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TRADITIONAL FERMENTED FOODS IN ANATOLIA

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ABSTRACT

Fermentation is an ancient and economical method to preserve foods. In Anatolia, several fermented products, including hardaliye, kurut, ayran, yogurt, cheese, koumiss, kefir, tarhana, shalgam, pickle, vinegar, boza, sucuk, and wine have traditionally been produced by the action of microorganisms from several raw materials. Some of these products, such as pickle, yogurt, cheese, ayran, and sucuk, have been highly standardized and industrialized. This study aimed to describe the most common traditional fermented foods in Anatolia, their production techniques, and their health benefits for humans.

Keywords: Anatolia, traditional, fermented foods, fermentation, microorganisms

INTRODUCTION

Food provides energy to the human body to satisfy metabolic requirements, as well as provide been with a sense of satisfaction and health. In addition, nutrients have different physiological functions and protect against some diseases. Functional foods provide nutrition, improve health, and reduce the risk of disease. The term functional foods was first introduced in Japan in the mid-1980s. After this, the functional food market started growing steadily. Traditional fermented foods are a category of functional foods (Butnariu and Sarac, 2019).

Fermented foods are foods or beverages produced through controlled microbial growth and the conversion of food components through enzymatic action. Two main methods are used in the fermentation of foods. Firstly, foods can be fermented naturally, which are called wild or spontaneous ferments. Secondly, foods can be fermented with starter cultures; this method is called culture-dependent ferments (Dimidi et al., 2019). Currently, more than 3500 traditional fermented foods, including beverages, are produced using traditional and commercial techniques in the world (Navarrete-Bolanos, 2012). Of these, dairy-fermented foods are common on the commercial market or in homes. On the other hand, health problems, such as lactose intolerance and high cholesterol, limit the consumption of dairy-based traditional fermented foods. Traditional non-dairy fermented foods are produced most often using traditional methods (Mahasneh and Abbas, 2010; Ekinci et al., 2016). Traditional fermented foods are typical products of a specific region and are affected by various factors, such as environmental conditions, social patterns, consumption practices, and substrate availability (Navarrete-Bolanos, 2012).

Anatolia is located at the point where the continents of Asia and Europe meet. The word Anatolia originated from the Greek word *Anatolē̃*, which means the East or sunrise. The oldest known name of Anatolia is the Land of the Hatti. Geographically, Anatolia

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or Asia Minor is a mountainous peninsula between the Black Sea, the Mediterranean, and the Aegean Sea in the westernmost part of the Asian continent. It acts as a bridge between East and West. From the beginnings of civilization, Anatolia was a crossroads for numerous people migrating or conquering from either continent. Because of its location, the ancient Anatolian lands have been home to many civilizations with different cultures, religious beliefs, and languages and dialects. Presently, the Republic of Turkey is located on the Anatolian peninsula in south-west Asia and the Balkan region of south-east Europe. Because of their past, Turks immigrating to Anatolia from Central Asia have a rich culture. Fermented foods and beverages have been part of the human diet since the beginning of Anatolian civilization. Dairy-based (yogurt, torba yogurt, kurut, ayran, kefir, and koumiss), cereal-based (tarhana and nonalcoholic beverage named boza), fruits-and-vegetable-based (pickle, shalgam, and hardaliye), and meat-based (sucuk) fermented foods have been traditionally produced at homes in Anatolia throughout history in addition to commercial production. The production techniques of traditional fermented foods and beverages vary from region to region. Initially, these traditional foods were produced through natural fermentation. However, presently, several traditional foods are produced with the addition of a starter culture. Therefore, the fermentation process has become more automated and reproducible (Tangüler, 2014).

The term fermentation is derived from the Latin word fermentum, whereas ferment is derived from the Latin word fervere, which means to boil. Although the pioneer of fermentation biology was Louis Pasteur, Eduard Buechner clarified the chemistry of fermentation (Some and Mandal, 2020). The fermentation of foods dates back at least 6000 years. In ancient times, food fermentation was performed only for preservation and flavor improvement. Today, however, modern-technology-based food fermentation adds value and stability to perishable and indigestible materials (Vilela, 2019).

Fermentation mainly achieves food safety (Tangüler, 2014). Fermented foods have the following advantages: *i*) it transforms perishable and indigestible raw materials into pleasant foods and drinkable beverages that are rich in flavors, nutritional value, and textures; *ii*) it preserves food through the formation of inhibitory metabolites, such as lactic acid, acetic acid, formic acid, propionic acid, ethyl alcohol, carbon dioxide, diacetyl, reuterin, and bacteriocins, combined with the reduction of water activity (by drying or the use of salt); *iii*) it biologically enriches substrates; *iv*) it detoxifies and eliminates undesirable substances in raw foods, such as cyanide, phytates, tannins, and polyphenols; *v*) it lowers fuel requirements; *vi*) it inhibits food pathogens; and *vii*) it reduces the cooking time of food (Ray and Joshi, 2014; Tangüler 2014, Sharma et al., 2020).

Steinkraus (1983; 1996; 2002) classified fermentations according to the following categories: *(i)* Fermentations producing textured vegetable protein meat substitutes in legume/cereal mixtures *(ii)* High-salt/savory meat-flavored/amino acid/peptide sauce and paste fermentations *(iii)* Lactic acid fermentations *(iv)* Alcoholic fermentations *(v)* Acetic acid/vinegar fermentations *(vi)* Alkaline fermentations *(vii)* Leavened breads *(viii)* Flat unleavened breads.

Some of these are typically employed in food preparation. Cereals, fish, fruits, milk, meat, and vegetables have been commonly used for preparing different fermented foods by choosing varied substrates, starter cultures, and fermentation conditions (Some and Mandal, 2020). Fermentation is characterized by the breakdown of sugars into alcohol or organic acids under anaerobic conditions. Fermentation does not involve oxidative phosphorylation for ATP (adenosine triphosphate) production through glycolysis. During fermentation, pyruvate is metabolized into different compounds, such as lactic acid, acetic acid, and ethanol (Mani, 2018).

Fermentative microorganisms are mentioned in Table 1. Bacteria, yeasts, and molds play an important role in food fermentation, and the fermentation process varies according to the substrate used (Cuvas-Limon et al., 2020). Among bacteria, lactic acid bacteria (LAB) are the most significant microorganism in fermentation and can produce lactic acid from carbohydrates. LAB, including *Enterococcus*, *Streptococcus*, *Lactobacillus*, *Lactococcus*, *Leuconostos*, and *Pediococcus*, are commonly detected in numerous fermented foods (Sharma et al., 2020). LAB possesses physiological features, such as substrate utilization, metabolic capabilities, and probiotic properties, which

Table 1. Microorganisms used in the production of fermented foods (adapted from Sharma et al., 2020)

