation, 24

equipment, 45

rennet (use in sour cream), 285, 288

processing principles, 2

representative sample, 13

protein adsorption, 24

restriction-modification, 97

protein tests, 120

reverse osmosis (RO), 25

dye-binding, 120

rheological tests, 123

infrared analyzer, 120

apparent viscosity, 123

Kjeldahl, 120

rupture stress, 123

proteins, minimum requirements, 315

stress/strain curve, 123

nutritional values, 315

thixotrophic fluids, 123

Pseudomonas spp. 93

viscometer, 123

pumps, 3

sampling, 49

quality assurance, yogurt plant, 247

sediment, 14

analytical tests, 254

sensory analysis of yogurt, 270

daily reference values, 250

attributes and references, 272

defects in yogurt and causes, 262–263

judging criteria, 267

Food and Drug Administration, 247

quality terms, 268

food labeling, 249

sensory analysis techniques, 265

nutrient claims, 251–253

sensory descriptors, 271

nutrition facts label, 254

USDA quality guidelines, 266

quality control programs, 255–256

sensory evaluation, 265, 273

compositional analysis, 258

appearance, 267, 274

criteria for live and active yogurt, NYA,

consistency, 267

258–260

flavor, 267, 273

microbiological, 258

odor, 273

overrun, 258

taste, 273

quality tests, 257

texture, 274

sensory, 258

sensory tests, 126

shelf life test, 258

acceptance testing, 126

viscosity, 258

basker's tables, 126

regulatory obligations, 247

descriptive analysis, 126

specification program, 260

flavor thresholds, 127

process and product specification, 261

free-choice profiling, 127

raw milk quality, 260

in quality control, 127

trouble shooting, 262–263

preference testing, 126

weight control, 263

procrustes analysis, 127

separation, 9

production, 304

serum cholesterol reduction, 322

quality, 304

shelf stable packaging, 145–146

sweeteners, 58, 59, 60, 184

aseptic packaging, 146

high intensity, 188

post-fill retorting, 145

acesulfame-K, 189

shrikhand, 7, 14

alitame, 190

silo, 15

aspartame, 188

single service containers, 45, 48

cyclamates, 190

single-stage, 23

neotame, 189

Siphoviridae, 96

saccharin, 189

skyr, 7, 12, 297, 306, 331

stevia, 190

smoothing screen, 289

sucralose, 189

solids, total, 119

thaumatin, 190

forced-draft oven, 119

nutritive, 184–188

hot air oven, 119

corn sweeteners, 186–187

infrared instrument, 119

liquid sugar, 185

microwave oven, 119

maltodextrins, 186

sand pan method, 119

sucrose, 184

sour cream, 285–294

sour cream cultures, 285, 287, 288

tanker, 13

sour cream history, 285, 286, 287

temperature, 43, 44, 46, 50, 51

soy milk yogurt, 273

testing body, 286

specific gravity, 36, 122

tests, 118–127. See also analysis

spiral wound, 26

texture attributes, 271

stabilizers, 58, 60, 70, 190, 286, 287, 289

nonoral viscosity, 271, 272

in yogurt, 191

oral viscosity, 271, 273

pectin, 192

thermal processing, 19

Standard Methods for the Examination of Dairy Products, *thermal properties, 34*

118, 119, 120, 124, 125

threshold, 269

standardization, 16

titratable acidity, 58, 59, 61, 121

standards, 287, 290

tubular, 26

standards of identity, 57

turbulence, 23

cream, 58

cultured milk, 58

ultrafiltered milk, 183

milk, 58

ultrafiltration (UF), 25

sour cream, 59

Universal Product Code, 68

stayed provisions, 59

yogurt, 59

starch, native/modified, 191

vaginitis, 322

starter culture

viili, 7, 12, 92, 93, 297, 331

characteristics, 101, 102

history, 306

definition of, 89

microbiology, 307

factors affecting, 90, 93–98

violet red bile agar, 124

functions of, 90, 93, 100

viscometer, 123

miscellaneous, 113

viscosity, 36, 123

production of, 112–113

vitamins, 30, 318

types of, 96

volumetric flow, 5

yogurt and fermented milks, 89–116

volumetric flow meter, 15

Stokes law, 21

