1 History and consumption trends

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1.1 Overview of the world dairy industry

According to the UN Food and Agriculture Organization (FAO, 2011), the world production of milk in 2009 was 701.4 million metric tons (MT). This was estimated to increase to 713.6 million MT in 2010 and to 727.6 million MT in 2011. India is the largest producer of milk (including milk of cows and water buffaloes) in the world, with an estimated 121.7 million MT in the year 2011.

The 2009 world production of cow milk in the selected countries shown in Table 1.1 was 432.7 million MT. The documented number of cows was 129 296 thousand heads. Individual cow-milk yield varies widely around the world. In 2009, the USA and Japan were the most efficient milk producers, with 9.33 MT/cow, followed by Canada, with a yield of 8.46 MT per cow. Milk yield was lowest in India (1.13 MT/head), followed by Brazil (1.67 MT/head) and Mexico (1.70 MT/head).

1.2 Milk production in the USA

The trend in the last decade indicates a noticeable decrease in dairy-cow population, from 9.151 million heads in the year 1998 to 9.117 million heads in 2010 (Table 1.2). In the year 2010, 9.117 million cows produced 87.46 million MT (192 819 million pounds) of milk (IDFA, 2011). Table 1.2 also shows that during the period 1998–2010 there is a steady increase in milk production per cow, from 7.79 MT (17 185 pounds) to 9.59 MT (21 149 pounds). Concomitantly, milk production in the USA registered an increase from 76.33 million MT (157 262 million pounds) to 87.46 million MT (192 819 million pounds). Approximately 20% of the world's milk is produced in the USA. The American dairy farm has been able to achieve its current milk output through the application of scientific and management advancements in milk production. On the dairy farm, selection of dairy cows, their breeding, and judicious use of balanced feed rations have been instrumental in increasing milk output per cow. As a result of continuous efficiencies in milk production at the farm,

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Table 1.1 World milk production in 2009. Adapted from USDA (2011a) and DairyCo (2011).

Country	Milk cows (1000 head)	Milk yield/cow (MT/head)	Total milk production (1000 MT)
Canada	979	8.46	8280
Mexico	6400	1.70	10866
USA	9203	9.33	85881
Argentina	2100	4.93	10350
Brazil	17200	1.67	28795
EU—27	24192	5.53	133700
Russia	9530	3.42	32600
Ukraine	2856	3.98	11370
India	42600	1.13	48160
China	7115	4.00	28445
Japan	848	9.33	7910
Australia	1676	5.56	9326
New Zealand	4597	3.69	16983
Total	129296	–	432666

Table 1.2 Milk production in the USA. Adapted from IDFA (2011).

Year	Milk cows (1000 head)	Milk yield/cow		Total milk production	
		Pounds	MT	Million pounds	Million MT
1998	9151	17185	7.79	157262	76.33
1999	9153	17763	8.06	162589	73.75
2000	9199	18197	8.25	167393	75.93
2001	9103	18162	8.24	165332	74.99
2002	9139	18608	8.44	170063	77.14
2003	9081	18759	8.51	170348	77.27
2004	9010	18960	8.60	170832	77.49
2005	9050	19550	8.87	176931	80.25
2006	9137	19895	9.02	181782	82.45
2007	9189	20204	9.16	185654	84.21
2008	9315	20395	9.25	189982	86.17
2009	9203	20573	9.33	189334	85.88
2010	9117	21149	9.59	192819	87.46

milk production per cow has doubled in the last 30 years. California continues to be the leading milk-producer state, followed by Wisconsin, New York, Idaho and Pennsylvania.

1.3 Production of dairy foods in the USA

At dairy farms, modern milking and milk-handling equipment, including automated milking systems, have improved the speed of cleaning, sanitizing, cooling and delivering good-quality raw milk to processing plants. The USA has the distinction of being the largest processor of milk and dairy products in the world. Advanced processing and packaging technologies ensure efficient delivery and a long shelf-life of high-quality milk products, including yogurt and fermented milks. Currently, the US dairy industry is valued at 110 billion US dollars (USD). Approximately 30% of the US milk produced on the farm is

processed into fluid milk and cream products (Schultz, 2011b). Fluid milk products include whole milk (3.25% fat), reduced-fat milk (2% fat), low-fat milk (1% fat), nonfat milk (<0.5% fat), half and half (10.5 to <18% fat), light cream (18 to <30% fat), light whipping cream (30 to <36% fat), heavy cream (not less than 36% fat), cultured milk (3.25% fat), cultured reduced-fat milk (2% fat), cultured low-fat milk (1% fat), cultured nonfat milk (<0.5% fat) (cultured buttermilk), yogurt (3.25% fat), reduced-fat yogurt (2% fat), low-fat yogurt (1% fat), nonfat yogurt (<0.5% fat) and cottage cheese (4, 2, 1 or <0.5% fat).

The remaining 70% of farm milk is used in dairy manufacturing plants, where it is transformed into more than 300 varieties and styles of cheese, 100 flavors of ice cream, frozen desserts and frozen yogurt. In addition, dairy plants produce an array of flavored milk, ranging from fat-free to full-fat, butter, sweetened condensed milk, evaporated milk, dry milk, lactose, whey products and cultured products such as sour cream and dips, buttermilk and yogurt drinks/smoothies. According to Schultz (2011a), Wisconsin has the most dairy plants (210), followed by New York state (108) and California (106). The dairy-processing industry has demonstrated several packaging and marketing innovations in competing aggressively for consumer food dollar share.

