Chapter 6

Fermented beverages: geographical distribution and bioactive compounds with health benefits

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Introduction

One of the most important developments permitting the formation of civilization was the ability to produce and store large quantities of food. An overview of the human history of nutrition showed that traditional empirical knowledge has been used for the preservation and preparation of food products. Some of the earliest evidence of food preservation comes from the post−glacial era, from 15000 to 10000 BCE, and from 6000 to 1000 BCE the *fermentation* was used to produce beer, bread, wine, vinegar, yogurt, cheese, and butter [1]. Nowadays, fermented foods form a significant proportion, typically around one-third, of human food intake in all diets and in all regions of the world [2]. Fermentation is one of the oldest and most economical methods used in food preservation; it can be described as a desirable process of biochemical modification of primary food products brought about by microorganisms and their enzymes [3]. During this biochemical process, raw materials are fermented under specific conditions to create attractive and desirable products, enriched with improved flavor and texture, prolonged shelf-life, and fortified with health-promoting bioactive compounds (Fig. 6.1A) [4]. Beverages that are produced in this way represent an important part of human nutrition in practically every food culture around the world [5].

Fermentation can be performed either by natural or spontaneous microbial community, by *back-slopping*, in which a small quantity of the previous fermentate is used as inoculum for the next fermentation step, or by the addition of starter cultures. By spontaneous fermentation the raw material and its initial treatment will encourage the growth of an indigenous microbiota. As illustrated in Fig. 6.1B, three different types of fermentation processes are known to take place in beverages production, namely, alcoholic, lactic acid, and acetic fermentation. Alcoholic fermentation results in the production of ethanol by yeast (as in wine and beer). Lactic acid fermentation (homofermentative or heterofermentative) is mainly carried out by lactic acid−producing bacteria (LAB). Under excess aeration acetic acid bacteria (AAB, mainly *Acetobacter* spp.) convert alcohol to acetic acid in the presence of oxygen [6].

In most spontaneous fermentation a microbial succession takes place: quite often LAB will dominate initially followed by various species of yeasts. Molds only grow aerobically, limiting their occurrence in certain types of fermented products [7−9]. Lactic acid bacteria and yeasts are predominant in fermented dairy, cereal, and vegetable fermented foods and beverages. Also, AAB play a pivotal role in the production of some of these products. Generally, LAB produce lactic acid and other antimicrobial substances that inhibit the growth of harmful bacteria along with reducing the sugar content, thereby prolonging the shelf-life of the product, yeasts mostly produce aroma components and alcohols. When molds are involved in fermentation, they generally contribute by producing both intra- and extracellular proteolytic and lipolytic enzymes that highly influence the flavor and texture of the product [10]. *Fermented beverages (FBs)* are the hubs of consortia of microbiota and mycobiota (functional, nonfunctional, and pathogenic contaminants), which may be present as natural indigenous microbiota in uncooked plant or animal substrates, utensils, containers, earthen pots, or environments [11,12], or as a result of the intentional addition of the microorganisms as starter cultures in an industrial food fermentation process [13].

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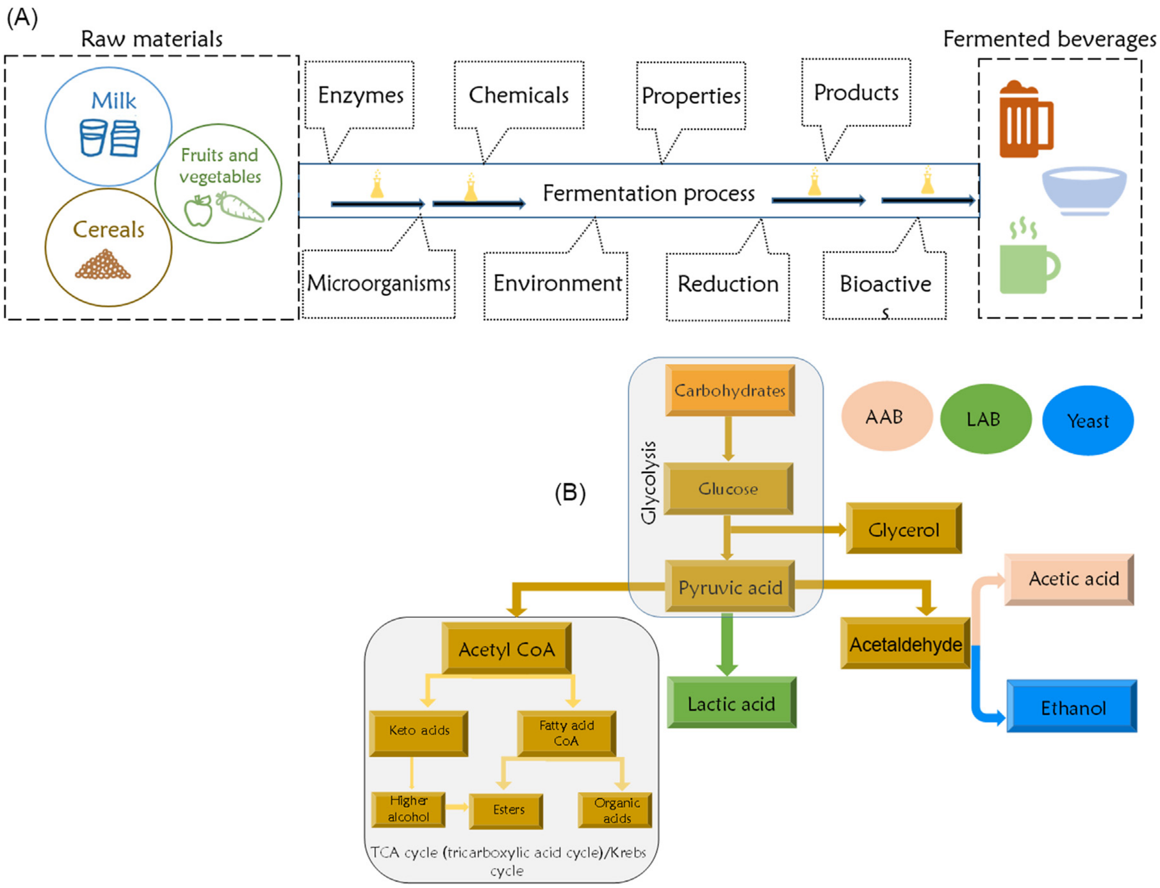

FIGURE 6.1 Overview of the transformation of fermented foods (A) with the mechanism of bacteria (AAB and LAB) and yeast metabolisms (B). *AAB*, Acetic acid bacteria; *LAB*, lactic acid−producing bacteria.

In physicochemical terms, Tamang and Fleet [10] were defined the fermented foods and beverages as products with the 3A or the A^3 connotation. This is because the acidic, alkaline, and alcoholic properties are the primary features of this food category. The major sensory properties of fermented foods are as follows: some of them are acidic in taste (low pH), such as lactic fermented foods ("kimchi," yogurt); some foods are alkaline in nature (high pH), such as "pidan"; some are alcoholic—beer, wine, saké, and "pulque." In lactic fermentation the substrates are kept in an airtight container (less or no oxygen or anaerobic conditions) to allow LAB to grow on starchy materials to obtain the acidic product. In alkaline fermentation, semianaerobic or aerobic conditions should be maintained to facilitate the growth of aerobic bacilli (mostly *Bacillus subtilis*) as in "kinema" and "natto." After saccharification (starch to glucose) and glycolysis (glucose to alcohol), CO_2 is obtained during the production of alcoholic beverages. Traditionally, the producers (ethnic people) know how to obtain desired products for consumption using their indigenous knowledge.