Fermented foods	Microorganisms involved in fermentation
Dairy products	*Lactococcus lactis*, *Lactococcus cremoris*, *Lactobacillus acidophilus*, *Lactobacillus bulgaricus*, *Lacticaseibacillus casei*, *Lacticaseibacillus paracasei*, *Lactobacillus thermophilus*, *Lactobacillus kefiri*, *Lactobacillus caucasicus*, *Penicillium camemberti*, *Penicillium roqueforti*, *Acetobacter lovaniensis*, *Kluyveromyces lactis*, *Saccharomyces cerevisiae*
Vegetable products	*Leuconostoc mesenteroides*, *Aspergillus* spp., *Rhizopus oligosporus*, *Rhizopus oryzae*, *Lactobacillus sakei* (new name *Latilactobacillus sakei*), *Lactiplantibacillus plantarum*, *Thermotoga* spp., *Lactobacillus hokkaidonensis*, *Lacticaseibacillus rhamnosus*, *Rhodotorula rubra*, *Leuconostoc carnosum*, *Bifidobacterium dentium*, *Enterococcus faecalis*, *Weissella confusa*, *Candida sake*
Cereals	*Lactobacillus pantheris*, *Lactiplantibacillus plantarum*, *Penicillium* spp., *Saccharomyces cerevisiae*, *Lactobacillus mesenteroides*, *Enterococcus faecalis*, *Trichosporon pullulans*, *Pediococcus acidilactici*, *Pediococcus cerevisiae*, *Delbrueckii hansenii*, *Delbrueckii tamari*
Beverages	*Aspergillus oryzae*, *Zygosaccharomyces bailii*, *Saccharomyces cerevisiae*, *Acetobacter pasteurianus*, *Gluconacetobacter*, *Acetobacter xylinus*, *Komagataeibacter xylinus*
Meat products	*Latilactobacillus sakei*, *Lactobacillus curvatus* (new name *Latilactobacillus curvatus*), *Lactiplantibacillus plantarum*, *Leuconostoc carnosum*, *Leuconostoc gelidium*, *Bacillus licheniformis*, *Enterococcus faecalis*, *Enterococcus hirae*, *Enterococcus durans*, *Bacillus subtilis*, *Bacillus lentus*, *Lactobacillus divergens*, *Lactobacillus carnis*, *Enterococcus cecorum*

aid fermentation. *Acetobacter* species producing acetic acid are the second most key microorganism in fermentation and are used mainly in fruit and vegetable fermentations. Fruit vinegar, including apple cider vinegar, is produced by acetic acid fermentation. The third most important group of bacteria in fermentation is the *Bacillus* species, such as *Bacillus subtilis*, *Bacillus licheniformis*, and *Bacillus pumilus*, which is involved in alkaline fermentation. This fermentation is commonly applied to protein-rich foods such as soybeans and other legumes (Ray and Joshi, 2014; Some and Mandal, 2020). Yeasts are also involved in food fermentation. Yeast enzymes are used in the biochemical production of wine, beer, and ethanol. The *Saccharomyces* family, especially *Saccharomyces cerevisiae*, is beneficial in food fermentation (Ray and Joshi, 2014; Rezac et al., 2018). Several yeasts have been commonly isolated from traditional fermented foods and non-food mixed amylolytic starters; these are *Brettanomyces anomalus*, *Candida javanica*, *Geotrichum candidum*, *Hansenula anomala*, *Pichia burtonii*, *Rhodotorula glutinis*, *Saccharomycopsis fibuligera*, *Saccharomyces dairensis*, *Saccharomyces globosus*, *Saccharomyces kluyveri*, *Saccharomyces sake*, *Torulopsis versatilis*, *Trichosporon pullulans*, and *Zygosaccharomyces rouxii* (Cuvas-Limon et al., 2020). Molds, important microorganisms in food fermentation, are used both as spoilage and as a food preservative in food processing. Several molds produce commercial enzymes, such as pectinase by *Aspergillus niger*. The *Aspergillus* species produces citric acid from waste like apple pomace. Moreover, the *Penicillium* species is also associated with ripening and developing flavor in some cheeses (Mani, 2018).

This review summarizes the traditional fermented foods in Anatolia, their production techniques, and their health benefits for humans. Moreover, technological improvements in production techniques are discussed.

FERMENTED MILK

Milk and milk products have a high nutritional value and are consumed widely by humans. Milk contains sufficient and balanced nutrients; therefore, it is also a suitable medium for the growth of microorganisms. Milk should be consumed in a short time or should be transformed into various products, such as yogurt and cheese. Milk fermentation has been used for thousands of years. Milk can be fermented by inoculating with appropriate bacteria, such as LAB (*Lactobacillus* spp., *Leuconostoc* spp., and *Lactococcus* spp.) (Behara et al., 2017).

In Anatolia, the history of natural milk fermentation dates back thousands of years. Initially, these products were produced in an artisanal and traditional way to prolong their shelf life. Recently, some have become a popular part of the human diet and are processed commercially. However, other milk-based products are processed at home using traditional methods. Fermented milk products used worldwide are yogurt, cheese, and sour cream. Some dairy products, such as kefir, kurut, ayran, yogurt, torba yogurt, and koumiss, were traditionally produced throughout the history of Anatolia (Tangüler, 2014).

Yogurt

The word yogurt is derived from the Turkish word "yoğurmak", which means 'to thicken', coagulate, or curdle. The use of yogurt by the Medieval Turks was recorded in Divan Lügat al-Turk by Mahmud Kashgari and Kutadgu Bilig by Yusuf Has Hacib, both written in the 11th century. Yogurt is an ancient food known by the following names: *katyk* in Armenia, *dahi* in India, *zabadi* in Egypt, *mast* in Iran, *leben raib* in Saudi Arabia, *laban* in Iraq and Lebanon, *roba* in Sudan, *iogurte* in Brazil, *cuajada* in Spain, *dovga* in Azerbaijan, and *matsoni* in Georgia, Russia, and Japan (Fisberg and Machado, 2015).

In Anatolia, yogurt is a traditional fermented milk product commonly produced in homes. In industry, several types of yogurts, such as plain yogurt, low-fat yogurt, non-fat yogurt, Turkish-type creamy yogurt, filtered yogurt, winter yogurt, fruity yogurt, flavored yogurt, buttermilk, strained yogurt, salty yogurt, tulum yogurt, torba yogurt, and frozen yogurt are produced (Kabak and Dobson, 2011; Yıldırım et al., 2014). Yogurt is obtained from the milk of several domestic animals, such as cows, sheep, goats, yaks, horses, buffalo, and camels (Kaur et al., 2017). In the traditional yogurt production method, milk is boiled and cooled to body temperature. Subsequently, it is inoculated with yogurt made the previous day. This mixture is kept overnight for fermentation and is called leftover yogurt, which is consumed after cooling in the refrigerator (Yıldırım et al., 2014). The industrial production of yogurt was initiated by Isaac Carasso in 1919 (Aryana and Olson, 2017). In recent years, yogurt production methods have evolved, with several types of yogurts being produced industrially. The industrial production of yogurt consists of the following three steps: *i)* mix culture preparation and corresponding physical treatments, such as homogenization, heat treatment, cooling, and deaeration; *ii)* the fermentation process after the inoculation of the mix culture; and *iii)* yogurt harvesting, post-treatment, and packaging. According to the steps used for yogurt production, it can be classified into set-type, stirred, drinking, and concentrated yogurts (Corrieu and Béal, 2016). The industrial yogurt production process is well described in the scientific literature. Therefore, we will not definite the production process in detail.