The products manufactured in the years 2006–2010 and their volumes are shown in Table 1.3. Butter production increased from 0.66 million MT (1448 million pounds) to 0.71 million MT (1564 million pounds), whereas natural cheese registered an increase from 4.32 million MT (9525 million pounds) to 4.73 million MT (10 436 million pounds). Process cheese declined from 1.06 million MT (2349 million pounds) to 0.96 million MT (2124 million pounds). Frozen desserts, including ice cream, whole milk, reduced-fat and low-fat milk, fluid cream and egg nog showed a decline. Nonfat milk and flavored milks showed some increase in volume. In the fermented-dairy-products category, refrigerated yogurt displayed explosive growth, from 1.50 million MT (3301 million pounds) in 2006 to 1.90 million MT (4181 million pounds) in 2010. However, sour cream and dips showed a relatively steady production volume (0.57 million MT (1256 million pounds) to 0.59 million MT (1292 million pounds)), whereas buttermilk production declined from 0.23 million MT (504 million pounds) to 0.21 million MT (473 million pounds).

During 2001–2006, per capita consumption of skim milk, 2% milk and whole milk declined slightly. In 2008, whole-milk consumption per capita was 22.9 kg (50.7 pounds), followed by 28.5 kg (62.9 pounds) for 2% milk, 10.2 kg (22.4 pounds) for 1% milk and 12.3 kg (27.1 pounds) for nonfat milk (Schultz, 2011b). Compared to the previous year, the 2010 total sales of conventional fluid milks declined by 1.8%. Whole-milk sales fell by 5.4%, nonfat white milk by 1.4% and flavored whole milk by 4.1%. However, sales of low-fat white milk and flavored reduced-fat milk increased by 2.3 and 1.1%, respectively.

The frozen dessert category comprised 385 plants in 2010. These plants manufactured 3452 million l (912 million gallons) of regular ice cream, 1438 million l (380 million gallons) of low-fat ice cream, 188 million l (49.7 million gallons) of frozen yogurt and 187 million l (49.3 million gallons) of sherbet (Schultz, 2011a). The most popular flavor of ice cream continued to be vanilla (29%), followed by chocolate (14%) and strawberry (3.3%). The per capita consumption of regular ice cream in 2008 was 6.3 kg (13.9 pounds); that of low-fat ice cream was 3.1 kg (6.8 pounds). The per capita consumption of ice cream (10% fat or less) has declined in recent years. However, the premium ice-cream (16–18% fat) market has prospered. Also, frozen-yogurt consumption was 1.9 kg (4.3 pounds) per person (Schultz, 2011a).

Dairy farmers and dairy processors alike abide by strict state and federal sanitary standards. Grade A Pasteurized Milk Ordinance (PMO) regulations are basically the

Table 1.3 Production of dairy products in the USA during 2006–2010. Adapted from IDFA (2011) and USDA (2011b).

	Million pounds for year				
Product	**2006**	**2007**	**2008**	**2009**	**2010**
Butter	1448	1533	1644	1572	1564
Natural cheese	9525	9777	9913	10074	10436
Processed cheese[a]	2349	2287	2202	2198	2124
Frozen desserts[d]	1576	1567	1540	1509	1481
Ice creams[d]					
Regular	982	956	931	918	912
Low-fat and nonfat	393	396	399	416	396
Cottage cheese[b]	778	783	723	738	742
Milk (plain)					
Whole	16443	15736	15309	15021	14192
Reduced- and low-fat	24271	24698	19125	19404	18630
Nonfat	8123	8203	8246	8231	8285
Other fluid milk products	894	1093	207	654	1211
Flavored milk and drink	4452	4368	4308	4198	4800
Fluid cream[c]	2459	2529	2456	2452	2338
Egg nog	132	122	124	128	127
Refrigerated yogurt	3301	3476	3570	3832	4181
Frozen yogurt[d]	66	74	79	46	50
Sour cream and dips	1256	1313	1278	1275	1292
Buttermilk	504	508	547	580	473

[a] Includes process cheese, foods, spreads and cold pack.
[b] Includes creamed, low-fat and nonfat cottage cheese.
[c] Includes half and half, light cream and heavy cream.
[d] Millions of gallons.

recommendations of the Public Health Service of the Food and Drug Administration (FDA) of the United States Department of Health and Human Services (USDHHS, 2009). The PMO is meant for voluntary adoption, but its importance in ensuring the quality and safety of the milk supply in the country is recognized by the dairy industry as well as by state regulatory and sanitation officials. The PMO is a constantly evolving set of regulations designed to accommodate advancements and developments in science and technology related to milk production, processing, packaging and distribution. From time to time, modifications in the regulations are adopted following an agreement among the representatives of government, industry (milk producers, processors, equipment manufacturers and suppliers), academia and research institutions. To conform to the PMO, dairy farms and dairy plants are visited regularly by representatives of government regulatory agencies, who conduct quality-assurance and safety inspections. The inspectors confirm herd health, oversee veterinary practices, monitor sanitation of the facilities and milking equipment, and verify that the milk is being rapidly cooled and properly stored before delivery to processing facilities. They also ensure that the processing of milk is in accordance with the state and federal food laws. In some instances, state standards differ and may be even more stringent than the federal standards. The state, and in some cases local communities, has jurisdiction over standards for milk in its own market. The reader is referred to Chapter 3 for information on the regulatory requirements for milk production, transportation and processing. Chapter 4 details product standards and labeling.

The PMO defines Grade A specifications and standards for milk and milk products in order to facilitate the movement of milk across state lines. Market milk, cream, yogurt, cultured buttermilk and sour cream are governed by the Grade A standards. Reciprocity rights maintain that milk conforming to the PMO sanitary standards in one state will not require further inspection for acceptance by another state.

The dairy-food industry has consolidated and continued to make large investments in new, state-of-the-art dairy manufacturing facilities. During the past decade, such developments have enabled a drastic reduction in the number of manufacturing facilities, while total output has increased by 4–5% annually. Continued investment will mean still lower processing costs and higher milk output.

1.4 Fermented/cultured dairy products

Fermented dairy foods have constituted a vital part of human diet in many regions of the world since times immemorial. They have been consumed ever since the domestication of animals. Evidence for the use of fermented milks comes from archeological findings associated with the Sumerians and Babylonians of Mesopotamia, the Pharoes of northeast Africa and the Indo-Aryans of the Indian subcontinent (Chandan, 1982, 2002; Vedamuthu, 1991; Ahmed and Wangsai, 2007; Tamime and Robinson, 2007; Chandan and Nauth, 2012,). Ancient Indian scriptures, the Vedas, dating back some 5000 years, mention *dadhi* (modern dahi) and buttermilk. Also, the ancient Ayurvedic system of medicine cites fermented milk (*dadhi*) for its health-giving and disease-fighting properties (Aneja *et al*., 2002).

