

Dairy Science and Technology Handbook

2 Product Manufacturing

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**Dairy Science and
Technology Handbook
2 Product Manufacturing**

PREFACE

Although there are many professional reference books on the science and technology of processing dairy products, this 3-volume set is unique in its coverage (topics selected, emphasis, and latest development) and its authors (experts with diversified background and experience).

Volume I discusses four important properties and applications of milk and dairy ingredients: chemistry and physics, analyses, sensory evaluation, and protein. Each chapter is not a comprehensive treatment of the subject, since more than one reference book has been written on each of the four disciplines. Rather, each chapter discusses the basic information in reasonable details that are supplemented by new research data and advances. This assures that each chapter contributes new information not available in many reference books already published.

Volume II discusses the manufacture technology for yogurt, ice cream, cheese, and dry and concentrated dairy products. The direction of each chapter is carefully designed to provide two types of information. Each chapter details the currently accepted procedures of manufacturing the product and then explores new advances in technology and their potential impact on the processing of such products in the future. The fifth chapter in this volume discusses microbiology and associated health hazards for dairy products. The goal of this chapter is obvious, since there are so much new information on this topic in the last few years. The authors have done an excellent job in reviewing available data on this highly visible field.

Volume III is unique because it covers five topics not commonly found in professional reference books for dairy manufacture: quality assurance, biotechnology, computer application, equipment and supplies, and processing plant designs. The length

of each chapter is limited by the size of the book. As a result, I assume full responsibility for any missing details since I assigned a fixed length to each chapter.

The appendix to Volume I alphabetically lists products and services in the dairy industry. Under each product or service, the appendix describes the names of companies that provide those products and services. In Volume III, the appendix provides information for each company listed in Volume I. This includes contact data and the types of products and services for each company. The appendixes for Volumes I and III are not repeated in Volume II in order to assure a reasonable price for the books.

As for the expertise of the authors, you are the best judge since most of them are known among scientists, technologists, and engineers in the dairy discipline.

This three-volume set is a reference book and will benefit dairy professionals in government, industry, and academia. The information is useful to individuals engaged in research, manufacturing, and teaching. In general, the texts form an excellent background source for professionals who just enter the field. For expert dairy professionals, these books serve as a subject review as well as a summary of what is new. Any chapter in the three volumes can be used as a supplement material for a class teaching a specific topic in or an overview of the science and technology of processing dairy products.

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October 1992

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1.1 Introduction

Yogurt has emerged as a significant dairy product of modern times. Historically, fermented milks have constituted a vital component of the human diet in many regions of the world. The main objective of fermenting milk has been to preserve the precious fluid milk which otherwise would deteriorate rapidly under the high

Table 1.1 CONSUMPTION OF YOGURT AND OTHER FERMENTED MILKS IN CERTAIN COUNTRIES IN 1988

Country	Annual Per Capita Consumption (kg)		Annual Total Consumption (1000 Tons)	
	All Fermented Milks	Yogurt	All Fermented Milks	Yogurt
Australia	3.6	3.6	60.8	60.8
Austria	9.8	7.2	73.6	54.2
Belgium	8.4	6.9	83.6	68.3
Bulgaria	42.2	42.2	379.0	379.0
Canada	3.3	3.3	86.6	86.6
Czechoslovakia	6.6	3.2	102.8	49.3
Denmark	14.8	7.8	75.7	39.8
Finland	39.0	11.4	192.8	56.3
France	15.2	—	846.6	—
Germany (West)	11.2	10.8	690.0	638.0
Hungary	3.0	1.5	31.7	15.9
Iceland	23.0	8.6	5.7	2.1
India	4.3	4.3	3410.0	3410.0
Ireland	3.3	3.3	11.6	11.6
Israel	22.1	9.4	98.0	41.8
Italy	3.7	2.4	210.2	135.0
Japan	8.0	3.8	520.0	465.0
Luxembourg	6.8	—	2.5	—
Netherlands	18.9	18.9	278.5	278.5
Norway	15.3	4.3	64.3	18.0
Poland	1.8	—	70.0	—
South Africa	3.6	1.6	105.9	47.2
Spain	7.9	7.9	297.7	297.7
Sweden	29.1	6.8	245.5	188.4
Switzerland	16.9	16.9	114.0	114.0
United Kingdom	3.9	3.9	220.0	220.0
USA	—	2.1	—	517.9
USSR	7.9	—	2250	—

Source: International Dairy Federation (1990).⁵

ambient temperatures of the Middle East, where it is likely to have originated. Conversion of milk to yogurt with a distinctive thicker consistency, smooth texture, and unmistakable flavor has added safety, portability, and novelty to the nutrition of milk for the consumer.