The fermentation of milk, cereals, and other substrates to produce beverages wit is indigenous to many regions of Asia, Africa, Europe, the Middle East, and South America. Different bacterial and yeast species are present in each case, which contribute to the unique flavors and textures present in the final product. The diversity of traditional FBs in Asia and Africa has been well described in many different review articles [14−16], while FBs traditional consumed in European societies have been extensively reviewed by Baschali et al. [5]. Because of the multitude of food−microbe combinations, there are thousands of different types of FBs. At least some forms of these products are consumed by nearly every culture worldwide. For example, boiled rice is the staple diet with ethnic fermented and nonfermented legume products, vegetables, pickles, fish, and meat on the side in the Far East, South and North Asia, and the Indian subcontinent, excluding western and northern India. In the west and north of India, wheat/barley-based bread/loaves are the staple diet together with milk and fermented milk products, meat, and fermented meats. This diet is also followed in West Asia, Europe, North America, Australia, and New Zealand. Sorghum/maize porridges are the main diets with ethnic fermented and nonfermented sorghum/maize/millet, cassava, wild legume seeds, meat, and milk products in Africa and South America [17]. Fermented foods are popular throughout the world and in some regions make a significant contribution to the diet of millions of individuals in many underdeveloped countries in Africa and Asia [18]. Instead, in North America and Europe, which have extremely efficient and rapid distribution systems and an overall availability of cooling and freezing systems, most of the traditional FBs, with the exception of fermented dairy (yogurt and cheese) and alcoholic beverages, have been replaced by fresh agricultural products, making the process of fermentation obsolete [19]. This trend, away from fermentation, seems to have come to a recent stop and is now gradually reversing, and recently, the scientific community has suggested that fermented food should be included as a part of the national dietary recommendation [20,21].

The closer the underlying that some fermented foods also promote human health, large cohort investigations have revealed strong associations between consumption of fermented dairy foods and weight maintenance [22]. Moreover, the evidence is accumulating for antidiabetic and antiobesity benefits of kimchi [23]. Several peptides and peptide fractions having bioactive properties have been isolated from yogurt, kefir, dahi, and other FBs. These and different peptides are being investigated for their antihypertensive, antithrombotic, satiety, opioid, immunomodulatory, osteogenic, and antioxidant effects [24]. Another biomolecule, conjugated linoleic acid, a fatty acid with putative athero-protective properties, can be enriched by LAB in the fermented dairy product [25]. In plant and vegetable fermentation the growth of fermentative bacteria enhances the conversion of phenolic compounds such as flavonoids to biologically active metabolites via expression of glycosyl hydrolase, esterase, decarboxylase, and phenolic acid reductase [26].

Many FBs have something known for their health-promoting attributes, this interest is now being exploited by the industry to develop a new generation of functional FBs. The global functional beverage market is a growing sector of the food industry. The modern consumers show increasing attention for foods that improve the well-being and reduce the risk of disease. As reported by Marsh et al. [27], fermented kinds of milk, especially yogurt-style products, are the most popular functional beverages with *kefir* in Western Europe and North America and *ymer* in Denmark being good examples. The functional food and drink market experienced a global increase in value terms of 26.7% from 2009 to 2013 [28]. With an annual average growth rate of about 8.5% the global market for functional foods is expected to exceed US$ 305.4 billion by 2020 [29].

The trends toward natural (minimally processed or without additives), high nutritional value, health-promoting, and flavor-rich beverages have been increasing with the consciousness of consumers [30]. Because of this, the present chapter is written considering the literature regarding traditional FBs with reputed *bioactive molecules* [31,30,29,28]. Special attention has been paid to the geographical distribution of FBs connected to the content of bioactive compounds, providing some guidance for researchers in further investigations and for industries in developing new products.

Diversity of substrates and microbial community in global fermented beverages

Every community in the world has distinct food culture including FBs, symbolizing the heritage and sociocultural aspects of the ethnicity. The word "culture" denotes food habits of ethnicity; another meaning for the same word "culture" is a cluster of microbial cells or inoculum, an essential biota for fermentation, often used in the microbiology [18]. Several researchers have reviewed the microbiology, biochemistry, and nutrition of fermented foods from different countries of Asia [1,32–35], Africa [16,36–39], Europe [2,5,15,40], and North and South America [41–46]. Many genera/species of microorganisms have been reported in relation to various FBs across the world. Here, there is an attempt to collate and review the updated information on globally FBs considering their microbial community and bioactive compounds content. In the following sections, different FBs are categorized as raw materials (substrate).

Diversity of traditional milk-based beverages and associated microbes

According to the International Dairy Federation (1988) "fermented milk is a milk product prepared from milk, skimmed or not, with specific cultures; the microflora is kept alive until the sale to the consumer and may not contain any pathogenic germ" [47]. For a reason of clarity the classification reported by Marshall [48], that considering the dominating microflora distinguish four categories of traditional fermented milk, is considered (Fig. 6.2).

Fermented dairy beverages were originally produced by spontaneous fermentation using wild starter cultures, so-called naturally fermented milk. Fermented milks are predominantly composed of lactic acid bacteria, even if the exact microbial content may vary depending on the source of milk (cow, buffalo, camel, goat, mare, sheep, and yak), treatment of the milk (e.g., pasteurization), use of starters, nature of the local environmental microbes present, temperatures, hygiene, the type and treatment of containers used, and the length of the fermentation process. Among the LAB genera involved in fermentations, two different mechanisms can be identified: *homolactic* or *heterolactic*. The first results in the production of lactic acid as the primary by-product of glucose fermentation. Instead, during the heterolactic fermentation ethanol, lactic acid and CO_2 are released from the glucose fermentation [49].

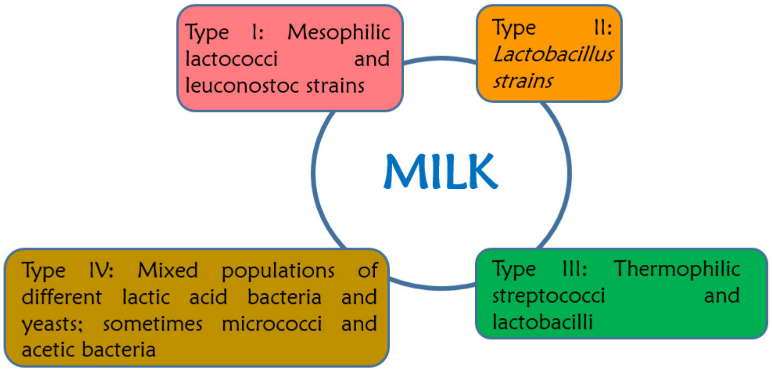

FIGURE 6.2 Milk fermentation process classified considering the dominant microflora [48].

TABLE 6.1 Dairy-based fermented beverages worldwide.

Continent	Country	Product name	Substrate	Microorganisms
Africa	Ghana	Nyarmie	Camel milk	LAB/yeast
	Ghana	Nunu	Cow milk	LAB/yeast
	East Africa of Kenya and Somalia	Suusac	Camel milk	LAB/yeast
	Rwanda	Kivuguto	Various milk sources	LAB and molds not identified
	Sudan	Garris	Camel milk	LAB/yeast
	Sudan	Rob	Various milk sources	LAB/yeast
Asia	Asiatic steppes and Mongolia	Koumiss/airag	Mare milk	LAB/yeast
	Caucasian region/Turkey	Kefir	Various milk sources	LAB/yeast/AAB
		Ayran	Cow milk	LAB
	China/Kazakhstan	Shubat	Camel milk/yeast	LAB
	Indonesian	Dadih	Buffalo/cow milk	LAB
	Nepal, India, Bhutan	Mohi	Cow milk	LAB/yeast
	Sikkim	Dahi	Cow/yak milk	LAB
	Turkey (Anatolia)	Torba yoghurt	Cow/goat/sheep milk	LAB
	India, Pakistan	Kassi	Cow/goat milk	LAB
Europa	Scandinavia	Cow milk	Viili	LAB
	Sweden		Tatmjolk	LAB
	Iceland	Sheep milk	Skyr	LAB

AAB, Acetic acid bacteria; *LAB*, lactic acid–producing bacteria.

Yeasts are able to multiply in milk and may result in spoilage or, conversely, in the enhancement of flavor (and alcohol production). The major species include *Saccharomyces cerevisiae*, *Kluyveromyces marxianus*, and *Candida lusitaniae* [50,51]. Since the quality of the final product is unpredictable, the production of FBs has been optimized utilizing commercial starter cultures (*Lactobacillus* strains) and controlled conditions (temperature, pH, and oxygen concentration). This type of fermented milk (Type II; Fig. 6.2) involved thermophilic bacteria, originally isolated from the human gastrointestinal tract, used in the production of FBs such as "Yakult" produced in Japan. However, industrial production of FBs, since it has already been published in many scientific papers, has not been taken into consideration in the present work [52–55]. The naturally fermented milk, which is undoubtedly the simplest and probably the oldest, is considered. The milk source and microorganisms involved in dairy beverages manufacture, as well as the bioactive compounds produced are given in Table 6.1. Based on this, it should be seen that the use of natural microbial cultures allows several communities around the world to develop different and characteristic fermented dairy products. The production of fermented milk-based beverages occurs especially in Europe, Africa, and Asia. Historically, fermented dairy products were mainly a key component in the diets of pastoral communities, but increasingly milk has also been playing an important role in the diets of the growing population of sedentarized pastoralists as well as urban communities [56]. Up to now, it has been possible to identify regional production of some traditional milk, based on the climate and temperature of growth of microorganisms used for fermentation. Fermented milk produced with mesophilic starters ("viili/taetmjolk," sour milk) is typical in north-east Europe, while that prepared with thermophilic starters (yogurt, Bulgarian milk, "ayran") are traditionally produced in Africa, Central and South Asia as well as in south-east European regions [47].