Historically, products derived from fermentation of the milk of various domesticated animals resulted in conservation of valuable nutrients which would otherwise deteriorate rapidly under the high ambient temperatures prevailing in South Asia and the Middle East. Thus the process permitted consumption of milk constituents over a period significantly longer than was possible for milk itself. Concomitantly, conversion of milk to fermented milks resulted in the generation of a distinctive viscous consistency, smooth texture and unmistakable flavor. Furthermore, fermentation provided food safety, portability and novelty for the consumer. Accordingly, fermented dairy foods evolved into the cultural and dietary ethos of the people residing in the regions of the world where they owe their origin.

Milk is a normal habitat of a number of lactic-acid bacteria, which cause spontaneous souring of milk held at bacterial-growth temperatures for an appropriate length of time. Depending on the types of lactic-acid bacteria gaining entry from environmental sources (air, utensils, milking equipment, milking personnel, cows, feed), the sour milk attains a characteristic flavor and texture.

Approximately 400 diverse products derived from the fermentation of milk are consumed around the world. As mentioned before, fermentation conserves vital nutrients of milk. Simultaneously, it modifies certain milk constituents to enhance their nutritional status, and furnishes to the consumer live and active cultures in significant numbers, providing distinct heath benefits beyond conventional nutrition. The fermented-milk products may be termed "functional foods." They represent a significant and critical sector of human diet. The products fit into the cultural and religious traditions and dietary patterns of the people who consume them. In addition to the main ingredient, milk, other food ingredients are incorporated, innovating a range of nutritional profiles, flavors, textures and mouth feels, thereby offering an array of choices for the consumer.

The fermented foods and their derivatives constitute a staple meal, or may be consumed as an accompaniment to a meal. They may be also used as a snack, drink, dessert, condiment or spread, or as an ingredient of cooked dishes.

The diversity of fermented milks may be ascribed to:

- Use of milk obtained from a variety of domesticated animals.
- Application of diverse microflora as starters.
- Addition of sugar, condiments, grains, fruits and nuts to create a variety of flavors and textures.
- Application of additional preservation methods; for instance, freezing, concentrating and drying.

1.5 Occurrence and consumption of fermented milks in various regions

The diversity of fermented milks in various regions of the world is illustrated in Table 1.4.

The variety of fermented milks in the world may be ascribed to various factors.

1.5.1 Milk of various species

Milk of various domesticated animals differs in composition and produces fermented milk with a characteristic texture and flavor (Table 1.5).

The milk of various mammals exhibits significant differences in total solids, fat, mineral and protein content. The viscosity and texture characteristics of yogurt are primarily related to its moisture content and protein level. Apart from quantitative levels, protein fractions and their ratios play a significant role in gel formation and strength. Milk proteins further consist of caseins and whey proteins with distinct functional properties. In turn, caseins consist of α_{s1}-, β- and κ-caseins. The ratios of casein fractions and the ratios of casein to whey protein differ widely in milks of various mammals. Furthermore, pretreatment of the milk of different species prior to fermentation produces varying magnitudes of protein denaturation. These factors have a profound effect on the rheological characteristics of fermented milks, leading to bodies and textures ranging from drinkable fluid to firm curd. Fermentation of the milk of buffalo, sheep and yak produces a well-defined custard-like body and firm curd, while the milk of other animals tends to generate a soft gel consistency.

Cow milk is used for the production of fermented milks, including yogurt, in a majority of the countries around the world. In the Indian subcontinent, buffalo milk and blends of buffalo and cow milk are used widely for dahi (a type of fermented milk) making, using mixed mesophilic cultures (Aneja *et al*., 2002). Buffalo milk is the base for making yogurt using thermophilic cultures in several Asian countries, whereas sheep, goat and camel milk are the starting materials of choice for fermented milks in several Middle Eastern countries.

1.5.2 Cultures for production of fermented milks

Various microorganisms characterize the diversity of fermented milks around the world. Lactic fermentation by bacteria transforms milk into the majority of products (Salampessy and Kailasapathy, 2011). A combination of lactic starters and yeasts is used for some

Table 1.4 Major fermented dairy foods consumed in different regions of the world. Adapted from Chandan (2002), Josephsen and Jespersen (2004), Tamime and Robinson (2007) and Yildiz (2010).

Product name	Major country/region
Acidophilus milk	USA, Russia
Ayran	Turkey, Azerbaijan, Bulgaria, Macedonia, Kazakhstan, Kyrgyzstan
Ayrani	Cyprus
Busa	Turkestan
Chal	Turkmenistan
Cieddu	Italy
Cultured buttermilk	USA
Dahi/dudhee/dahee	Indian subcontinent
Donskaya/varenetes/kurugna/ryzhenka/guslyanka	Russia
Dough/ abdoogh/mast	Afghanistan, Iran
Ergo	Ethiopia
Filmjolk/fillbunke/fillbunk/surmelk/taettemjolk/tettemelk	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
Lassi, Mattha, Ghol, Chhas	India, Bangladesh, Pakistan, Nepal
Leben /laban/laban rayeb	Lebanon, Syria, Jordan
Mazun/matzoon/matsun/matsoni/madzoon	Armenia
Mezzoradu	Sicily
Pitkapiima	Finland
Roba/rob	Iraq
Shosim/sho/thara	Nepal
Raita	India, Pakistan
Shrikhand	India
Skyr	Iceland
Tan/Tahn	Armenia
Tarag	Mongolia
Tarho/taho	Hungary
Viili	Finland
Yakult	Japan
Yiaourti	Greece
Ymer	Denmark
Zabady/zabade	Egypt, Sudan

products, and in a few cases lactic fermentation combined with molds makes up the flora. For a summary of starter cultures around the world, see Table 1.6.