The symbiosis of lactic acid producer strains (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*) plays a crucial role in producing yogurt. The process is performed in a sterile environment at a lower temperature (36–42°C) for approximately 3–8 h. Moreover, both these bacterial strains must remain active in the final product. The two LAB strains exhibit a positive interaction or protocooperation in milk to produce yogurt. This phenomenon results in faster growth and acidification, higher production of flavor compounds and exopolysaccharides, and more pronounced proteolysis (Corrieu and Béal, 2016). These yogurt bacteria are added as starter cultures at a 2–5% inoculum rate, preferably at a 1:1 ratio (Kabak and Dobson, 2011). Sometimes, other bacterial strains, such as *Lactobacillus acidophilus*, *Lactobacillus casei*, *Lactobacillus lactis*, *Lactobacillus jugurti*, *Lactobacillus helveticus*, *Bifidobacterium longum*, *Bifidobacterium bifidus*, and *Bifidobacterium infantis* are also used as yogurt starter cultures to increase health benefits (Kaur et al., 2017).

Yogurt can be classified into standard culture yogurt and bio-yogurt or probiotic yogurt. For making standard yogurt, milk is first fermented with *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. These bacteria are able to stimulate the friendly microflora already present in the gut helping to maintain the general intestinal health. However, bio-yogurt or probiotic yogurt is produced by culturing beneficial microorganisms such as *Bifidobacteria* spp. and *Lactobacillus acidophilus*. Unlike standard yogurt, this yogurt is milder, creamier, and less acidic (Weerathilake et al., 2014). The daily consumption of yogurt has numerous beneficial effects on human health, such as promoting dental and bone health; improving diet quality; reducing the incidence of chronic diseases, such as obesity and cardiovascular disease; inhibiting pathogens; fulfilling nutritional requirements (particularly calcium); and reducing the risk of gastrointestinal disease. Yogurt is also suitable for people with a cow's milk allergy, type 2 diabetes, metabolic syndrome, respiratory diseases, and lactose intolerance (Sfakianakis and Tzia, 2014; Kaur et al., 2017).

Kurut

Kurut, which is obtained by drying yogurt or ayran, is a fermented dairy product. The word kurut is derived from the Turkish word kurutmak, which means dry. Kurut has several other names throughout Anatolia, including *keş*, *geşk*, *çörten*, *çortan*, *tarak*, *pestigen*, *pesküten*, *pestikan*, and *terne* (Kabak and Dobson, 2015). Kurut is usually produced in villages and towns in Southern and Eastern Anatolia. Kurut is commonly produced in summer when milk is abundant and is consumed during the winter months. Kurut is similar to *Kashk* in Iran, *Kishk* in Lebanon, and *Kuşuk* in Iraq (Patır and Ateş, 2002).

Yogurt is a coagulated product which is produced by lactic acid fermentation using *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. Yogurt is preferred by the consumer due to its high nutritional value, while another crucial feature of yogurt is that it contains viable LAB. However, yogurt has a limited shelf life, hence various methods, such as water removal, are used to extend its shelf life. Drying increases the shelf life of yogurt, which is 30–35 days at 7°C for concentrated yogurt. Drying is commonly used for preserving traditional dairy products. In industrial processes, yogurt is not dried under the sun; however, traditionally, sun-drying is used to obtain kurut (Say et al., 2015).

In the traditional method of kurut production, milk is boiled at 80–85°C for 15–20 min after milking and complete draining. The milk is then cooled to a suitable fermentation temperature (up to 44°C), inoculated with fresh yogurt (1–2%) made the day before, and incubated at 37°C for 2.5–3 h. Subsequently, yogurt is cooled to 30°C and is placed in linen cloth bags for 10–20 days to remove the water. Thoroughly filtered yogurt is transferred into large containers, cream (5–10%) and salt (1–3%) are added, and the yogurt is kneaded intermittently for a few days. Sometimes, a small amount of (1–2%) wheat flour is added to the yogurt to obtain an acceptable consistency during the kneading process. The strained yogurt of the desired consistency is divided into 20–60 g pieces and shaped by hand. These shaped pieces are placed on a clean cloth and dried under the sun for 1–2 weeks on a flat surface. Finally, it is stored in a cool and dry place. One kg of kurut is obtained from 16–17 kg of yogurt (Kabak and Dobson, 2011).

Ayran

Ayran is a traditional fermented milk product consumed mainly during the summer months, and not know exactly where and how ayran was first produced. Drunk in abundance by the Turks for hundreds of years, ayran is a Turkish invention, according to historical records (Şanlı et al., 2011). Products similar to ayran include *doogh* in Iran, *lassi* in Southern Asia, and *tahn* in Armenia (Kabak and Dobson, 2011). However, these products are classified as low viscosity yogurt, drinkable yogurt, or lactic beverages. Unlike ayran, these products are produced with the addition of flavorings, sweeteners, coloring agents, or fruit syrups to increase their taste. The shelf life of ayran is approximately 10–15 days at refrigerator temperature. On the basis of its fat content, ayran is classified into full-fat, half-fat, and non-fat types. The fat content should be at least 1.5% in full-fat ayran, 0.8% in half-fat ayran, and at most 0.15% in fat-free ayran (Patır et al., 2006).

Ayran is produced using two methods: *i*) the addition of water and salt into yogurt and *ii*) the addition of yogurt culture to dry-matter-adjusted milk (Koçak et al., 2006). Ayran is traditionally produced from yogurt with added water (30–50%) and salt (0.5–1%; the dry matter ratio is at least 6% and the salt ratio at most 1%) in specific proportions. Yogurt is produced in the initial part of this method, and water is added to the yogurt according to the desired dry matter value after the yogurt clot breaks. Salt and stabilizer, if used, are also added at this stage. Ayran is packaged under aseptic conditions and refrigerated. At home, it is consumed fresh, without the requirement of individual packaging (Altay et al., 2013). Commercially, raw milk is homogenized and pasteurized at 90–95°C for 5–10 min. The pasteurization process results in the production of ayran with the optimal microbiological quality. Pasteurized milk is cooled to 43–45°C and inoculated with starter cultures, such as *Streptococcus salivarius* subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. Incubation is terminated immediately when the pH reaches 4.4–4.6. Before the clot-breaking process, fermented samples are cooled. Salt and water are added, and the ayran is stored until use (Tamuçay-Özünlü and Koçak, 2010; Altay et al., 2013).

Ayran is composed of 1.07–11% total dry matter, 1.44–3.48% protein, 0.17–1.75% salt, 1% ash, and 0.1–3% fat (Altay et al., 2013). Ayran includes all of the nutrient elements of yogurt, depending on the amount of added water. Therefore, ayran is a yogurt-like product containing rich nutritive components, such as calcium, phosphorus, riboflavin, thiamine, and vitamin B_{12}. In addition to reducing the cholesterol level in the blood, ayran neutralizes toxic substances in the human body. Moreover, ayran contains high-quality protein and calcium, thereby contributing to bone health (Ayar and Burucu, 2013).