Mesophilic lactic acid–producing bacteria

Fermented milk, typically produced in Scandinavian, Central, and Eastern European countries, are dominating microflora and consists of mesophilic lactococci (Type I; Fig. 6.2), very often with the contribution of leuconostocs. These LAB generally grow in the temperature range from 10°C to 40°C with an optimum around 30°C. The important characteristics of fermented milk derived from mesophilic fermentations are the consistency, which is due to the lactic acid coagulation of milk proteins, the aroma and flavor produced by citric acid, and lactose fermentation. The "filmjölk," a Swedish mesophilic fermented milk beverage, is made by fermenting cow's milk with a diversity of strains. The bacteria metabolize lactose into lactic acid during growth and produce a limited amount of diacetyl, which gives "filmjölk" its characteristic aroma [57]. "Viili" is a traditional Finnish fermented milk product originally made in the summer as a way to preserve milk excesses. It is also known as "viilia"; similar and related products are "piima," "pitkapiima," and "viilipiima," from Finland; "långfil" and "tatmjolk" from Sweden; "taette" from Norway; and "ymer" from Denmark [58]. Most of these products share a thick and sticky consistency, with some degree of stretchiness plus a subtle sweet taste. Viili is produced by fermenting milk with special strains of *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris* producing extracellular polysaccharides [59].

Thermophilic lactic acid–producing bacteria

Thermophilic LAB (Type III; Fig. 6.2) responsible for the fermentation of milk are spontaneous microflora of milk collected in areas where the temperature exceeds 40°C [60,61]. The great diversity of physiological features and metabolic activities of these strains allows the production of milk with different nutritional and health values as well as different organoleptic properties. Among fermented dairy beverages produced, with thermophilic lactic acid bacteria, the most popular of course is *yogurt* [58]. The origin of yogurt is not very clear. According to some sources, its origin was in Asia, where the ancient Turks lived as nomads, while other authors are of the opinion that it comes from the Balkans [47]. Today, yogurt is the major commercial fermented milk around the world. Among the factors contributing to the great success of this fermented milk the image of a natural product, attractive organoleptic characteristics (fresh, acidulated taste, and pleasant flavor), nutritional value, prophylactic and therapeutic properties, and moderate cost (due to high productivity) can all be mentioned [62]. Yogurt can be produced from the milk of cow, buffalo, goat, sheep, yak, and other mammals, although cow's milk is predominant in industrial production.

"Skyr" is another fermented milk product made in Iceland. It is prepared from skimmed, boiled milk treated at 40°C with rennin and simultaneously with a starter derived from previously fermented milk, before its consumption. "Skyr" is mixed with whole fresh milk [63]. "Ayran" is a traditional Turkish fermented milk prepared from cow's milk and added water. It is often produced from goat's or sheep's milk as well. In India, different fermented milk such as "dahi," "lassi," "shrikhand," and "payodhi" are produced using thermophilic lactic acid bacteria. They are obtained from cow's or buffalo's or mixed milk and are similar to yogurt (dahi) or are concentrated and sweetened by the addition of sugar ("shrikhand" and "payodhi"). Also in the Middle East (Lebanon, Syria, and Jordan), cow's, goat's, or sheep's milk and thermophilic lactic acid bacteria are used to produce "leben," "lebneh," or "kishk." In Africa the "amasi" is a traditional FB consumed in South Africa and Zimbabwe, and its preparation involves thermophilic LAB fermentation for several days of raw milk in calabashes made of gourd, or in stone jars [36]. Produced from raw unpasteurized milk, "nunu" is also a spontaneously fermented yogurt-like product made in Ghana and other parts of West Africa [64].

Lactic acid–producing bacteria and yeast population

In the production of fermented milk of type IV (Fig. 6.2) the dominant microflora is composed of lactic acid bacteria combined with yeasts. Lactic acid bacteria represent mesophilic as well as thermophilic strains belonging to different species. Yeasts are mainly represented by *Kluyveromyces*, *Candida*, and *Saccharomyces* strains. Moreover, different yeast strains can be used, depending on the product and geographical region. The main products of microflora metabolism are lactic acid and ethyl alcohol; hence, these products can be called acid-alcoholic fermented milk. Certainly being the best known milk-based FB, the "kefir," alcohol-containing milk from Caucasian countries, is fermented by a coculture of yeasts and lactic acid bacteria. There are several ways of making "kefir": (1) it is produced by fermented milk with grains (traditional production); (2) the commercial process by the Russian or European method, which consists of a series fermentation process, beginning with the fermentation of the grains and using the percolate; and (3) kefir produced by using commercial starter cultures directly inoculated into the milk (industrial production) [65,66]. "Kefir" grains consist of a mixture of lactic acid bacteria, yeasts, and AAB. The nutritional benefits of "kefir" are related to nutrients such as carbohydrates, proteins, minerals, and vitamins. The health effects caused by "kefir" and "kefir" products may be attributed to several components such as lactic acid bacteria, yeasts, exopolysaccharides, organic acids, antioxidants, and bioactive peptides. In South Russia and Siberia the fermentation of horse milk results in "koumiss," also alcohol-containing yeasts and lactic acid bacteria as biological agents. Another alcoholic acid milk is "mazun" from Armenia, a FB made from cow, goat, or buffalo milk fermented at 30°C [67,68].

Examples of other FBs include "kivuguto" from Rwanda, "suusac" from East Africa, "nyarmie" from Ghana, and "rob" and "garris" from Sudan. Considering that most of these are derived from the spontaneous fermentation of milk by its innate microbiota, it is likely that the fermented milk, although known by different names, are actually quite similar and can be, in combination, referred to as naturally fermented milk [27].

Fermentation of cereal products and their use in beverages elaboration

Cereals constitute a major source of dietary nutrients all over the world (Fig. 6.3). A large proportion of their world production is processed by fermentation prior to consumption, the most simple and economical way of improving their nutritional value, sensory properties, and functional qualities [69]. The cereal grain consists of embryo and endosperm that are enclosed by the epidermis and covered by a seed coat or husk. The starchy endosperm is made up of varying sizes of granules and contains the carbohydrate. The embryo contains amino acids, lipids, sugars, minerals, vitamins, and a range of hydrolytic enzymes such as amylases. These enzymes hydrolyze starch and make them available for microorganisms in the form of sugars. The seed coat contains pectin, minerals, cellulose, pentosans, and some contain polyphenols. However, these chemical components stored in cereal grains are not available for microorganisms, which are primarily controlled by low water activity, and the endogenous enzymes are inactive. The fermentation of cereal is usually trigged by water addition and milling or comminution. These technological measures act on the metabolic resting cereal grains and direct the ecological factors that control the activity of bacteria and lactic acid yeasts [70]. In most