1.5.3 Forms of fermented milks

Fermented milks may be mixed with water to make a refreshing beverage. Salt, sugar, spices or fruits may be added to enhance taste. Liquid yogurt is the prime example. Spoonable yogurt has significant commercial importance all over the world. It is sold in cups and tubes. In the USA, the 2010 yogurt production in 116 processing plants was 1.9 billion kg

Table 1.5 Approximate composition of the milk of mammals used for fermented milks. Adapted from Chandan and Shahani (1993) and Chandan (2002).

Mammal	% total solids	% fat	% total protein	% casein	% whey 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

Table 1.6 Starter cultures used in the manufacture of commercial fermented milks. Adapted from Chandan and Shahani (1995), Josephsen and Jespersen (2004), Tamime and Robinson (2007) and Chandan and Nauth (2012).

Product	Primary microorganism(s)	Secondary/optional-microorganism(s)	Incubation temperature and time	Major function of culture
Yogurt	*Lb. delbrueckii* subsp.b*ulgaricus* *Strept. thermophilus*	*Lb. acidophilus* *Bifidobacterium longum/bifidum/infantis* *Lb.casei/lactis/rhamnosus/helveticus/reuteri*	43–45 °C/2.5 hours	Acidity, texture, aroma, flavor, probiotic
Cultured buttermilk and sour cream	*Lc. lactis* subsp. *lactis* *Lc. lactis* subsp. *cremoris* *Lc. lactis* subsp. *lactis* var. *diacetylactis*	*Leuconostoc lactis* *Leuconostoc mesenteroides* subsp. *cremoris*	22 °C/12–14 hours	Acidity, flavor, aroma
Probiotic fermented milks	*Strept. thermophilus* *Lb. acidophilus* *Lb. reuteri* *Lb. rhamnosus GG* *Lb. johnsoni* *Lb. casei*, *Bifidobacterium longum/bifidus*	*Lc. lactis* subsp. *lactis/cremoris*	22–37 °C/ 37–40 °C/ 8–14 hours	Acidity, flavor, probiotics
Kefir	*Lc. lactis* subsp. *lactis/cremoris* *Lb. delbrueckii* subsp.*bulgaricus* *Lb. delbrueckii subsp lactis* *Lb. casei/helveticus/brevis/kefir* *Leuconostoc mesenteroides/dextranicum*	Yeasts: *Kluyveromyces marxianus* subsp. *marxianus* *Torulaspora delbruecckii* *Saccharomyces cerevisiae* *Candida kefir* Acetic-acid bacteria: *Acetobacter aceti*	15–22 °C/ 24–36 hours	Acidity, aroma, flavor, gas (CO_2), alcohol, probiotics
Koumiss	*Lb. delbrueckii subsp. bulgaricus* *Lb. kefir/lactis* Yeasts: *Saccharomyces lactis* *Saccharomyces cartilaginosus* *Mycoderma* spp.	Acetic-acid bacteria: *Acetobacter aceti*	20-25 °C/ 12–24 hours	Acidity, alcohol, flavor, gas (CO_2)

(4.2 billion pounds) (Schultz, 2011a). The current yogurt retail market is estimated to be over 4 billion USD. Greek-yogurt consumption is rising rapidly, and in 2012 it commanded >30% of the total yogurt market. The per capita consumption of all types of yogurt in the USA in 2010 was 6.14 kg (13.53 pounds) (IDFA, 2011), which is only 21% of the per capita consumption in Sweden, reported to be 28.48 kg (62.8 pounds). To enhance its health appeal, the trend now is to deliver prebiotics as well as probiotic organisms through conventional yogurt (Sanders and Marco, 2010). In many countries, yogurt and fermented milks with probiotic cultures are available. These are made with defined cultures that have been scientifically documented to display certain health benefits (Sanders, 2007; Chandan and Kilara, 2008; Chandan, 2011). It has been estimated that about 80% of the yogurt sold in the USA contains probiotic *Lactobacillus acidophilus* (Schultz, 2011a). Yogurt is regarded as a functional food. It is being used as an ingredient in breakfast cereals, ice cream, food for cats and dogs, tooth paste, mouthwash, facial masks and suntan products (Schultz, 2011a). Sour-cream production in the USA totaled 0.544 billion kg (1.2 billion pounds) in 2010. The number of plants manufacturing sour cream was 116.

Yogurt/buttermilk may be concentrated by removing whey via straining through cloth or by mechanical centrifugation to generate high-protein product. This forms the basis of Greek yogurt in Europe and North America. The concentrate may be mixed with herbs, fruit, sugar or flavorings to yield shrikhand in India, quarg/tvorog/topfen/taho/kwarg in Central Europe and fromage frais in France. Similarly, cream cheese and Neufchâtel cheese are obtained by culturing their respective bases standardized for fat and nonfat solids.

To extend shelf-life, fermented milks and yogurts may be sun-dried to concentrate them or spray-dried to get a powder form. Leben zeer of Egypt and than/tan of Armenia are examples of concentrated yogurt *without* whey removal. In Lebanon, the concentrated yogurt is salted, compressed into balls, sun-dried and preserved in oil. Another way to preserve yogurt is to smoke it and dip it in oil. Labneh anbaris and shanklish are partially dried yogurt products preserved in oil. Spices are added to shanklish and the balls produced are kept in oil. In Iran, Iraq, Lebanon, Syria and Turkey, the concentrated yogurt is mixed with wheat products and sun-dried to get kishk. More information on this topic is available in Chapter 19.

Frozen yogurt is available in North America and countries around the world.