Torba yogurt

Torba yogurt or filtered yogurt has been produced in Anatolia for centuries. Similar products are also manufactured in the Balkans and Eastern Mediterranean countries, Turkmenistan, and the Indian subcontinent by using different methods (Yerlikaya et al., 2015). Torba yogurt is known as *labneh* or *lebneh* in the Middle East, *leben zeer* in Egypt, *skyr* in Iceland, *chakka* and *shrikhand* in India, *than* or *tan* in Armenia, and *ymer* in Denmark (Kesenkaş et al., 2017). Moreover, it is used to produce kurut, another traditional product in Anatolia (Kabak and Dobson, 2011).

Torba yogurt is produced by cow's milk, goat's milk, sheep's milk, or a mixture of them using two procedures. In the first, the set-type yogurt is boiled, and salt is added (Kesenkaş et al., 2017). In the second method, plain yogurt is strained in a specific cloth bag for 10–14 h to remove the whey. Subsequently, it is packed and stored at 4°C. In addition, to extend the shelf life of the final product, salt can be added to torba yogurt (Şanal et al., 2011). In the commercial method of torba yogurt production, centrifugation, ultrafiltration and reverse osmosis are employed (Yerlikaya et al., 2015). The shelf life of torba yogurt packed in a cloth bag is between 14 and 21 days (Al-Kadamany et al., 2002). Torba yogurt contains 70.0–82.0% moisture, 25.3–25.4% total solids, 9.9–10.9% crude protein, 7.5–9.0% fat, 4.3–6.7% lactose, and 0.56–0.82% minerals. Torba yogurt is a major source of phosphorus, calcium, magnesium, selenium, and zinc (Kesenkaş et al., 2017).

Kefir

Kefir is an acidic, viscous, and slightly alcoholic milk beverage that originated from the Caucasus mountains in Central Asia thousands of years ago (Nielsen et al., 2014). The word kefir is derived from the Turkish word keyif, which means good feeling. Kefir is widely consumed in Eastern and Northern Europe, Russia, and Southwest Asia and is also known by several names, such as *kephir*, *kipi*, *kippi*, *kefyr*, *kiaphur*, *kefer*, and *knapon* (Koyu and Demirel, 2018). Although cow's milk is most commonly used in kefir production, milk from different animals, such as goats, sheep, and camels is also used. Kefir can also be prepared using non-dairy beverages, such as soy milk, rice milk, peanut milk, cocoa-pulp beverage, walnut milk, and coconut milk (Behara et al., 2017).

Kefir is produced using the traditional or industrial method. Traditionally, kefir is produced from kefir grains; therefore, the kefir production process is different from that of other fermented dairy products (Kabak and Dobson, 2011; Gul et al., 2015). Kefir grains are elastic, irregularly shaped (with a diameter of 3 mm to 35 mm), gel-like, and white-yellowish colored. The kefir grain is a complex community of approximately 30 species (or more) of LAB (*Lactobacillus* spp., *Lactococcus* spp., *Streptococcus* spp., and *Leuconostoc* spp.) and yeast, such as *Kluyveromyces maxianus*, *Torulaspora delbrueckii*, *Saccharomyces cerevisiae*, *Candida kefir*, *Saccharomyces unisporus*, *Pichia fermentans*, *Kazachastania aerobia*, *Lachanceae meyersii*, *Yarrowia lipolytica*, and *Kazachstania unispora* (Nielsen et al., 2014). These microflora act in symbiosis to produce kefir. Kefiran is the main polysaccharide matrix on the outer surface of kefir and contains D--glucose and D-galactose in a 1:1 ratio. *Lactobacillus kefiranofaciens* and *Lactobacillus kefiri* are important microorganisms contributing to kefiran formation (Koyu and Demirel, 2018). In the traditional method, kefir grains are added to pasteurized cow's milk as a starter culture. Although the ideal ratio of grain/milk ranges between 1:30 and 1:50 w/v, the quantities used in the traditional method are determined empirically (Tomari et al., 2020). The milk with kefir grains is incubated at temperatures ranging from 8–25°C for 10–40 h until a pH of 4.4 is reached. However, the commonly used temperature is 20–25°C for 18–24 h. At the end of the incubation period, kefir grains are separated from the fermented milk through filtration. Finally, kefir can be consumed immediately or stored in a refrigerator for later consumption. During cooling, aroma components increase due to maturation. Separated kefir grains can be reused as a starter culture for a new batch of kefir. Kefir grains increase by approximately 2–7% at the end of the fermentation. Kefir grains can be stored using several ways, for example, they remain active for 8–10 days at 4°C. Alternatively, they can be stored at room temperature for 36–48 h and 12–18 months in dried form (Bengoa et al., 2019; Tomari et al., 2020). Commercial kefir is produced using the Russian method or the pure-culture method. In the former method, bulk culture prepared from kefir grains is used for large-scale kefir production by using a series of fermentation processes; in the latter, pure cultures isolated from kefir grains or commercial cultures are employed (Prado et al., 2015). According to the Turkish Food Codex Communique on Fermented Dairy Products, the number of total microorganisms in kefir should be at least 10^7 CFU/mL, with a yeast count of at least 10^4 CFU/mL (Koyu and Demirel, 2018). Depending on the amount of kefir grain added, kefir contains 90% moisture, 3.0% protein, 0.2% lipid, 6.0% sugar, 0.7% ash, 1.0% lactic acid, 0.48% alcohol, and 201.7–277.0 mL/L CO_2 (Farag et al., 2020).

Kefir is a probiotic food. Organisms isolated from kefir grains have several positive effects on human health (Setyowati and Setyani, 2016; Moretti et al., 2022). These organisms produce substances with antagonistic activity to pathogen growth, such as lactic acid, acetic acid, carbon dioxide, hydrogen peroxide, ethanol, diacetyl, and bacteriocins. They inhibit the cytotoxic effect of *Clostridium difficile* on eukaryotic cells *in vitro* and demonstrate antimicrobial activity due to bacterial interference as *Lactobacillus* adheres to receptor sites in the gut (Ahmed et al., 2013). They inhibit *Helicobacter pylori*, which causes chronic gastritis, ulcers, and gastric cancer, and affect blood pressure through angiotensin-converting enzyme (ACE) inhibition. They kill cancer cells in vitro and inhibit cancer growth in vivo, exhibit immunomodulating effects, aid in lactose digestion, and reduce the symptoms of lactose intolerance (John and Deeseenthum, 2015). They can be used to treat tuberculosis and gastrointestinal disorders in cases of unsuccessful medical treatment and affect the adhesion of *Salmonella typhimurium* to Caco-2 cells (Kabak and Dobson, 2011; Nielsen et al., 2014).

Koumiss

Koumiss is also known as *kumiss*, *kumis*, *kymis, kymmyz*, or *coomys* and is a traditional milk beverage that originated from the nomadic tribes of Central Asia steppes (Dhewa et al., 2015). This mild alcoholic beverage is consumed widely by Turks, Bulgars, and Mongols. Moreover, it is significant for Kazakhs, Kyrgyz, Uyghurs, and Yakuts (Bayat, 2020).