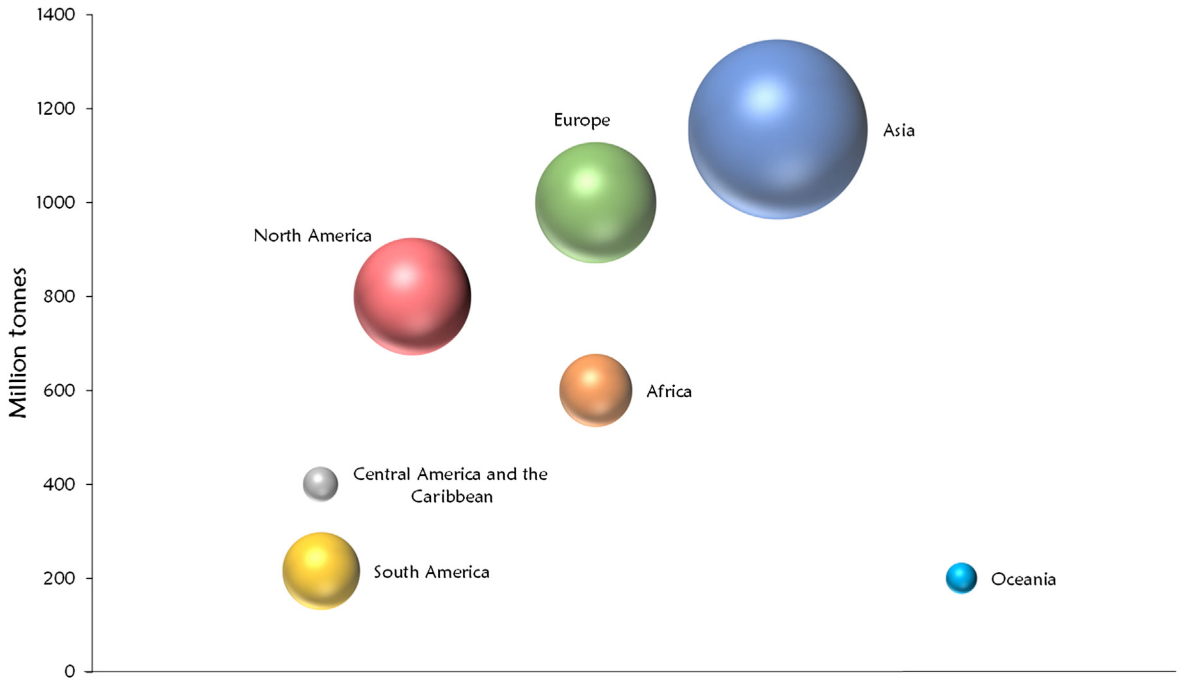

FIGURE 6.3 World cereal production reported in FAO cereal supply and demand brief released on February 7, 2019. *FAO*, Food and Agriculture Organization.

of these beverages the fermentation involves mixed cultures of yeasts, bacteria, and fungi. Some microorganisms may participate in parallel, while others act in a sequential manner with a changing dominant flora during the course of the fermentation [69]. The common fermenting bacteria are species of *Leuconostoc*, *Lactobacillus*, *Streptococcus*, *Pediococcus*, *Micrococcus*, and *Bacillus*. The fungi genera *Aspergillus*, *Paecilomyces*, *Cladosporium*, *Fusarium*, *Penicillium*, and *Trichothecium* are the most frequently found in certain cereal-based FBs. The common fermenting yeasts are species of *Saccharomyces*, which results in alcoholic fermentation [71].

Cereal fermentation is, except for beer wort, usually carried out on nonheated raw materials. Compared to the dairy industry, where nearly all the milk is at least pasteurized before fermentation, cereal starter has to be much more competitive. A *pasteurization* step is not possible, due to the gelatinization of starch and the inactivation of endogenous cereal enzymes, which are required for fermentation. The most traditional technique in use for cereal fermentation is back-slopping: it is the inoculation of the raw material with a small amount of dough from a previous successful fermentation. There are several criteria by which cereal fermentation process can be identified, the classification reported by Hammes et al. [70] appears to be the most useful. Based on this, four different hydrolytic activity processes, to obtain the fermentable carbohydrates from the cereal grains, have been identified: (1) malting, that is, the management of endogenous activity; (2) "Koji" technology, that is, the use of physiological fungal activities; (3) use of hydrolytic activities originating from external enzyme sources, for example, from fungi, bacteria, plants, or human saliva; and (4) dough (batter or gruel) fermentation. This means that combining these processes with the most common types of cereals (such as rice, wheat, maize or sorghum), a wide range of cereal-derived FBs can be produced in many parts of the world, with specific local differences in composition and method of preparation. As reported in Table 6.2, most of those products are made in Asia, whose food intake is principally based on cereal. Nevertheless, in some cases, the production of FBs can be closely connected to the cultural and social identity of a population, such as in Mesoamerica where different beverages are obtained by fermenting maize. In Europe, people still practice the old traditional method of preparation of beers using commercial yeast strains. The technology for production of European barley beer, the biochemical and microbiological changes that take place during malting, fermentation, and subsequent processing and storage are well documented in the literature [72–74]. There is, though, the Belgian "lambic" sour beers produced through spontaneous fermentation of water, barley malt, unmalted wheat, aged dry hops in horizontal wooden casks, and matured for up to 3 years. They are produced by *spontaneous fermentation* that lasts from 1 to 3 years before bottling [75]. In Africa, traditional beers differ from the Western-type; they are often sour, less carbonated, and have no hops [69]. They are consumed unrefined, including unfermented substrates and microorganisms [76]. "Pito" and "burukutu" are brewed concurrently by fermenting malted or germinated single cereal grains or a mixture of them. "Pito" is a cream-colored liquor, while "burukutu" is a brown-colored suspension [77,78]. Other examples of African brews are "ajon" from finger millet, "omuramba" from sorghum and "kweete" from maize and millet [79]. "Chicha" is produced following handmade ancestral procedures and is related to the brewery process [80]. It is produced using a great variety of procedures, depending on the maize varieties employed, utensils, and local traditions. As starch hydrolysis is an essential step, methods used for maize flour treatment vary rather widely. Traditionally, the production of "chicha" involved saliva as inoculum that served as amylase source to convert starch into fermentable sugars. Nowadays, alternatives for amylase production are malting (germination) of maize kernels (chicha de jora) or adding a prefermentation step during the manufacturing process [81].

Rice beers are typically prepared in the Asia-Pacific countries. Different types of rice beer are "jou," "chu," and "chako" in different Indian's regions. These beverages are processed by unique starter cultures that are found to contain yeasts and other associated microorganisms to carry out fermentation [82]. In eastern Asian subcontinent, rice-based FBs such as Indonesian "tapé ketan," Korean "takju," and Indian (Eastern Himalayas) "bhaati jaanr" are extensively produced [83]. The common microbes involved in their fermentation are molds, yeasts, and bacteria, mainly LAB [84,85]. Generally, these groups of microbes play a dominant role in fermenting based food products by secreting different hydrolytic enzymes and producing sugars, organic acids, vitamins, and other bioactive substances [84]. "Amazake" is a sweet fermented rice beverage that is the nonalcoholic precursor to sake, produced in Japan. Steamed rice is mixed with rice-"koji" (*Aspergillus mycelia* and rice) and water and is heated to 55°C–60°C for 15 h. Enzymes breakdown the rice and form glucose content of approximately 20%. "Amazake" is highly nutritious and is consumed for its purported health benefits [86].

"Boza" is a Bulgarian traditional cereal-based FB with a pleasant sweet–sour, bread-like taste. It is also consumed in some areas of Turkey, Albania, and Romania. Different cereals (wheat, millet, and rye) can be used for "boza" production, and fermentation is performed by natural mixtures of yeast and lactic acid bacteria. Interactions between microorganisms are uncontrolled during the process, which leads to variability in the product quality [87]. "Pozol," a FB common produced in south-eastern Mexico using maize grains, is composed of a variety of microorganisms including LAB, non-LAB, yeasts, and other fungi. Also "atole agrio" is a Mexican, nonalcoholic, acidic beverage derived

TABLE 6.2 Cereal-based fermented beverages.