1.6 Major commercial fermented milks

1.6.1 Yogurt

Yogurt represents a very significant dairy product worldwide in modern times. It is a semi-solid fermented product made from a heat-treated standardized milk mix by the activity of a symbiotic blend of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* (Clark and Plotka, 2004; Ozer, 2010). In certain countries, the nomenclature "yogurt" is restricted to the product made exclusively from the two lactic cultures, whereas in other countries it is possible to label a product as "yogurt" if it is made with yogurt cultures and adjunct probiotic cultures. The more common adjunct cultures are *Lactobacillus acidophilus*, Bifidobacterium spp., *Lactobacillus reuteri*, *Lactobacillus casei, Lactobacillus rhamnosus GG*, *Lactobacillus gasseri* and *Lactobacillus johnsonii LA1* (Chandan, 1999; Pannell and Schoenfuss, 2007; Maity and Misra, 2009; Chandan and Nauth 2012). For a detailed account of the health attributes of probiotics, the reader is referred to clinical studies summarized in USProbiotics (2012).

Yogurt can be produced from the milk of cow, buffalo, goat, sheep, yak and other mammals. However, in industrial production of yogurt, cow milk is the predominant starting material. To get a custard-like consistency, cow milk is generally fortified with nonfat dry milk, milk-protein concentrate or condensed skim milk. Varieties of yogurt available include plain, fruit-flavored, whipped, drinking-type, smoked, dried, strained/Greek and frozen. Details of yogurt technology are given in various chapters and texts (Chandan and Shahani, 1993; Chandan, 1997; Mistry, 2001; Robinson *et al*., 2002; Tamime and Robinson, 2007; Gurakan *et al*., 2010; Chandan and Nauth, 2012). In order to meet the regulatory obligations regarding food safety, product standards and labeling, it is imperative to conduct standard analytical tests, as discussed by Deibel and Deibel (2008).

The popularity of yogurt has been propelled by its perceived health benefits. The health-promoting attributes of consuming yogurt containing live and active cultures are well documented (Chandan, 1989; Fernandes *et al*., 1992; Chandan and Shahani, 1993; Patel and Walker, 2004; Yildiz, 2010; USProbiotics, 2012). The current trend of using prebiotics and probiotic cultures in the manufacture of fermented milks and yogurt products is supported by clinical trials (Chandan, 1999, 2007, 2011; Khurana and Kanawjia, 2007; Sanders, 2007). The beneficial effects documented in numerous studies and reviews include prevention of cancer, reduction in diarrhea associated with travel, antibiotic therapy and rotavirus, improvement of gastrointestinal health, enhancement of immunity of the host, amelioration of lactose-intolerance symptoms, protection from infections caused by food-borne microorganisms, control of vaginitis and vaccine-adjuvant effects (Chandan and Kilara, 2008). More information is given in Chapter 20, 21 and 22 of this book.

Following the world trends relating to the enhanced consumption of fermented milks, the per capita sales of yogurt in the USA have also shown enormous growth. The past 3 decades have witnessed a dramatic rise in per capita yogurt consumption, from nearly 1.13 kg (2.5 pounds) in 1980 to 6.12 kg (13.5 pounds) in 2010 (IDFA, 2011). Figure 1.1 illustrates the trends in per capita consumption of yogurt, sour cream and dips and buttermilk in the last decade. The increase in yogurt consumption may be attributed to yogurt's perceived natural and healthy image, providing to the consumer convenience, taste and wholesomeness attributes. Sour-cream consumption per person increased slightly in 2010 to 1.90 kg (4.2 pounds), but this was below 1.99 kg (4.4 pounds), the record level observed in the years 2005 and 2007. Buttermilk consumption per person continues to decline from 0.99 kg (2.2 pounds) in 2000 to 0.68 kg (1.5 pounds) in 2010.

In the year 2010, yogurt sales in the USA topped 1896 million kg (4181 million pounds). Yogurt is widely used as a breakfast food, snack or lunchtime meal.

It is interesting to note that cultured-buttermilk consumption is on the decline (Figure 1.1) as yogurt registers its significant growth. Of late, Greek yogurt has exhibited a significant growth within the yogurt category, capturing approximately 30% of the total yogurt market. The rise in yogurt consumption is also related to the choices available in the marketplace. Besides the varieties of flavors, diversification in the yogurt market includes different textures and packaging innovations—fulfilling consumer expectations of health-food trends, convenience and portability—plus a magnitude of eating occasions.

Buttermilk sales declined from 471 million kg (1039 million pounds) in 1987 to 214 million kg (472 million pounds) in 2010. Sour-cream-and-dips sales have grown from 315 million kg (694 million pounds) in 1987 to 586 million kg (1292 million pounds) in 2010. The recent popularity of Mexican cuisine has in part enhanced the consumption of sour cream.

Figure 1.2 illustrates the segmentation of various forms of yogurt in the US market.

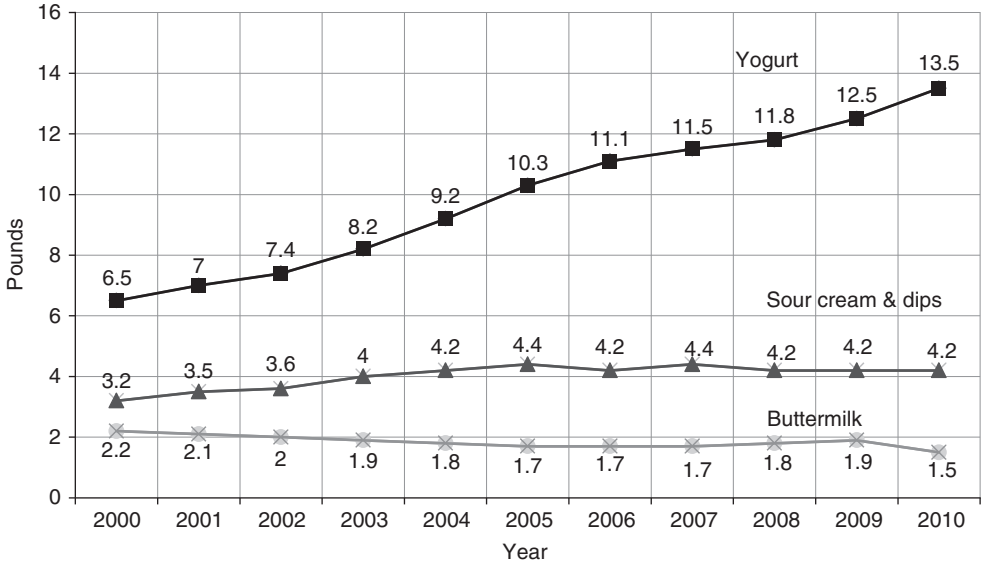

Figure 1.1 Trends in the per capita consumption of refrigerated yogurt, sour cream and dips and buttermilk in the USA. Adapted from IDFA (2011).