Streptococcus, 106, 125

warm separation, 18

thermophilus, 94, 95, 106, 108

water, 19

surface activity, 37

water-holding capacity, 123

surface concentration of protein, 24

whey, 51

sweet acidophilus milk

solids, 182

history, 303

whey products, 173

microbiology, 305

microparticularted whey protein, 174

whey powders, 173

light, 226

whey protein concentrates, 173

market, 214–219

whey proteins, 25, 314

natural yogurt, 229

bovine serum albumin, 25, 26, 314

organic, 229230

denaturation, heat, 220

plain, 223

immunoglobulins, 25, 26, 314

flow sheet diagram, 224

-lactalbumin, 25, 314

post culturing heat treatment, 234–235

-lactoglobulin, 25, 314

processes, 220

proteose peptones, 25

pumping, 223

smoothies, drinks, 230–231

yakult, 330

flow sheet diagram, 232

yeast and mold counts, 124

starter production, 212, 214

ymer, 7, 12, 331

stirring, 223

yogurt, 90, 270, 271, 274, 328

styles and definitions, 214–217

acidification, 167

sundae style, 226–227

bulk starter, 215

vanilla flavored, 227

effect of processing on starter, 91

whips, mousse, 231

flavor, 167

yogurt market, 10, 11

formulation, 224

sales trends, 10, 218, 219

lactic agar, 125

segmentation, 11

manufacture, 149, 211–236

yogurt microstructure, 170, 176

blended/swiss-style, 223

fat globules, 170

concentrated, greek, 232

yogurt packaging, 143–145, 212

custard, 226

yogurt: plant cleaning and sanitizing,

drink/smoothies, 230, 231

237–246

french style, 226

bacteriophage control, 244

frozen, 233

CIP cleaning, 242

fruit-flavored, 223

cleaning, 237

heat-treated, 234, 235

COP cleaning, 241

light, 226

foam cleaning, 240

natural, 229

manual cleaning, 239

nutritional profile, 314

normal soils, 238

organic, 229, 230

complex carbohydrates, 238

plain, 223

fat, 238

plant cleaning and sanitizing, 237–246

minerals, 239

sundae style/fruit on the bottom, 226, 227,

proteins, 238

228

sugars, 238

vanilla

phage control, 244

whips/mousse, 231

sanitizing, 243

yogurt: fruit preparations and flavoring materials, 151–166.

special soils, 239

See also fruit preparations

bacteriophage, 239

yogurt, manufacture of various types, 211–236

biofilms, 239

blended, 224

yogurt processing, principles of,

flow sheet diagram, 225

195–210

classification, 216

changes during processing, 206

coagulation, 222

carbohydrates, 206

concentrated/strained yogurt, 232–233

cell mass, 207

cooling, 222

flavor compounds, 206

custard style, 226

lipids, 206

french style, 226

post-fermentation, 208

frozen, 233–234

proteins, 206

flow sheet diagram, 234

vitamins, 207

fruit flavored, 223

coagulation, 222

fruit on the bottom style, 228

cooling, 222

general procedure for all yogurt types, 211

heat treatment, 195, 220

greek style, 232

homogenization, 197, 221

yogurt processing, principles of (continued)

milk powders, 171

mix preparation, 195

seasonal variations in milk, 170

processing steps, 196, 220

yogurt: sensory analysis, 265

starters for yogurt, 197–198

packaging, 211

characteristics, 199

statistics, 214, 215

collaborative growth, 201

styles and definition, 214, 216, 217

factors for growth, 198–199

types of, 91, 13

inhibiting factors, 203

yogurt starters, production, 212

strain selection, 204

yogurt texture, 167

yogurt properties, effect of milk

homogenization, 171

breed and genetic variants, 170

mammalian species, 168

zabady, 13, 331

Document Outline

- *Cover*
- *Contents*
- *Chapter01*
- *Chapter02*
- *Chapter03*
- *Chapter04*
- *Chapter05*
- *Chapter06*
- *Chapter07*
- *Chapter08*
- *Chapter09*
- *Chapter10*
- *Chapter11*
- *Chapter12*
- *Chapter13*

- *Chapter14*
- *Chapter15*
- *Chapter16*
- *Chapter17*
- *Chapter18*
- *Chapter19*
- *Chapter20*
- *Chapter21*
- *Chapter22*
- *Index*