Continent	Country	Product name	Substrate	Microorganisms
Africa	Africa, Arabian Gulf	Mahewu	Maize	LAB
	Ethiopia	Borde and Shamita	Maize	LAB/yeast and other bacteria
	Ghana	Koko	millet	LAB
	Ghana/Nigeria	Burukutu	Sorghum/millet	LAB/AAB/yeast
	Kenya/Tanzania/ Uganda	Uji	Maize, sorghum, millet	LAB
	South Africa	Kaffir	Malt of sorghum. maize	LAB
	Tanzanian	Togwa	Maize, sorghum and millet (combined with cassava)	LAB/yeast
	Uganda	Bushera	Sorghum, millet	LAB
	West Africa	Ogi	Maize/sorghum/millet	LAB/yeast/other bacteria
Asia	Bhutan, India, Nepal	Kodo	Millet	Yeast
	China	Sura	Millet	Yeast
	East Central India	Haria	Rice	LAB/yeast
	Egypt	Kishk	Wheat	LAB/yeast
	Egypt/Turkey	Boza	Millet, rice, and wheat	Yeast
	Korea	Takju	Rice/wheat	Yeast
	India	Cooked barley rice	Chhang	Yeast
	India	Rabadi	Pearl millet	Yeast
	India	Torani	Rice	LAB
	Indonesia	Tapekekan	Glutinous rice	Yeast
	Northeast India	Boiled rice	Jou	Yeast
	Philippine	Tapuy (rice wine)	Glutinous rice	Yeast
Europa	Albania, Bulgaria, Romania	Boza	Wheat, millet, rye, maize	LAB
	Belgium	Lambic beer	Barley	AAB/LAB/yeast
	Eastern Europe	Kvass	Barley malt, rye flour, and stale rye bread	LAB
	Europe	Beer	Barley	Yeast
South America	Andean region	Chicha	Corn (corn beer)	Yeast
	Colombia, Ecuador, and Peru	Wheat, rye, and maize or their combinations	Champús	Yeast
	Mexico	Pozol	Maize	LAB

AAB, Acetic acid bacteria; *LAB*, lactic acid−producing bacteria.

from fermented maize [88]. It is traditionally prepared by spontaneous fermentation in households, and raw materials, equipment, and manufacturing processes differ noticeably between batches and producers leading to highly variable end products. "Atole agrio" can be prepared either by liquid or solid-state fermentation; the end product is flavored with sugar, cinnamon, cocoa, or consumed as such [89].

It is important to complete the present passage considering different cereal-based FBs produced by LAB fermentation. In Africa, these beverages are often used to wean children, and as a high-energy diet supplement. "Togwa," a sweet and sour, nonalcoholic beverage, is one of the better studied African cereal beverages. Produced from the flour of maize, sorghum, and finger millet, sometimes cassava root, the chosen substrates are boiled, cooled, and fermented for approximately 12 h to form a porridge, which is then diluted to drink [90]. "Mahewu" is similar in that maize or sorghum meal is fermented with millet or sorghum malt and is available commercially [91]. "Koko" sour water is the fermented liquid water created in the production of the fermented porridge. This contains a high portion of LAB and is used by locals to treat stomach aches and as a refreshing beverage [92].

Fruits and vegetable fermentation for nutritive beverages production

The *World Health Organization (WHO)* and the *Food and Agriculture Organization (FAO)* recommended intake of a specific daily dose of vegetables and fruits to prevent chronic pathologies such as hypertension, coronary heart problems, and risk of strokes [93]. Nevertheless, many of fruits and vegetables, and their roots or tubers are consumed fresh, but large quantities of harvested fruits are wasted during peak harvest periods, due to the high temperature and humidity, poor handling, inadequate storage facilities, and microbial infections. Therefore microbial fermentation from such raw materials is considered a good alternative to utilizing surplus and over-ripe products for generating beverages with high nutritional value. FBs fruits and vegetables-based are popular throughout the world and their production is important in many countries in providing income and employment. As always, fermentation of fruits and vegetables involves either lactic acid, acetic acid, or alcoholic fermentation, or a combination of these different fermentation types. Alcoholic fermentation is mainly used in the production of alcoholic beverages such as wine. AAB are used for the production of vinegar, which consists of a two-stage fermentation process in which the first stage includes an alcoholic fermentation that is followed by the oxidation of ethanol via acetaldehyde to acetic acid [94]. However, a wide variety of fruits and vegetables undergo typical lactic acid fermentation by a spontaneous or back-slopping method [95]. The most frequent species of LAB involve are *Lactobacillus plantarum*, *Lactobacillus brevis*, *Lactobacillus rhamnosus*, *Lactobacillus acidophilus*, *Leuconostoc mesenteroides*, *Leuconostoc citreum*, *Leuconostoc fallax*, *Leuconostoc kimchi*, *Pediococcus pentosaceus*, *Pediococcus acidilactici*, *Weissella confusa*, and *Weissella cibaria* [96]. Table 6.3 shows several fruits- and vegetables-based FBs, their production area, the plant species used in their elaboration, and the microorganisms involved in the process.

Winemaking is the most ancient of the fermentation processes and is now one of the most commercially prosperous [97]. The technique of winemaking is known since the dawn of civilization and has followed human and agricultural progress [98]. It is well known that polyphenols and other bioactive compounds in the source materials are bonded to insoluble plant compounds. Yeast fermentation releases many of these bioactive components into an aqueous ethanolic solution, thus making them more biologically available for absorption during consumption [99]. However, according to the routine definition, wine is a FB produced from grapes only; otherwise, wine is given the prefix of the fruit from which it originates [100]. FBs obtained from apple is a popular drink in many Western countries known as apple wine or cider, it is prolific throughout England and the rest of the United Kingdom as well as in Germany, France (Brittany and Normandy), Spain (Asturias, Basque Country, and Galicia), Ireland, Argentina (Patagonia and Mendoza), and Australia (Tasmania) [97]. In Africa the yeast fermentation of sap extracted from tropical plants belonging to the Palmae family (i.e., *Elaeis guineensis*) produces the palm wine. It is an alcoholic beverage that is consumed in very large quantities in West Africa, and it is known throughout the major parts of Africa under various names, such as "mimbo" in Cameroon, "nsafufuo" in Ghana, and "emu" in Nigeria [101]. Thus, in various African countries and beyond, the sap of the palm tree is tapped and allowed to undergo spontaneous fermentation, which promotes the proliferation of yeast species for the conversion of the sweet substrate into an alcoholic beverage containing important nutritional components, including amino acids, proteins, vitamins, and sugars. The palm sap is obtained from either the immature male inflorescence (inflorescence tapping) or from the stem (stem tapping) [102]. However, in Cameroon and Ghana, the process of tapping palm wine involves first felling or cutting down the tree, leaving the felled tree for a period of about 2 weeks for the sap to concentrate, followed by tapping for up to 8 weeks [103].

Again, in the winemaking context, in Mexico, different Agave species are exploited for the production of "pulque" [104]. This FB is obtained by spontaneous fermentation of the Agave sap or aguamiel. Most of the "pulque" production involves a complex fermentation in which LAB (*Lactobacillus* sp. and *Leuconostoc* sp.) and yeasts (non-*Saccharomyces* and *Saccharomyces*) are present in stable mixed populations or succeeding one another. These microorganisms develop three distinctive metabolic products: lactic acid, ethanol, and the extracellular polysaccharides, which include dextrans and fructans produced from sucrose [105]. At present, "pulque" is also produced on a small industrial

TABLE 6.3 Fruit/vegetable-based fermented beverages.

Continent	Country	Product name	Substrate	Microorganisms
Africa	East African Great Lakes Region	Isongo/Mbege/Tonto/Urwagwa/ Urwaga	Banana juice	LAB/yeast and molds
	Southern Africa	Marula Buganu	Amarula fruits	Yeast
	West Africa	Gari	Cassava roots	LAB/molds
	West Africa	Palm wine/Mimbo	Sap or coconut pal tree	LAB/yeast
Asia	China	Kombucha	Tea leaves	AAB/yeast
	India, Pakistan	Palm wine	Sap or coconut pal tree	LAB/yeast
	India	Kanji	Black carrots	LAB
	Malaysia	Tapai ubi	Cassava or tapioca flour	Sap or coconut pal tree
	Turkey	Hardalye	Red grape and mustard seeds	LAB
	Turkey	Shalgam juice	Black carrots	LAB
Europe	England	Ginger beer	Ginger roots	LAB/yeast
	Europe	Cider	Apple	LAB/yeast
	Europe	Wine	Grapes	LAB/yeast
South America	Guyana	Parakari	Cassava roots	LAB/yeast/molds
	Mexico	Pulque	Agave	LAB/yeast

AAB, Acetic acid bacteria; *LAB*, lactic acid–producing bacteria.

scale through a pure mixed starter culture industrialized process to control the quality and safety of the product, which is canned and exported as a novel Mexican product [104]. In tropical areas, also the cassava roots can be processed into wine or beer by using spontaneous alcoholic fermentation. The traditional procedure is the same as making beer, whereby the starch is hydrolyzed into fermentable sugar by application of crude preparation from *Aspergillus* spp. grown on cereals (e.g., "koji"), and the mash is subsequently fermented into beer [43]. "Parakari" is a fermented cassava beverage popular among Amerindians of Guyana, it is unique among the New World beverages because it involves the use of an amylolytic mold (*Rhizopus* sp., *Mucoraceae*, *Zygomycota*) followed by a solid substrate ethanol fermentation [106]. The FB called "tapai ubi" prepared from tapioca or cassava flours is popular among the ethnic group of East Malaysia. It has an alcoholic aroma with a combination of sweet–sour–bitter taste and sometimes sparkling feel [107]. The fermentation by yeast of banana juice allows the production of a home-brewed banana beer that can be considered the oldest FB produced in most East African countries. It is given different names in the different countries, for example, it is called "urwagwa" in Rwanda, "tonto" in Uganda, "mbege" in Tanzania, "urwaga" in Kenya, and "isongo" in Burundi [108]. The high production of banana beer is about the fact that it is the dominant fruit grown in the East African regions and its year-round harvest assures a continuous source of food and income. The production of ginger beer in England is something which is worthy of exploration. It is a sparkling soft drink with acidic taste, and due to its low alcoholic content, it has become popular among children. There are many different recipes for the production of ginger beer; however, the basic ingredients used are ginger, lemon, sugar, and yeast. Other ingredients used to improve its taste are mainly sugar, cream of tartar, dried ale or bread yeast, juniper berries [109].