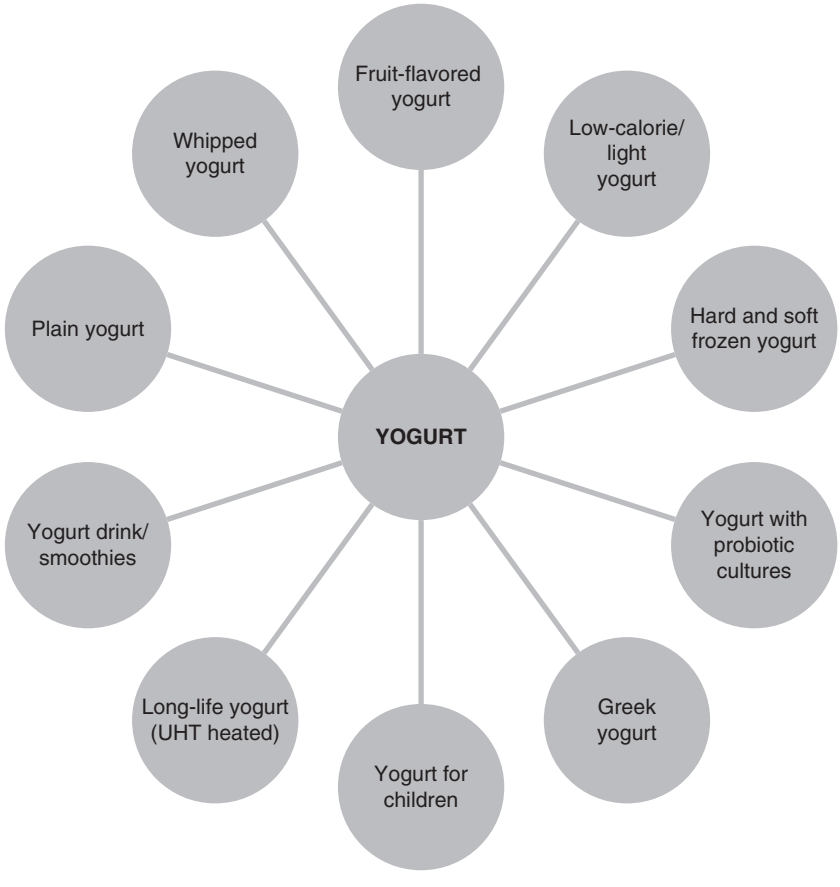

Figure 1.2 Segmentation of the yogurt market. Adapted from Chandan and Nauth (2012).

1.6.2 Cultured buttermilk

Cultured buttermilk is an important fermented milk in the USA. It is obtained from pasteurized skim or part-skim milk cultured with lactococci and aroma-producing bacteria leuconostocs. Generally, milk is standardized to 9–10% milk solids-not-fat (MSNF) and <0.5% fat and is heat-treated at 85 °C (185 °F) for 30 minutes or at 88–91 °C (178–196 °F) for 2.5–5.0 minutes. After homogenization at 137 kPa (2000 psi), it is inoculated with lactic starter and ripened for 14–16 hours at 22 °C (72 °F). The pH should be 4.5. The coagulum is broken and blended with 0.18% salt and butter flakes while cooling to 4 °C (39–40 °F). The product is packaged in paper/plastic containers.

Buttermilk is primarily consumed as a beverage. In addition, it is used in cooking, especially in bakery items. The reader is referred to Chapter 17 of this book for a detailed discussion on cultured buttermilk.

1.6.3 Sour/cultured cream

Sour/cultured cream is a significant fermented-milk product in North America. It is manufactured by culturing pasteurized cream with lactococci and aroma-producing bacteria leuconostocs (Table 1.6). It has a butter-like aroma and flavor. Cream is standardized to 18% fat, 9% MSNF and 0.3% stabilizer to get a stable acid gel. The blend is heat-treated at 72 °C (162 °F) for 20 minutes and homogenized at 172 kPa (2500 psi) at 72 °C (162 °F), single-stage, two times. It is cooled to 22 °C (72 °F), inoculated with 2–5% of the starter and cultured for 16–18 hours at 22 °C (72 °F) or until the pH drops to 4.7. It is packaged in cartons and cooled to 4 °C (39–40 °F) to develop a thick consistency. Individual serving cups/packages are also available. In this case, fermentation is carried out by filling the sour-cream base seeded with the starter, then packaging, incubating and cooling.

Crème fraiche is popular in France and other European countries (Goddik, 2012). This product resembles sour cream, except it contains a higher proportion of fat (50%, as compared to 18% in sour cream) and has a higher pH of 6.2–6.3.

Cultured cream is used as a topping on vegetables, salads, fish, meats and fruits, and as an accompaniment to Mexican meals. It is also used as a dip, as a filling in cakes, and in soups and cookery items. Chapter 18 contains detailed discussion on sour/cultured cream.