The objective of this chapter is to furnish basic information, including recent trends, on various aspects of the yogurt industry. It is not intended to serve as a treatise on yogurt science and technology. For detailed information, the reader is referred to various books and chapters on the subject.¹⁻³ Vedomuthu,⁴ in a series of articles, has reviewed various technological aspects of yogurt manufacture.

Yogurt and other fermented milks have been particularly popular in countries located in the Mediterranean region; in central, southern, and southwestern Asia; and in central and eastern Europe. Table 1.1 shows the per capita consumption of

Table 1.2 ANNUAL TOTAL AND PER CAPITA
SALES OF REFRIGERATED YOGURT
IN THE UNITED STATES

Year	Total Sales (Millions of pounds)	Per Capita Sales (Pounds)
1972	281	1.3
1977	533	2.4
1982	613	2.6
1987	1094	4.5
1988	1142	4.6
1989	1030	4.2

Source: Milk Industry Foundation (1990).⁶

yogurt and yogurtlike products. In many parts of the world yogurt is still made at home by traditional kitchen recipes involving milk of various mammals, mainly cows, water buffaloes, goats, sheep, mare, or camel. The milk is boiled, cooled, and inoculated with yogurt left over from the previous day and incubated at ambient temperature for 4 to 6 h until it acquires a thick consistency. It is then utilized for consumption in the fresh state as a snack, as an accompaniment as a salad containing fresh vegetables (carrots, cucumber, boiled potatoes, etc.), as a sweet or savory drink, or as a dessert containing sugar and fresh sliced banana and other seasonal fruits.

In the United States the past two decades have witnessed a dramatic rise in the annual yogurt consumption from nearly 1 lb to 4.2 lb per capita. The increase in yogurt consumption may be attributed to its perceived natural and healthy image, providing to the consumer convenience, taste, and wholesomeness attributes. Table 1.2 summarizes recent trends in consumption of refrigerated yogurt in the United States.

The popularity of yogurt consumption is also related to sophisticated marketing techniques in response to consumer demand. Figure 1.1 illustrates the point. Diversification of the yogurt category has created niches to fill the needs of various consumer segments (Table 1.3). The total yogurt market (refrigerated and frozen) in the United States has grown sixfold during the last 20 years. Total sales for refrigerated yogurt alone are over 1 billion dollars. Frozen yogurt sales are estimated to reach 2 billion dollars in 1991. According to the USDA,⁷ sales of frozen yogurt in 1989 reached almost 83 million gallons. In 1990, the sales increased 45%. The frozen yogurt market comprises soft-serve yogurt and hard-pack yogurt. All the major segments of the yogurt market are expected to grow moderately in the future.

The success of yogurt in the market place can be attributed to various factors, including⁴:

- Scientific evidence is mounting to corroborate consumer perception of yogurt's good-for-you image. Indeed, clinical studies have established that yogurt is well tolerated by lactose-intolerant individuals who generally have distressing symptoms of flatulence and diarrhea associated with the maldigestion of milk sugar

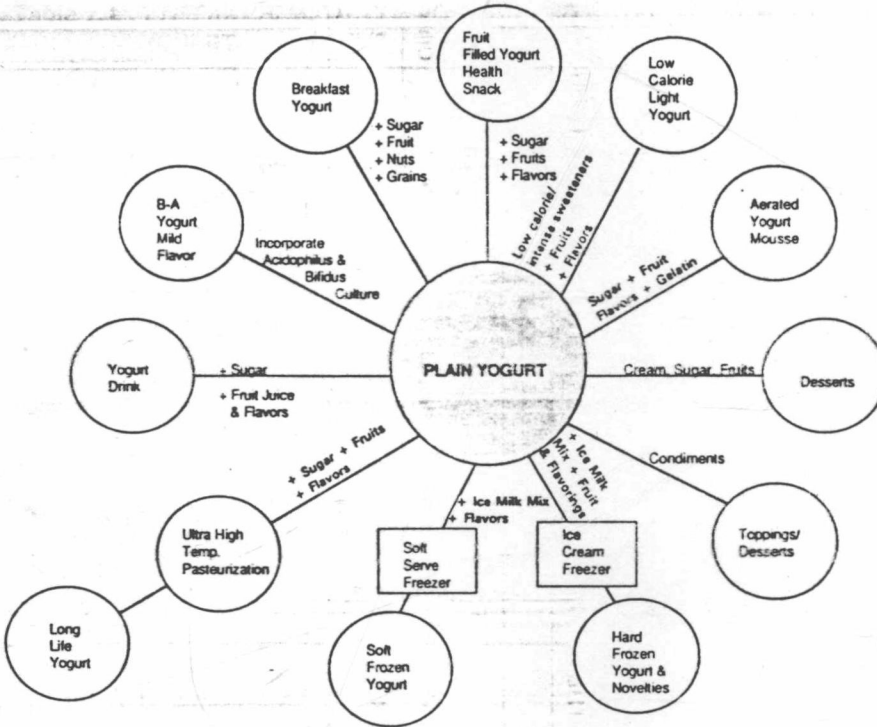


Figure 1.1 Segmentation of yogurt market.