Therefore the study of the geographical distribution of FBs emphasizes interesting things; in Europe (and recently also in California, Australia, and New Zealand), the grape is successfully used to produce wine, while in another country when it is processed with lactic fermentation the nonalcoholic beverage named "hardaliye" is produced. "Hardalye" is obtained from red grape or grape juice with the addition of crushed mustard seeds and benzoic acid and can be found in Turkey [30,110,111]. Mustards include glucosinolates sulfur-containing compounds, which are enzymatically broken giving to the final FB the specific mustard flavor [112]. Remaining in Turkey, the "shalgam" juice, a red-colored, cloudy and sour, soft beverage, is a traditional FB in which mainly LAB play an important role [30,113]. It is produced by the lactic acid fermentation of black (purple) carrot, turnip, sourdough, salt, bulgur flour, and adequate water. In India a similar product named "kanji" is produced via the natural fermentation of carrots and the addition of salt, chilies, and crushed mustard [114]. "Kombucha" is one of the most popular plants FB in the world; black tea and white sugar are used for its production, although green tea can also be used [115,116]. Nowadays, kombucha is produced on a large scale for commercial use as well as for domestic consumption. The drink was originally popular in China but nowadays is consumed worldwide, showing increasing popularity as a traditional soft drink. "Kombucha" has a slightly sweet, carbonated, acidic taste resembling sparkling apple cider [117]. This FB is obtained from a symbiotic culture of acetic acid AAB (*Komagataeibacter*, *Gluconobacter*, and *Acetobacter* spp.) [75], LAB (*Lactobacillus*, *Lactococcus*) [27], and yeasts (*Schizosaccharomyces pombe*, *Saccharomycodes ludwigii*, *Kloeckera apiculata*, *S. cerevisiae*, *Zygosaccharomyces bailii*, *Torulaspora delbrueckii*, and *Brettanomyces bruxellensis*) [118] in a sweet medium, generally black tea. Its fermentation process also leads to the formation of a floating biofilm on the surface of the growth medium due to the activity of certain strains of AAB [119]. The tea fungus "Kombucha," which is the basis of a fermentation beverage, is not a fungus in the botanical sense, but a symbiosis of AAB and osmophilic yeast species in a zoogleal mat which is left to ferment for 1−8 weeks [116]. After the end of the fermentation the tea fungus is removed from the surface and kept in a small volume of fermented tea for future use. The taste of the kombucha changes during fermentation from a pleasantly fruity sour-like sparkling flavor after a few days to a mild vinegar-like taste after a long incubation period. Optimum fermentation time is required for the production of kombucha with pleasant flavor and taste. Longer fermentation produces high levels of acids (like mild vinegar) that may pose potential risks when consumed [116,120].

Bioactive compounds in fermented foods with health-promoting effects

During fermentation, foods are enriched with bioactive compounds, improving the safety, nutritional, and sensorial properties of the final products. As examples, cereal-based LAB fermentation increases the content of folates, soluble dietary fibers, phenolic compounds showing health benefits and improve protein digestibility [121]—bioactive compounds in fermented white cabbage [122], soy milk [123], kidney beans [124], lentils [125] that increase the nutritional value of the foods. In 2006 kimchi, the most important traditional fermented food in Korea and one of the most widely consumed in Japan and China, has been selected as one of the world's healthiest foods due to its many beneficial properties [126].

Bioactive compounds in FBs act against hypertension, a cardiovascular risk factor, and are responsible for mortality at the global level; they are able to scavenge *reactive oxygen species (ROS)*, dangerous species that damage DNA, proteins, lipids, and carbohydrates producing serious diseases such as inflammation, cancer, and atherosclerosis [27,127,128]. They show apoptotic activity on cancer cell lines and antimicrobial activity against several pathogens. Based on the presence of bioactive compounds, fermentation may be considered an efficient biotechnological process to produce functional foods both from animal and plant origin.

Vitamins

Vitamins are organic compounds necessary for supporting the physiological functions of the mammalian cells. For humans, essential vitamins include both fat-soluble and water-soluble vitamins (Figs. 6.4−6.6). The first are vitamins A, D, E, and K; the latter vitamin C; thiamine (vitamin B1); riboflavin (vitamin B2); niacin (vitamin B3); pantothenic acid (vitamin B5); vitamin B6; folate (vitamin B9); and cyanocobalamin (vitamin B12). Being not endogenously synthesized, the only source of vitamins is the diet. Even if they occur in numerous foods and the required daily amounts are very small, vitamin deficiency in humans is often caused by insufficient food or unbalanced dietary intakes, in particular for categories at risk as children, pregnant women, and old people [129,130]. In this scenario, FBs represent an excellent source of vitamins. In tempeh the levels of niacin, nicotinamide, riboflavin, and pyridoxine are increased by *Rhizopus oligosporus*, whereas cyanocobalamin (vitamin B12) is synthesized by nonpathogenic strains of *Klebsiella pneumoniae* and *Citrobacter freundii* [131,132]. Thiamine, riboflavin, and methionine contents in idli are increased during fermentation [133,134]. Pulque, produced by lactic acid fermentation of juices of the cactus plant, is rich in thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, and biotin and serves as an important diet for children of low economic status in Mexico [135]. Garris and suusac, produced by LAB and yeasts from camel milk, are rich in niacin, while in dahi from cow and yak milk, vitamin B2 and B5 are mainly present.

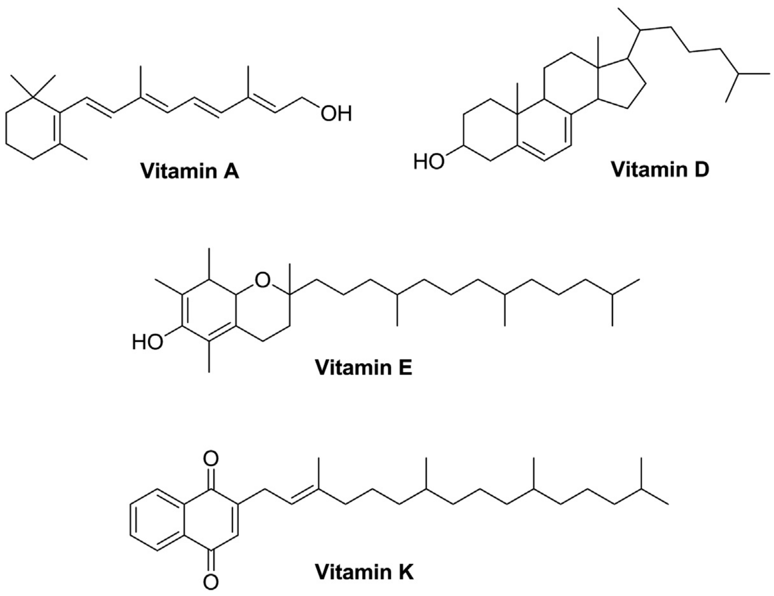

FIGURE 6.4 Vitamins A, D, E, and F.