Koumiss is produced using mare's milk. Because of its small amounts of casein and fat, mare's milk is not suitable for making cheese and butter. Mare's milk has an unstable structure at temperatures above 40°C; therefore, it is cooled immediately after milking and should be consumed within 6–9 h. The most suitable method for the long-term preservation of mare's milk is to produce koumiss (Tegin and Gönülalan, 2014). Traditionally, koumiss is produced by heating mare's milk at 90–92°C for 5–10 min and then cooling to 26–28°C. Fresh mare's milk (usually unpasteurized) is incubated in wooden casks or bags made of animal skin. Nowadays, porcelain urns are also used. Fresh mare's milk is mixed with a part of the previous day's batch of koumiss, which contains LAB and yeast as a starter culture, and is incubated at ambient temperatures (approximately 20°C). In another method, 10–30% of the starter culture (one part of *Lactobacillus bulgaricus* grown at 37°C in mare's milk for 7–8 h and two parts of *Torula* spp. grown at 30°C for 15 h) is added to achieve an initial acidity of 0.45% (lactic acid). The mixture is stirred vigorously for approximately 1 h to introduce air and to create a suitable environment for yeast growth. This mixture is then incubated at 28°C to achieve 0.7–0.8% acidity. Finally, the mixture is cooled to 20°C, with continuous stirring for 1–2 h (Özer and Kirmaci, 2014; Dhewa et al., 2015) (Fig. 1). The final product is bottled and left for ripening at 6–8°C for 1–3 days. The alcohol level of the finished koumiss is between 0.7% and 2.5% (Dhewa et al., 2015).

For koumiss production, mare's milk is fermented using indigenous microorganisms. The microbial composition in original koumiss is quite variable, with the major microflora being *Lactobacillus delbrueckii*, *Lactobacillus bulgaricus*, *Lactobacillus salivarus*, *Lactobacillus buchneri*, *Lactobacillus plantarum* (new name *Lactiplantibacillus plantarum*), *Lactobacillus caseii* (new name *Lacticaseibacillus casei*), *Lactobacillus fermentum* (new name *Limosilactobacillus fermentum*), *Lactobacillus helveticus*, *Lactobacillus rhamnosus* (new name *Lacticaseibacillus rhamnosus*), *Lactobacillus acidophilus*, lactose-fermenting yeasts (*Torula koumiss* and *Saccharomyces lactis*, *Kluyveromyces lactis*), and non-lactose-fermenting yeasts such as *Saccharomyces unisporus* (Kabak and Dobson, 2011). *Lactobacillus* spp. plays an important role in the fermentation process of koumiss and affects the aroma, texture, and acidity of the final product. *Lactobacillus* spp. is also beneficial to human health as a probiotic culture. Moreover, during koumiss production, the yeasts generate alcohol through alcoholic fermentation. Based on its lactic acid content, koumiss is classified into strong, moderate, and light. *Lactobacillus bulgaricus* and *Lacticaseibacillus rhamnosus* acidify the milk by lowering the pH to 3.3–3.6 and convert 80–90% of lactose into lactic acid during the production of the strong koumiss. Moderate koumiss contains *Lactobacillus* spp., such as *Lactobacillus acidophilus*, *Lactiplantibacillus plantarum*, *Lacticaseibacillus casei*, and *Limosilactobacillus fermentum*, with restricted acidification properties that lower the pH to 3.9–4.5 in the final product; the average conversion ratio is 50%. Light koumiss is a slightly acidified product (pH 4.5–5.0) and consists of *Streptococcus thermophilus* and *Streptococcus cremoris*. Among the three types of koumisses, moderate koumiss is the best beverage (Danova et al., 2005).

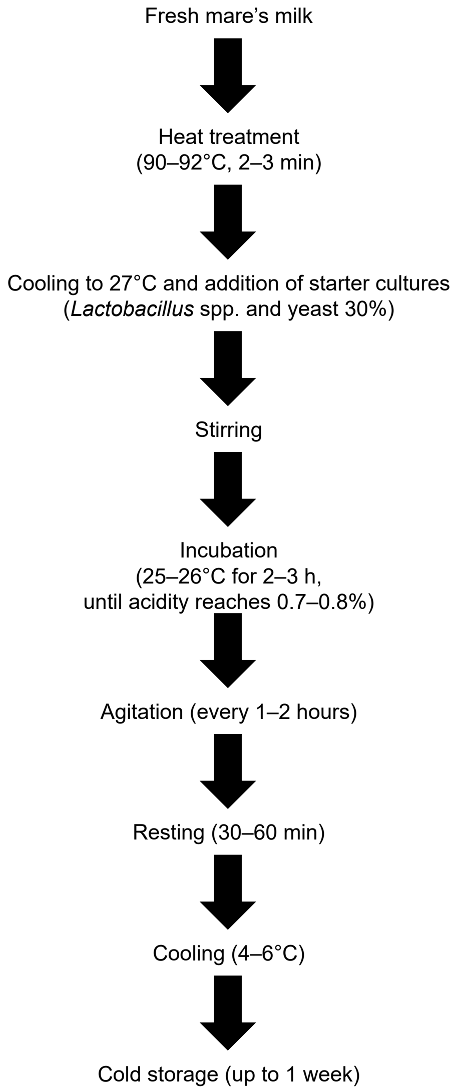

Fig. 1. Traditional koumiss production from mare's milk (adapted from Özer and Kirmaci, 2014; Aladeboyeje and Sanli, 2021)

Koumiss is a valuable beverage due to its high nutrition content. The lactose in mare's milk is converted into lactic acid, ethanol, and CO_2 during the fermentation process (Zhao et al., 2023). Therefore, milk becomes a source of nutrition for lactose-intolerant people. Koumiss is an excellent source of probiotic microorganisms for humans (Kondybayev et al., 2021). The nutritional and organoleptic properties of the probiotic koumiss protect against infections. In addition to its probiotic nature, koumiss possesses antibacterial and antifungal properties, regulates immunity, maintains a healthy gastrointestinal system, regulates cholesterol and blood sugar levels, regulates blood pressure, and induces the production of essential ingredients such as vitamins and minerals (Afzaal et al., 2021; Kirdar, 2021). Koumiss may also be used for skin beautification because of its moisturizing properties. Koumiss microflora form a biological barrier on the stomach walls and intestines. Moreover, it contains essential and rare compounds required for the smooth functioning of the neurological system (Kabak and Dobson, 2011; Dhewa et al., 2015).

CEREAL-BASED FERMENTED FOODS

Cereals are important sources of carbohydrates, proteins, minerals, fiber and vitamins in the diet. The fermentation of cereals, however, leads to a decrease in the level of carbohydrates and reduces the levels of polysaccharides and oligosaccharides. Cereals are fermented using different raw materials, starter cultures, and fermentation conditions in several parts of the world. Fermented cereal products are preferred by people with lactose intolerance and milk allergies and those who follow a low lipid or vegan dietary pattern. Moreover, they are novel probiotic delivery vehicles and potential functional foods (Tsafrakidou et al., 2020). In Anatolia, traditionally produced cereal products include tarhana, bread, bazlama, simit (a circular bread with sesame seeds), pide (flatbread), and boza. We have described tarhana and boza below.