(lactose) present in most dairy products. This effectively provides an opportunity for all consumers to benefit from the protein, calcium, B vitamins, and other significant nutrients available in milk and milk products through the consumption of yogurt. Also, recent data in the literature have suggested that yogurt containing live and active cultures may provide immunostimulatory effects. Furthermore, studies are indicating that yogurt bacteria may provide protection from pathogenic and undesirable bacteria introduced via food intake into the gastrointestinal tract.

- Use of sweeteners such as sugar and high-fructose corn syrups in yogurt manufacture adds a very desirable dimension to yogurt taste and tends to moderate harsh acidic flavor. Furthermore, intense sweeteners such as aspartame impart the desirable attribute without incurring caloric buildup in the product.
- Addition of fruit preparations, fruit flavors, and fruit purees further enhances versatility of taste, color, and texture. Fruits generally are perceived as healthy by the consumer. Their association with yogurt endorses the healthy image of yogurt even more.
- Incorporation of nuts and grains gives yogurt multiple textures and flavors, thus providing a packaged convenient and wholesome breakfast food.
- Development and availability of nonfat, low-fat, and reduced fat yogurts has encouraged consumers to benefit from the health-driven trends currently in vogue.

Table 1.3 TRENDS IN YOGURT STYLE AND PACKAGE SIZE IN THE UNITED STATES (PERCENT OF TOTAL PRODUCTION)

Year	Package Size			Fat Content			Style				
	8 oz	5.1-6.0 oz	Other	Full Fat	Low Fat	Nonfat	Fruit-on-Bottom	Swiss	French	Plain	Breakfast
1984	—	—	—	30	66	4	41	28	16	10	3
1987	59.8	17.3	22.9	17	73	10	28	50	5	13	0.2
											5

Source: Milk Industry Foundation (1990).³

Table 1.4 TYPICAL CHEMICAL COMPOSITION AND NUTRIENT PROFILE OF YOGURT

Constituent (per 100g)	Yogurt						
	Skim Milk	Plain			Fruit-Flavored		
		Full Fat	Low Fat	Nonfat	Full Fat	Low Fat	Nonfat
Protein (g)	3.50	3.88	3.55	4.35	3.90	3.60	3.80
Fat (g)	0.10	3.50	1.60	0.1	2.62	1.33	0.11
Lactose (g)	5.00	3.9	4.10	4.20	3.08	3.11	2.98
Galactose (g)	0.00	1.50	1.50	1.50	1.20	1.20	1.20
Total carbohydrate (g)	5.00	5.42	5.60	5.70	15.50	13.51	12.83
Lactic acid (g)	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Citric acid (g)	0.20	0.30	0.30	0.30	—	—	—
Sodium (g)	0.05	0.07	0.07	0.07	0.05	0.05	0.06
Potassium (g)	0.15	0.20	0.20	0.20	0.16	0.16	0.18
Calcium (g)	0.12	0.18	0.18	0.17	0.13	0.15	0.17
Phosphorus (g)	0.10	0.14	0.14	0.12	0.10	0.10	0.10
Chloride (g)	0.10	0.12	0.12	0.12	0.10	0.10	0.10
Energy value (KJ)	150	307	221	165	432	343	289
(calories)	38	73	53	39	103	82	69
Bacterial mass (g)	0	0.15	0.15	0.15	0.15	0.15	0.15

Source: Sellars (1989),⁸ Souci et al. (1990).⁹

- Marketing and merchandising practices have accelerated consumer acceptance and desirability of the product.
- Proliferation of sister yogurt products such as hard-frozen and soft-serve yogurt have provided alternatives perceived healthier than their counterpart ice cream product.

1.2 Definition of Yogurt

Yogurt is a semisolid fermented product made from a standardized milk mix by the activity of a symbiotic blend of *Streptococcus salavarius* subsp. *thermophilus* and *Lactobacillus delbruechii* subsp. *bulgaricus* cultures. For the sake of brevity we shall term the yogurt culture organisms as ST and LB.

Milk of various mammals is used for making yogurt in various parts of the world. However, most of the industrialized production of yogurt uses cow's milk. It is common to boost the solids-not-fat fraction of the milk to about 12% with added nonfat dry milk or condensed skim milk. The increased protein content in the mix results in a custardlike consistency following the fermentation period.

The typical composition and nutrient profile of yogurt are shown in Table 1.4. In general, yogurt contains more protein, calcium, and other nutrients than milk, reflecting extra solids-not-fat content. Bacterial mass content and products of lactic

fermentation further distinguish yogurt from milk. Fat content is standardized commensurate with consumer demand of lowfat to fat-free foods.