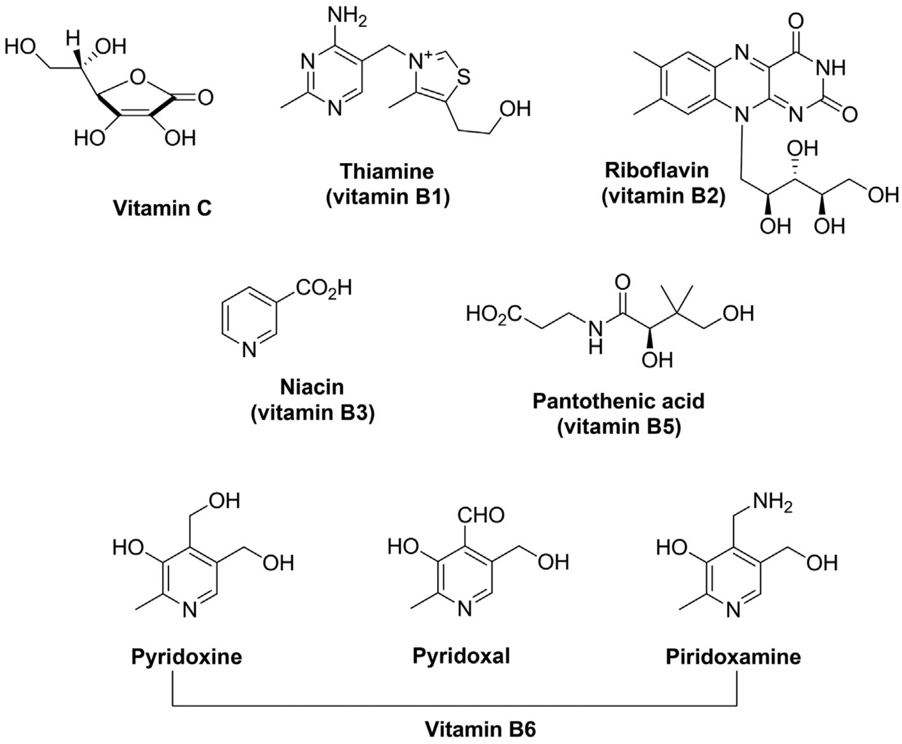

FIGURE 6.5 Vitamins C, B1, B2, B3, B5, and B6.

Peptides

Peptides are bioactive compounds of great interest for their health beneficial effects such as antihypertensive, antiinflammatory, antimicrobial, antithrombotic, anticancer, and antioxidant activities [136]. The most studied are found in dairy fermented products, legumes, and cereals. Peptide bioactivity relies on inherent amino acid composition, sequence, and size. Antihypertensive, antimicrobial, immunomodulatory, anticancer, antithrombotic, opioid, and antioxidant activities are some of the biological activities attributed to peptides of FBs [137]. Specific amino acid sequences exhibiting more than two biological activities are also known as *multifunctional peptides* [136]. Bioactive and

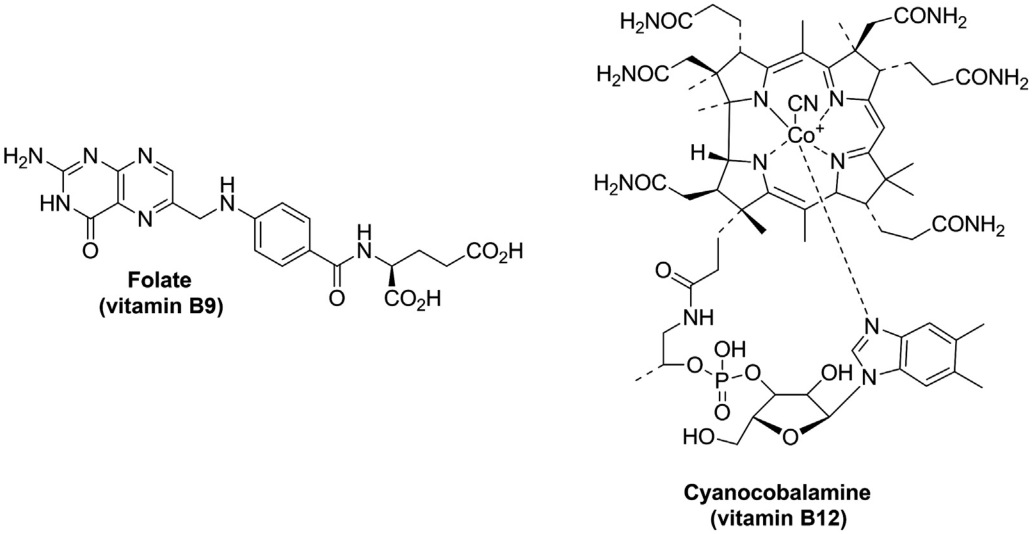

FIGURE 6.6 Vitamins B9 and B12.

multifunctional peptides were produced during the manufacture of FBs by the microbial proteolytic systems and/or by endogenous proteolytic systems. Biochemical pathways for peptide production have been extensively investigated [138,139]. These studies are also useful to implement strategies to produce peptides with specific biological activities. Many researchers have demonstrated the efficacy of orally administered peptides isolated from FBs in the prevention and treatment of hypertension exhibiting ACE (angiotensin-converting enzyme) inhibitory activity [140−143]. They are able to lower blood pressure via ACE inhibition that suppresses angiotensin II−mediated vasoconstriction. Strong ACE inhibitors are found in FBs derived from animal proteins as kefir (KAVPYPQ, NLHLPLP, SKVLPVPQ, LNVPGEIVE, YQKFPQY, SQSKVLPVPQ, VYPFPGPIPN). Other peptides present antithrombotic (YQEPVLGPVRGPFPIIV), antioxidant (VYPFPGPIPN, ARHPHPHLSFM, YQEPVLGPVRGPFPIIV), antimicrobial (VLNENLLR, YQEPVLGPVRGPFPIIV), and immunomodulating activity (YQEPVLGPVRGPFPIIV, LYQEPVLGPVRGPFPIIV) [144]. Chen et al. [145] indicated that koumiss, the fermented mare's milk, is rich in ACE inhibitory peptides (YQDPRLGPTGELDPATQPIVAVHNPVIV, PKDLREN, LLLAHLL, NHRNRMMDHVH). The peptide SKVVP is found in dahi, an Indian fermented product obtained by *Lactobacillus delbrueckii* ssp. *bulgaricus*, *Streptococcus salivarius* ssp. *thermophilus*, and *Lactococcus lactis* subsp. *lactis* biovar *diacetylactis* [146]. VPP and IPP are low-molecular-mass peptides with ACE inhibitory activity released from β and κ-casein during milk fermentation by proteases and peptidases of *Lactobacillus helveticus* strains. In addition, they exhibit antiinflammatory, antiatherosclerotic, antiadipogenic, and antiosteoporotic activities.

Exopolysaccharides

The research and development of many food industries in the dairy sector are devoted to improve the sensorial characteristics of FBs and to introduce in the market reduced-fat and reduced-calories products. For the structural, physical−chemical properties and biological effects the microbial exopolysaccharides (EPS) can offer many solutions.

EPS are linear or branched polymers with a molecular mass ranging from 10^4 to 10^6 Da. Based on the types of monomers, they are classified into homopolysaccharides (HoPS) and heteropolysaccharides (HePS). HoPS include cellulose, curdlan, dextran, levan, pullulan, and contain a single type of monomer (glucose or fructose). HePS (alginate, gellan, and xanthan) consist of units of glucose, rhamnose, guluronic acid, mannuronic acid (Table 6.4) and, in some cases, *N*-acetyl-D-glucosamine and *N*-acetyl-D-galactosamine.

EPS have hydrophilic nature and because of that they have a strong capacity to coordinate water molecules through hydrogen bonds. This property allows increasing the humidity of the product in which exopolysaccharides are present, with a consequent increase in the transformation yield. Furthermore, from their interaction with water and partially with proteins or other milk components, the final products result more viscous and compact. In particular, the chemical nature of EPS and their interactions with proteins and other components of the product determine different rheological effects. Some LAB produce EPS with a marked "stringy" tendency, obtaining a soft and creamy coagulum, representing

TABLE 6.4 Microbial EPS.