1.6.4 Culture-containing milks

These are seeded but unfermented milks which deliver significant doses of probiotic microorganisms. In this case, the growth of the culture is intentionally avoided in order to preserve the fresh taste of the milk. Accordingly, the product is maintained at refrigeration temperature at all times. In the past, acidophilus milk was marketed by fermenting sterilized milk with *Lactobacillus acidophilus*. The inoculated base was incubated at 37 °C (98.6 °F) for 24 hours. The plain product developed a titratable acidity of 1–2%. Consequently, it had a very harsh, acidic flavor. Its popularity declined rapidly as sweetened yogurt with fruit flavors began to dominate the market. However, *L. acidophilus* does have a strong consumer appeal. Most of the yogurts (80%) now sold in the USA contain *L. acidophilus*, which is either added after culturing with yogurt culture or is cocultured with yogurt culture.

Sweet acidophilus milk is an acceptable substitute for acidophilus milk. The product is based on pasteurized and chilled low-fat milk, to which a concentrate of *Lactobacillus*

acidophilus culture is incorporated to deliver a minimum of 1 million organisms per milliliter. It is sold in refrigerated form, with a shelf-life of 2–3 weeks. More recently, additional probiotic organisms have been incorporated in order to enhance healthy connotation of the product. Among the additional cultures are *Bifidobacteria*, *Lactobacillus delbrueckii* subsp. *bulgaricus, Sterptococcus thermophilus* and *Lactobacillus casei*. Chapter19 discusses the product in detail.

1.7 Scandinavian fermented milks

Scandinavians have a high per capita consumption of fermented milks. Sweden is reported to consume 28.48 kg (62.8 pounds) of yogurt per person (Schultz, 2011a). There are distinctive differences in flavor and texture among fermented milks in Scandinavian countries. These are generally characterized by a ropy and viscous body. They include viili, ymer, skyr, langfil, keldermilk and several local products.

1.7.1 Viili

Viili, a fermented milk of Finland, is sold as a plain as well as a fruit-flavored product. Its fat content ranges from 2 to 12%. Milk standardized to the required fat level is heat-treated at 82–83 °C (180–181 °F) and held at this temperature for 20–25 minutes. Homogenization is avoided. It is then cooled to 20 °C (39–40 °F) and inoculated with 4% starter, consisting of diacetyl-producing *Lc. lactis* subsp. *lactis*, *Leuc. mesenteroides* subsp. *cremoris* and a fungus, *Geotrichum candidum*. Following packaging in individual cups, incubation at 20 °C (39–40 °F) for 24 hours results in acid development (0.9% titratable acidity) and a cream layer on the top of the cup. The cream layer traps the fungus, giving a typical musty odor to the product (Mistry, 2001). The fermentation process also elaborates mucopolysaccharides, imparting ropiness and viscosity.

1.7.2 Ymer

Ymer is a Danish product with characteristic high protein (5–6%) and a pleasant acidic flavor with buttery notes. Protein enrichment may be achieved by ultrafiltration technology prior to fermentation. Alternatively, the traditional process involves removal of whey by draining curd after fermentation or inducing separation of whey by heating curd and then removing it. The standardized milk base is heated to 90–95 °C (194–204 °F) for 3 minutes and cooled to 20 °C (39–40 °F). It is then inoculated with a mesophilic culture consisting of a blend of *Lc. lactis* subsp. *lactis* biovar. *diacetylactis* and *Leuc. mesenteroides* subsp. *cremoris*. After incubation at 20 °C (39–40 °F) for 18–24 hours, the product is cooled and packaged.

1.7.3 Skyr

Skyr is another Scanadanavian product. In Iceland, it is obtained by fermenting skim milk with yogurt culture and a lactose-fermenting yeast. A small amount of rennet may be used to develop a heavier body. The milk base is cultured at 40 °C (104 °F) until a pH of 4.6 is

achieved, in 4–6 hours. It is then allowed to cool to 18–20 °C (64–68 °F) and held for an additional 18 hours for further acidification to pH 4.0. Following pasteurization, the mass is centrifuged using a clarifier-type separator at 35–40 °C (95–104 °F) to concentrate the solids and achieve a protein level of around 13%. Skyr has a flavor profile consisting of lactic acid, acetic acid, diacetyl, acetaldehyde and ethanol.

1.8 Russian and Eastern European fermented milks

1.8.1 Kefir

Kefir is a relatively popular fermented milk in Russia, Eastern Europe and certain Asian countries. In addition to lactic fermentation, this product employs yeast fermentation. Thus, a perceptible yeast aroma and alcohol content characterize this product. Also, a fizz is noticed due to the production of carbon dioxide as a result of yeast growth. Kefir utilizes natural fermentation of cow milk with kefir grains. Kefir grains consist of a curd-like material, which is filtered off after each use and reused for inoculation of the next batch. Kefir grains contain polysaccharides and milk residue embedded with bacteria *Lb. kefir*, *Lb. kefirogranum* and species of leuconostocs, lactococci and lactobacilli. Along with bacteria, the grains contain yeasts including *Saccharomyces kefir*, *Candida kefir* and *Torula* spp. Milk is heated to 85 °C (185 °F) for 30 minutes, cooled to 22 °C (72 °F) and incubated with kefir grains for 12–16 hours to obtain traditional kefir. Typical flavor compounds in kefir are lactic acid, acetaldehyde, diacetyl, ethanol and acetone.

Kefir is now available in the USA. It varies from traditional kefir in that it is 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 sugar and fruit juices/flavors.

1.8.2 Koumiss

Koumiss is obtained from mare or cow milk, using a more defined culture containing *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Lb. acidophilus* and Torula yeasts. This therapeutic product has perceived health benefits and is recommended for all consumers, especially those with gastrointestinal problems, allergies or hypertension/ischemic heart diseases (Mistry, 2001). Since mare milk has only 2% protein, no curdling is seen in the product. It contains 1.0–1.8% lactic acid, 1.0–2.5% ethanol and enough carbon dioxide to give it a frothy appearance.

1.9 Middle Eastern fermented milks

Fermented milk and their products have historically been associated with the Middle East.

1.9.1 Laban rayeb

This is prepared at home by pouring raw whole milk into clay pots and allow the fat to rise at room temperature. The top cream layer is removed, and partially skimmed milk is allowed to undergo spontaneous fermentation. Some variations of the product exist. One is called laban khad, which is fermented in a goat pelt. Another is named laban zeer, which is distinctly

fermented in earthenware pots. The organisms responsible for fermentation are thermophilic lactobacilli in the summer and mesophilic lactococci in the winter (Mistry, 2001).