Tarhana

Tarhana is a traditional fermented cereal product. Tarhana first came to Anatolia when Turks and Mongols immigrated from Central Asia in the sixth and seventh centuries (Coşkun, 2014; Özdemir and Zencir, 2017). Tarhana is known as *kishk* in Syria, Palestine, Jordan, Lebanon, and Egypt, *trahanas* in Greece, *kushuk* in Iran and Iraq, *talkuna* in Finland, *trahana* in Bulgaria, *tarana* in Macedonia, *trahan* in Albania, *göce* in Turkistan, *atole* in Scotland, and *thanu* in Hungary. Although tarhana production techniques are similar in all countries, the amount of the final product may vary according to the nutritional habits of the different countries (Şimşekli and Doğan, 2015; Yıldırım and Güzeler, 2016). According to the Turkish Standardization Institute, tarhana is produced by mixing wheat flour, crushed wheat, semolina, or a mixture of this with yogurt, salt, pepper, onion, tomato, and odorless herbal substances, followed by kneading, fermenting, drying, grinding, and sieving. On the basis of the amount of wheat flour, crushed wheat, and semolina used in tarhana production, tarhana is classified into flour tarhana, göce tarhana, semolina tarhana, and mixed tarhana (Coşkun, 2014; Yönel et al., 2018). Semolina is used instead of wheat flour in semolina tarhana production. At least two ingredients, such as wheat flour, crushed wheat, and semolina, are used in the production of mixed tarhana. Apart from these varieties, several types of tarhana are also produced in Anatolia. Because of the lack of a standard production method, tarhana formulation and preparation method can vary from region to region (Coşkun, 2014; Georgala, 2018). Tarhana varieties in Turkey are *wheat tarhana* in Aegean Region, *göce tarhana* in Ankara, Muğla, Maraş, and Aydın, *circular tarhana* in Isparta, *kızılcık tarhana* in Bolu, Kastamonu, and Bursa, *Thrace tarhana* in Edirne, Tekirdağ, and Kırklareli, *white tarhana* in Kütahya, *Gediz tarhana* in Gediz, *tarhana with minced wheat* in Thrace Region, *Beyşehir tarhana* in Konya, *göçmen tarhana* in Marmara Region, *wet tarhana* in Kastamonu, Eskişehir, and Bursa, *tarhana with turnip* in Maraş, *milk tarhana* in Çanakkale, *meat tarhana* in Karaman, *grape tarhana* in Tokat, *sweet tarhana* in Malatya, *dough tarhana* in Gölhisar, *tarhana with beet* in Kastamonu and *Maraş tarhana* in Maraş (Badem, 2020).

In the traditional method of tarhana production, the dough is prepared by mixing all raw materials and fermenting for 1–5 days at 30–35°C. Subsequently, it is dried under the sun, ground, and stored (Daglioglu, 2000). Lactic acid fermentation is used in tarhana production; bread yeast is also used in Central Anatolia. The benefits of using yeast in tarhana production include a shorter fermentation period and a different taste and odor due to the release of amino acids (Georgala, 2018). Because of the metabolic activities of LAB, organic acids, such as propionic acid, succinic acid, citric acid, formic acid, lactic acid, and acetic acid are formed during the fermentation process in tarhana production. These organic acids decrease the pH to approximately 3.8–4.2 (Tarakçı et al., 2004). Therefore, tarhana has both an acidic and sour taste. Moreover, it inhibits the growth of several pathogenic microorganisms. Yeasts, such as *Saccharomyces cerevisiae*, and LAB, such as *Lactobacillus bulgaricus*, *Streptococcus thermophilus*, *Lacticaseibacillus casei*, *Lactobacillus* *diacetylactis*, *Lactobacillus acidophilus*, *Lactiplantibacillus plantarum*, *Lactobacillus brevis* (new name *Levilactobacillus brevis*), *Lactobacillus casei* subsp. *pseudoplantarum*, *Lactobacillus helveticus*, *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Lactococcus lactis*, *Lactococcus diacetylactis*, *Pediococcus pentosaceus*, *Pediococcus acidilactici*, *Leuconostoc mesenteroides* subsp. *mesenteroides* and *Leuconostoc cremoris*, play an important role in the fermentation process of tarhana production (Tangüler, 2014; Badem, 2020).

Modern tarhana production is mainly conducted to straight and the sourdough methods. In the straight method, all ingredients are finely chopped and kneaded to obtain a dough, which is left to ferment for 5 days at 35°C. Subsequently, the dough is oven-dried at 55°C for 28 h with 10% moisture, and the dried tarhana is ground and stored. In the sourdough method, three different formulations are used. These three formulations (Table 2) should be well-balanced. In the first formulation, all ingredients are mixed, kneaded thoroughly, poured into steel trays, and fermented at 40–42°C for five days. At the end of this period, the ingredients of the second formulation are mixed in a separate container, and a fermented dough mixture from the first formulation is added to it. This mixture is kneaded and dried at 80°C with 8% moisture. Finally, the ingredients of the third formulation are prepared, mixed, and kneaded together with the first and second formulation dough mixture. This final dough mixture is poured

Table 2. Tarhana ingredients (adapted from Daglioglu, 2000; Işık Erol, 2010; Öney, 2015)

Straight method	
100 units of wheat flour	5 units of lentil flour
37.5 units semolina	1.5 units of vegetable oil
60 units yogurt	5 units of salt
37.5 units of onion	4 units of mint
7.5 units of tomato puree	20 units of yeast
7.5 units of pepper puree	1 unit of citric acid

Sourdough method		
Formula 1	Formula 2	Formula 3
100 units of wheat flour	100 units of tarhana dough	100 units of tarhana dough prepared from formula1
50 units semolina	60 units of wheat flour	125 units of tarhana dough prepared from formula 2
80 units yogurt	60 units semolina	6 units of tomato puree
10 units of tomato puree	4.8 units of tomato puree	6 units of pepper puree
10 units of pepper puree	4.8 units of pepper puree	
50 units onion	6 units of salt	
7 units of lentil flour	4 units starch	
7 units of salt	0.4 units of citric acid	
1.5 units of vegetable oil		
0.4 units of citric acid		

into trays of 1–5 thickness cm and dried at 80°C until the moisture content is below 10%. After drying, tarhana is ground and packaged (Daglioglu, 2000; Magala et al., 2013; Tangüler, 2014). The drying phase is the most crucial step in the tarhana production process. In the traditional method, tarhana is dried under the sun. Different techniques, however, are preferred, such as freeze-drying, tunnel drying, and microwave drying in modern technology. The drying process affects the physical and chemical properties, nutritional value, sensory properties, and microorganism load of the tarhana (Georgala, 2018).

Tarhana is a traditional food product obtained from vegetable and animal raw materials; therefore, it has a high nutritional value (Magala et al., 2013). Macromolecules such as proteins, carbohydrates, and fats are broken down by LAB during lactic acid fermentation in tarhana production. Therefore, tarhana is easy to digest with high nutritious properties (Ozdemir et al., 2007). Because of the degradation of lactose by LAB during the fermentation process, tarhana can be consumed by lactose-intolerant people. The levels of riboflavin, niacin, pantothenic acid, ascorbic acid, and folic acid in tarhana increase substantially due to fermentation (Tangüler, 2014). Tarhana, which is rich in vitamins A and B, also regulates the human intestinal system because of its fibrous structure (Yıldırım and Güzeler, 2016). Tarhana has high contents of minerals, such as calcium, iron, sodium, potassium, magnesium, zinc, and copper (Çekal and Aslan, 2017). Tarhana, one of the oldest probiotic foods, maintains blood cholesterol levels and reduces the risk of colon cancer (Gabrial et al., 2010; Yönel et al., 2018). Tarhana is commonly produced from wheat flour; therefore, tarhana consumption is forbidden for people with celiac disease. Celiac disease is a substantial autoimmune disease common in genetically predisposed individuals, wherein gluten ingestion leads to minor intestine damage (Tuluk and Ertaş, 2019).