1.2.1 Standard of Identity and Regulatory Aspects of Yogurt

Grandstrand¹⁰ discussed the current U.S. Food and Drug Administration standards of identity for refrigerated yogurt promulgated in September 1982, effective July 1, 1985. A summary of the requirements excerpted from the Code of Federal Regulations, April 1991¹¹ is presented below.

1.2.1.1 Yogurt

Description

Yogurt is the food produced by culturing one or more of the optional dairy ingredients specified below with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. One or more of the other optional ingredients described below may also be added. All ingredients used are safe and suitable. Yogurt, before the addition of bulky flavors, contains not less than 3.25% milkfat and not less than 8.25% milk-solids-not-fat, and has a titratable acidity of not less than 0.9%, expressed as lactic acid. In a subsequent action, the FDA stayed the titratable acidity requirement. The food may be homogenized and shall be pasteurized or ultrapasteurized prior to the addition of the bacterial culture. Flavoring ingredients may be added after pasteurization or ultrapasteurization. To extend the shelf life of the food, yogurt may be heat-treated after culturing is completed, to destroy viable microorganisms.

Optional Ingredients

Vitamins. (1) If added, Vitamin A shall be present in such quantity that each 946 ml (quart) of the food contains not less than 2000 International Units thereof, within limits of current good manufacturing practice. (2) If added, Vitamin D shall be present in such quantity that each 946 ml (quart) of the food contains 400 International Units thereof, within limits of current good manufacturing practice.

Dairy Ingredients. Cream, milk, partially skimmed milk, or skim milk, used alone or in combination.

Other Optional Ingredients. (1) Concentrated skim milk, nonfat dry milk, buttermilk, whey, lactose, lactalbumins, lactoglobulins, or whey modified by partial or complete removal of lactose and/or minerals, to increase the nonfat solids content of the food, *provided that* the ratio of protein to total nonfat solids of the food and the protein efficiency ratio of all protein present shall not be decreased as a result of adding such ingredients. (2) Nutritive carbohydrate sweeteners. Sugar (sucrose), beet or cane; invert sugar (in paste or syrup form); brown sugar, refiner's syrup; molasses (other than blackstrap); high-fructose corn syrup; fructose; fructose syrup; maltose; maltose syrup, dried maltose syrup; malt extract, dried malt extract; malt

syrup, dried malt syrup; honey; maple sugar, except table syrup. (3) Flavoring ingredients. (4) Color additives. (5) Stabilizers.

Methods of Analysis

The following referenced methods of analysis are from *Official Methods of Analysis of the Association of Official Analytical Chemists*, 13th edit. (1980), which is incorporated by reference. Copies are available from the Association of Official Analytical Chemists, 2200 Wilson Blvd., Suite 400, Arlington, VA 22201-3301, or available for inspection at the Office of the Federal Register, 1100 L St. NW, Washington, D.C. 20408. (1) Milkfat content—as determined by the method prescribed in Section 16.059 “Roese-Gottlieb Method (Reference Method) (11)—Official Final Action,” under the heading “Fat.” (2) Milk solids-not-fat content—calculated by subtracting the milkfat content from the total solids content as determined by the method prescribed in Section 16.032, “Method I—Official Final Action,” under the heading “Total Solids.” (3) Titratable acidity—as determined by the method prescribed in Section 16.023, “Acidity (2)—Official Final Action,” or by an equivalent potentiometric method.

Nomenclature

The name of the food is “yogurt.” The name of the food shall be accompanied by a declaration indicating the presence of any characterizing flavoring. (1) The following terms shall accompany the name of the food wherever it appears on the principal display panel or panels of the label in letters not less than one-half of the height of the letters used in such name: (a) The word “sweetened” if nutritive carbohydrate sweetener is added without the addition of characterizing flavor. (b) The parenthetical phrase “(heat-treated after culturing)” shall follow the name of the food if the dairy ingredients have been heat-treated after culturing. (c) The phrase “Vitamin A” or “Vitamin A added,” or “Vitamin D” or “vitamin D added,” or “Vitamins A and D added,” as appropriate. The word “vitamin” may be abbreviated “vit.” (2) The term “homogenized” may appear on the label if the dairy ingredients used are homogenized.

Label Declaration

Each of the ingredients used in the food shall be declared on the label as required by the applicable sections of Part 101.

1.2.1.2 Low-Fat Yogurt

Low-fat yogurt is the food produced according to the description given in the previous section for yogurt, except the milkfat content before the addition of bulky flavors shall be not less than 0.5% and not more than 2%. Percent milkfat shall be declared on the principal display panel in $\frac{1}{2}\%$ increments closest to the actual fat content of the food. All other provisions for yogurt apply for the nomenclature Low-Fat Yogurt.