1.9.2 Kishk

This is obtained from laban zeer. Wheat grains are soaked, boiled, sun-dried and ground into powder. The blend of wheat and laban zeer is allowed to ferment further for another 24 hours and then portioned into small lumps and sun-dried. The dried kishk has 8% moisture and 1.85% lactic acid. After proper packaging, its shelf-life is of the order of several years. Kishk may contain spices.

1.9.3 Labneh

This is prepared by concentrating fermented milk after the fermentation process is completed. The milk is fermented with a yogurt culture and then concentrated using a quarg separator. This product contains 7–10% fat. For more details see Chapter 13.

1.9.4 Zabady

This is an Egyptian product obtained by fermenting milk which has been concentrated by boiling and then fermented with yogurt culture. Further concentration of milk solids is achieved by heating it and separating the whey.

1.10 South Asian fermented milks

The following fermented milks and products derived therefrom are of commercial importance in India, Pakistan and Bangladesh (Aneja *et al*., 2002).

1.10.1 Dahi

Also called curd, dahi is a semisolid product obtained from pasteurized or boiled buffalo or cow and buffalo milk by souring, natural or otherwise, by a harmless lactic-acid or other bacterial culture. Dahi may contain cane sugar. It should have at minimum the same percentage of fat and solids-not-fat as the milk from which it is prepared (Aneja *et al*., 2002).

Use of the right type of culture is essential to the manufacture of good-quality dahi. A mixed culture containing *Lactococcus lactis* subsp. *lactis*, *Lactococcus latcis* subsp. *diacetilactis* or *Leuconostoc* species, and *Lactococcus lactis* subsp. *cremoris* in the ratio of 1 : 1 : 1 may be used. In addition, *Streptococcus thermophilus* may be a component of dahi culture, or a culture composed of *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *diacetilactis* may be employed.

Mild dahi is made from mesophilic lactococci. Leuconostocs may be used as adjunct organisms for an added buttery aroma and flavor. Sour dahi contains additional cultures belonging to a thermophilic group, which are generally employed in the manufacture of yogurt. These thermophilic organisms grow rapidly at 37–45 °C (98.6–113 °F), producing dahi in less than 4 hours.

1.10.2 Mishti doi

Mishti doi is a fermented-milk product with a cream to light-brown color, firm consistency, smooth texture and pleasant aroma. It contains 2–9% fat, 10–14% solids-not-fat and 17–19% sugar. The most common sweetener used is cane sugar. In some special varieties of mishti doi, fresh palm jaggery is used as a sweetener. Typically, a mix comprising 71.26% milk (3% fat, 9% solids-not-fat), 5.32% cream (35% fat), 5.42% nonfat dry milk and 18% crystalline sugar is blended. Caramel (0.1%) may be added as a flavor. The mix is heat-treated at 85–90 °C (185–194 °F) for 15 minutes and homogenized. The heating process develops a light-brown color in the mix. It is then cooled to 42 °C (107.6 °F). The starter is added at 1% level. Following dispersion of the starter, mishti-doi mix is dispensed into sanitized cups. The lids are heat-sealed to make the cups airtight and prevent leakage of the mix. The sealed cups are then incubated at 42 ± 1 °C (107–108 °F) for about 6–8 hours until the acidity develops to 0.7–0.8%. The product is moved to a cold room (4 °C/39–40 °F) with minimum disturbance, as the product at this stage has a weak body and an unstable top layer: excessive shaking will result in undesirable cracks on the top layer or in the curd mass.

Mishti doi is used as a dessert and snack in India and Bangladesh.

1.10.3 Shrikhand

This is a dahi-based product resembling Greek yogurt. The cultured milk or dahi is separated from whey to get chakka, which is blended with sugar, color, flavor and spices to reach a desired level of composition and consistency. The final product contains 8.5% fat, 10% protein, 42% sugar and 60% total solids. The acidity of the product is usually between 1.1 and 1.2%, expressed as lactic acid. Skim milk (9% MSNF, 0.05%fat) is heated to 90 °C (194.4 °F) for 10 seconds in a high-temperature–short-time (HTST) pasteurizer, cooled to 30 °C (86 °F) and inoculated with 0.25–0.50% dahi culture. After 8 hours of incubation or at a titratable acidity of 0.8%, the curd is ready for further processing. Chakka is prepared by separating the whey from dahi using a basket centrifuge, a quark separator or a desludging centrifuge. Shrikhand is prepared by adding sugar at a rate of 80% of the amount of chakka and mixed in a planetary mixer. A predetermined amount of plastic cream (80% fat) is added to the chakka, along with sugar and flavorings/spices, to obtain at least 8.5% fat in the finished product.

Shrikhand is used primarily as a snack and dessert.

1.10.4 Lassi

Lassi is a refreshing beverage derived from dahi. It is a popular drink in India, especially North India. Significant advances have been made towards the industrial production of lassi through the application of ultra-high-temperature (UHT) treatment of milk (Aneja *et al*., 2002). Standardized milk (9–10% solids-not-fat and 0.5–1.0% milk fat) is heated to 85 °C (185 °F) for 30 minutes or 91 °C (195.8 °F) for 2.5–5 minutes, cooled to 25 °C (77 °F) and cultured with dahi starter. It is then fermented at 25 °C (77 °F) to lower the pH to 4.5. The set curd is broken with the help of a stirrer, while 30% sugar solution is added to get 8–12% sugar concentration in the blend. In some variations, fruit flavor may be incorporated. The lassi is then homogenized at 13.7 kPa (2000 psi) and UHT-processed at 135–145 °C (280.4–293.0 °F) for 1–5 seconds and packaged aseptically, employing standard equipment.

Chapter 18 contains a detailed discussion of various fermented milks found in the world.

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