Boza

Boza is a cereal-based fermented beverage obtained from the fermentation of wheat or rice semolina or a combination of rye, oats, barley, and millet flour, and is popular in Turkey, South Russia, Kazakhstan, Kyrgyzstan, Albania, Bulgaria (Sofia, Varna, and Burgas), Macedonia, Montenegro, Bosnia and Herzegovina, and parts of Romania and Serbia. Beverages similar to boza are *Braga* or *brascha* in East European countries, *busa* in the Balkans, and *bouza* in Egypt (Baschali et al., 2017). The history of boza goes back as far as 8000–9000 years ago, when ancient populations lived in Anatolia and Mesopotamia. The term boza is derived from the Persian word *buze*, which means millet. Boza is considered the ancestor of beer and is sometimes consumed with cinnamon and roasted chickpeas in Anatolia (Levent and Cavuldak, 2017).

Boza is a viscous low-alcoholic beverage with a pleasantly sweet taste, slightly acid flavor (depending on its acid content), and varying color (from creamy-white and beige to light brownish) and is produced from various kinds of cereals. However, boza that the best quality and taste is manufactured from millet flour. The boza production process consists of six stages: raw material preparation, boiling, cooling, straining, sugar adding, and fermentation. In boza production, previously fermented boza can also be used as inoculum (2–3%) instead of a starter culture. Two different types of fermentation, namely lactic acid fermentation by LAB and alcohol fermentation by yeasts, occur during boza production (Tangüler, 2014). Therefore, LAB (such as *Lactobacillus confusus*, *Limosilactobacillus fermentum*, *Lactobacillus cryniformis*, *Lactobacillus sanfrancisco*, *Lactobacillus coprophilus*, *Lactobacillus paracasei* (new name *Lacticaseibacillus paracasei)*, *Levilactobacillus brevis*, *Lacticaseibacillus rhamnosus*, *Lactiplantibacillus plantarum*, *Lactobacillus acidophilus*, *Leuconostoc raffinolactis*, *Leuconostoc mesenteroides*, *Leuconostoc oenos*, *Leuconostoc brevis*, *Leuconostoc citreum*, *Pediococcus pentosaceus*, and *Lactococcus lactis subsp. lactis*) and yeasts (such as *Saccharomyces cerevisiae*, *Saccharomyces carlsbergensis*, *Candida pararugosa*, *Candida diversa*, *Candida boidinii*, *Candida lactiscondes*, *Candida lambica*, *Candida norvegica*, *Candida inconspicua*, *Candida tropicalis*, *Candida glabrata*, *Geotrichum penicillatum*, and *Geotrichum candidum*) are widely isolated from boza (Petrova and Petrov, 2017).

Boza is produced both in homes and industries (Tangüler 2014, Bayat and Yıldız, 2019). Raw materials, such as millet, wheat or bulgur, maize, rice, and semolina can be used in boza production. The boza production process is depicted in Figure 2. First, selected cereals are cleaned to remove foreign materials and broken into semolina-sized pieces (approximately 300–800 mm). The broken cereals are then boiled in an open or steam-jacketed boiler after the addition of drinking water. The mixture is boiled for 30–35 min using direct heat or for 60–120 min using indirect heat (Akpinar-Bayizit et al., 2010). When the color of the mixture is similar to that of oatmeal or well-baked bread crust, the boiling process is discontinued, and the mixture is immediately transferred into suitable marble vessels for cooling. This cooling stops the thermal effect, which could lead to caramelization and embittering of the product. The cooled material is filtered to remove the bran, hull, and other foreign materials. When the temperature falls below 35°C, the gruel is diluted with water to achieve 8% solid content and sweetened to obtain 15–20% sugar content (Tangüler, 2014). Subsequently, it is inoculated with previously fermented boza, sourdough, or yogurt as a starter culture (2–3%), and fermentation is performed at 26–28°C for approximately 24 h. Boza is then cooled to a refrigerator temperature that should not exceed 4°C and consumed within 3–5 days. Boza is the oldest traditional winter beverage in Turkey (Arici and Daglioglu, 2002). At the end of fermentation, the pH of boza ranges from 6.7 to 3.4, and the alcohol content varies from 0.02% to 0.79%. The acidity and alcohol content of boza depends on its fermentation period, and the content increases with a longer fermentation (Kabak and Dobson, 2011). Boza contains approximately 0.50–1.61% protein, 12.3% carbohydrate, 8–12% sugar, 75–85% moisture, 0.4–0.5% lipids, 29 mg Ca, 1.3 mg Fe, 95 mg phosphorus, 1 mg Zn, and vitamins (Petrova and Petrov, 2017).

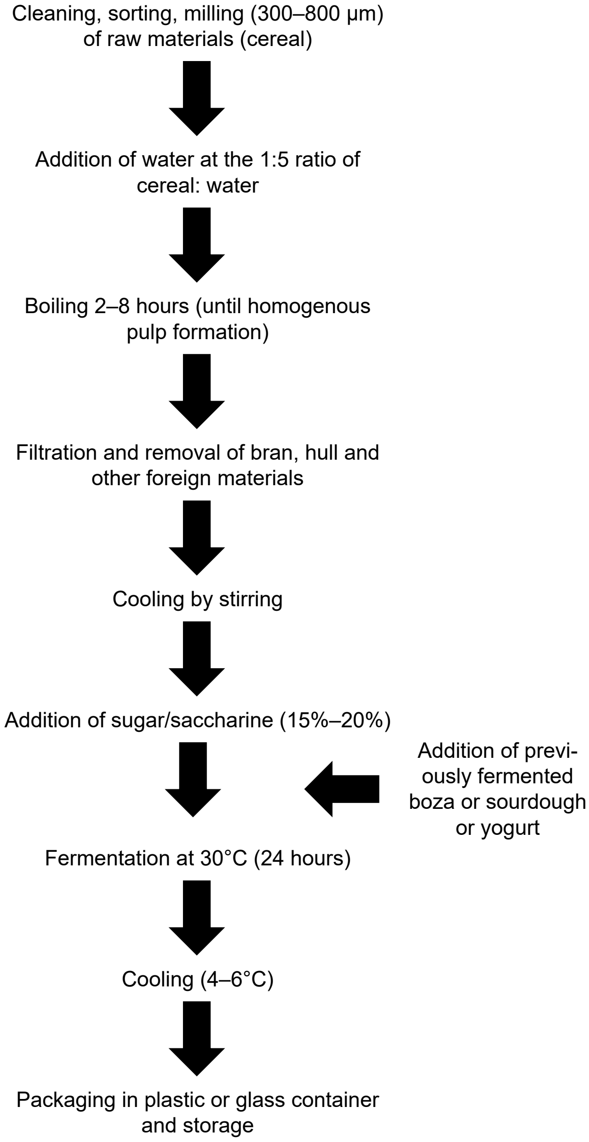

Fig. 2. Boza production (adapted from Tangüler, 2014; Aladeboyeje and Sanli, 2021)