EPS	Type	Monomer	Producer organisms
Cellulose	HoPS	Glucose	*Acetobacter xylinum, Gluconacetobacter xylinus*
Curdlan	HoPS	Glucose	*Alcaligenes faecalis*
Dextran	HoPS	Glucose	*Weissella cibaria, Leuconostoc mesenteroides*
Pullulan	HoPS	Glucose	*Aureobasidium pullulans*
Levan	HoPS	Fructose	*Saccharomyces cerevisiae, Bacillus subtilis*
Alginate	HePS	Guluronic acid, mannuronic acid	*Azotobacter chroococcum*
Gellan	HePS	Glucose, rhamnose, glucuronic acid	*Sphingomonas paucimobilis*
Xanthan	HePS	Glucose, rhamnose, glucuronic acid	*Xanthomonas campestris*

HePS, Heteropolysaccharides; *HoPS*, homopolysaccharides.

a valid response to the improvement of rheological properties of yogurt, fermented milk or certain types of cheese; other strains instead produce polymers with a structuring or thickening action, very often used to obtain the desired consistency in mozzarella or cheese. Furthermore, EPS could be useful for making low-calorie or dietetic products, succeeding in their action to compensate for the lack of fat. EPS produced from LAB are approved by the US Food and Drug Administration (FDA) as generally regarded as safe.

In addition to the food industry, EPS have various applications in the pharmaceutical, cosmetic, and textile sectors. They show many health benefits exhibiting antimicrobial, antiviral, antioxidant, hypocholesterolemic, antihypertensive, and anticancer activities. Recent studies demonstrated that the daily consumption of fermented milk containing EPS shows cholesterol-lowering effect [147]. EPS from LAB display in vitro and in vivo antioxidant activity blocking the ROS [148] and are effective against the growth of intestinal carcinoma [149]. Kefiran, found in kefir, elicit a gut mucosal response producing an immunomodulatory response [150]. Curdlan, in combination with zidovudine (AZT), displays antiretroviral activity and represents a promising anti-HIV drug [136].

Phenols

Phenolic compounds are a wide number of secondary metabolites present in the plant kingdom which play numerous biological activities [151]. They are characterized by a wide diversity of chemical structures; in fact, they may vary from simple, small molecules as phenolic acids (hydroxybenzoic and hydroxycinnamic acids) to complex compounds with a high molecular mass as tannins (condensed and hydrolyzable tannins).

Phenols are characterized by a strong antioxidant activity due to their peculiar chemical structure, thus exhibiting a wide range of beneficial health including the antihypertensive, cardioprotective, antiinflammatory [152], and anticancer activities [153−156]. Being present in plant foods, they are dietary natural compounds, and the nutritionists recommend their daily consumption to have beneficial effects on health. Unfortunately, these effects are often reduced by their low bioavailability. This property depends on the fact that generally in plants they are present as glycosides, esters and covalently bound to cell wall structural components such as cellulose, hemicellulose, lignin, pectin, and proteins.

In this scenario, food fermentation and biotechnological processes based on the use of hydrolytic enzymes are attractive for increasing the nutraceutical value of foods. Microbial enzymes such as glucosidase, amylase, cellulase, chitinase, xylanase, and esterase can simplify the chemical of complex polyphenolic structures and permit their extraction increasing the bioavailability. LAB are bacteria largely used in food fermentation for these purposes, and *L. plantarum* is the most studied in the fermentation of plant foods rich in phenolic compounds [157]. *L. plantarum* is able to degrade oleuropein, the main phenolic glucoside present in the olive fruit, to give rise to elenolic acid and hydroxytyrosol (Fig. 6.7) [158,159], a small phenol showing antioxidant, antiinflammatory, antihypertensive, and anticancer activities [153−155]. *L. plantarum* metabolizes also several phenolic acids by a decarboxylation reaction. Protocatechuic and gallic were converted into catechol and pyrogallol, respectively, and ferulic acid into vinyl guaiacol by a sequence of enzymatic reactions (Fig. 6.8) [160].

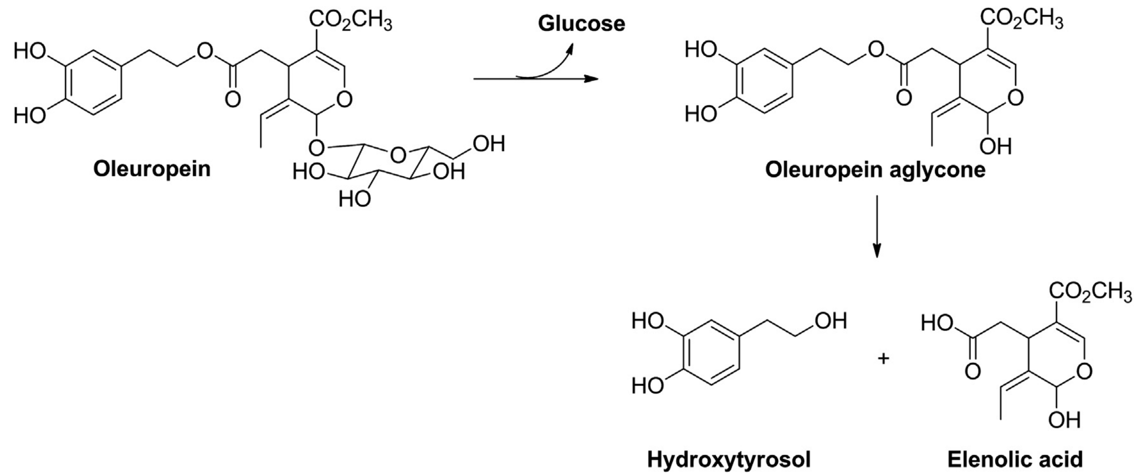

FIGURE 6.7 Conversion of oleuropein into hydroxytyrosol by *Lactobacillus plantarum* [160].

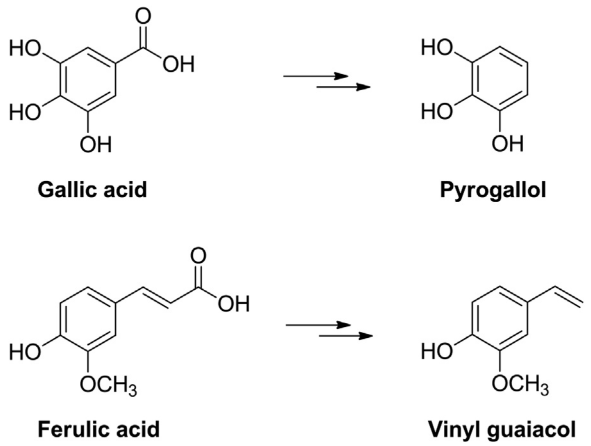

FIGURE 6.8 Decarboxylation reaction of gallic acid and ferulic acid by *Lactobacillus plantarum.*

In addition, *L. plantarum* degrades gallotannins by the action of tannase that catalyzes the hydrolysis reaction of the ester bonds present in hydrolyzable tannins releasing gallic acid (Fig. 6.7). This aspect is very important because tannins are present in plant foods but they are nutritionally undesirable being responsible for the precipitation of proteins, inhibition of digestive enzymes, and absorption of vitamins.

Conclusions from a global perspective

The fermented beverages presented in this chapter highlight as the fermentation is an ancient form of *biopreservation* common in all regions of the world. The FBs provide an important source of energy through the presence of vitamins, minerals, amino acids, phenols, fatty acids, sugars, and other bioactive compounds, essential to human health. These molecules are the outcomes of microbes' contributions. The enzymatic activity of lactic acid bacteria and yeasts, which are the predominant microorganisms during fermentation, changes the chemical properties of raw materials in a manner that has beneficial consequences for human health. The concentrations of available bioactive compounds may be dependent on the geographic regions from which the starting product was produced, strains of microorganisms utilized, availability of specific substrates in the fermentation process, environmental conditions, such as seasonality, and method of preparation or manufacturing process. The studies and literature regarding indigenous FBs have increased substantially in the last decades, demonstrating that these foods are important sources of nutrients for people living in developing countries such as Africa, Asia, and Latin America. In these places especially, it is important that the consumption of natural beverages, in an active state of fermentation, may contain an abundant array of potential probiotic bacteria. Based on their well-known health benefits, some traditional FBs have received growing interest; yogurt, kefir, and "kombucha" are perfect examples of these. Therefore there is a critical need for an additional fundamental study comparing different fermentation-associated strains for core properties expressed either for raw materials transformations, product synthesis, or bioactive compounds releasing. Such efforts are still needed because the role of traditional beverages in the future of the FB industry may be to inspire the development of new healthy products. FBs have been a part of the human nutrition for centuries and it would be appropriate to become important also for the future generations.

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