Boza is a rich source of probiotic bacteria, such as *Lactiplantibacillus plantarum*, *Lacticaseibacillus paracasei*, *Lacticaseibacillus rhamnosus*, and *Lactobacillus pentosus*. Since boza has prebiotic properties, it stimulates the growth of probiotic LAB (Altay et al., 2013). Due to its lactic acid, fat, calcium, carbohydrate, vitamin A, B_1, B_2, and B_6, nicotinamide, Ca, Fe, P, Zn, Na, β-glucan, and dietary fiber contents, boza has been evaluated as a healthy beverage that contributes to human nutrition, stimulate immune system, and decreases the cholesterol level (Ignat et al., 2020; Ucak et al., 2022). The inhibitory activity of an angiotensin-converting enzyme (ACE) of boza regulates blood pressure (Kancabas and Karakaya, 2013).

FERMENTED FRUITS AND VEGETABLES

Vegetables and fruits are crucial substrates used in different traditional fermented foods production, especially fermented beverages. Vegetables and fruits are rich in carbohydrates, dietary fiber, vitamins, proteins, minerals, amino acids, polyphenols, and phytochemicals (Garcia et al., 2020), and their chemical composition depends on the geographical location and climatic conditions where they are grown. The time of harvesting and the degree of maturity of the raw material used in fermented foods is not always the same for every processing (Cuvas-Limon et al., 2020). Vegetables and fruits are perishable foods, and their short shelf life can be improved by fermentation then by storing them in a refrigerator. Fermentation of fruits and vegetables can occur spontaneously because of the natural lactic bacteria on their surfaces (Swain et al., 2014).

Tursu (pickle)

Pickles are produced from various vegetables and fruits in several countries (Swain et al., 2014). However, in Anatolia, compared with fruits, vegetables are more suitable for pickle production. The word pickle is derived from the Persian word *torsh*, which means sour. Tursu is one of the oldest traditional products in Anatolia (Behera et al., 2020). Various vegetables, such as cucumber, cabbage, pepper, tomato, bean, and carrot, are used in pickle production. In addition, melon (unripe), okra, broccoli, celery leaf, cranberry, apple (raw green), plum (raw green), shalgam (raw green), apricot (raw green), peach (raw green), pear (ahlat), grapes (unripe), capers (large-sized capers), cherry, and sour cherry are also used in tursu production in some regions, according to consumers' preferences. Vinegar, salt, and several aroma ingredients, such as garlic, parsley, fresh mint leaves, ginger, fresh dill leaves, and bay leaves are also used in tursu production (Palamutoğlu and Baş, 2020).

Tursu is commonly produced at home, especially in autumn, and can be made spontaneously using the natural lactic acid bacteria found on surfaces (Kabak and Dobson, 2011). Currently, it is produced on a commercial scale to address quality, safety, and mass production issues. Tursu can be produced through lactic fermentation by using *Lactiplantibacillus plantarum*, *Levilactobacillus brevis*, *Leuconostoc mesenteroides*, *Enterococcus faecalis*, and *Pediococcus pentosaceus*, followed by yeast fermentation. Some fermentative yeasts, such as *Torulopsis*, *Hansenula*, and *Saccharomyces* spp., are isolated from tursu in the later steps of tursu fermentation (Tokatlı et al., 2012; Behera et al., 2020). Either plain or mixed tursu can be produced. However, in Anatolia, mixed tursu is preferred (Çetin, 2011). The traditional method of producing tursu involves three steps. First, vegetables and/or fruits are washed with fresh drinking water, and the cleaned raw materials and aroma ingredients are placed in either glass or plastic containers, where they can be preserved and pressed. Subsequently, brine (4.7–7.5% NaCl, w/v) consisting of grape vinegar is added to the container, and the tursu is left to ferment. The fermentation time at 17–20°C depends on the inoculation of a starter culture and/or the concentration of salt brine. In a low-salt brine solution (4.7% NaCl, w/v) with a starter culture, inoculated fermentation takes 11–12 days; without a starter culture, inoculated fermentation takes 35 days. An initial salt concentration (5–7.5% NaCl, w/v) for 4–5 days is optimum for the fermentation of pickling (Chavasit et al., 1991; Behera et al., 2020). The primary ingredient in tursu is vinegar (acetic acid), which can be obtained from various sources. Therefore, the aroma of tursu is substantially affected by the vinegar, depending on its sources. Moreover, tursu is highly acidic (pH 4.6 or below) in nature (Sayın and Alkan, 2015).

Anthocyanins vitamins, minerals, and carbohydrates prevent several diseases, such as diarrhea and cirrhosis of the liver (because of their probiotic properties), and contain pigments, such as flavonoids, lycopene, anthocyanin, β-carotene, and glucosinolates (antioxidants) (Swain et al., 2014).

Shalgam

Shalgam is a popular fermented beverage from the Çukurova region of southern Turkey, especially in Adana, Hatay, Antakya, İçel, and Kahramanmaraş. However, in recent years, its consumption has increased gradually in other regions of Turkey. Moreover, shalgam is available in some European cities where Turks live (İncedayi et al., 2008; Tangüler et al., 2020). Traditionally, shalgam is obtained through lactic acid fermentation of black carrot (*Daucus carota* L.), bulgur bran, chili powder, rock salt, turnip-root (*Brassica rapa* L.), and sourdough (Tangüler and Erten, 2013). Shalgam is a dark red, cloudy, and sour soft beverage. Black carrot, bulgur bran, sourdough (or sometimes baker's yeast, *Saccharomyces cerevisiae*), water, and rock salt are the main ingredients used in shalgam production, whereas turnip is a minor component. Black carrots contribute to the dark color of shalgam (Ekinci et al., 2016). The composition of shalgam is presented in Table 3 (Erten et al., 2008).

LAB, mainly *Lactobacillus* spp. (89.63%), *Leuconostoc* spp. (9.63%), and *Pediococcus* spp. (0.74%), and yeast (to a lesser extent), play an essential role in the production of natural shalgam. Microorganisms obtained from sourdough are *Lactobacillus pontis*, *Levilactobacillus brevis*, *Lactiplantibacillus plantarum*, *Lactobacillus sanfranciscensis*, *Lactobacillus alimentarius*, *Lactobacillus arabinosus*, *Lactobacillus delbruecki*, *Lactobacillus fructivorans*, *Lactobacillus paracesii*, *Lactobacillus reuteri* (new name *Limosilactobacillus reuteri)*, *Limosilactobacillus fermentum*, and *Saccharomyces cerevisiae*; moreover, *Saccharomyces exiguous*, *Candida krusei*, and *Candida milleri* are obtained to a lesser extent (İncedayi et al., 2008; Üçok and Tosun, 2012; Altay et al., 2013). Lower levels of *Lactobacillus* species are also detected as a secondary microbiota of non-*Lactobacillus* LAB strains (Erten et al., 2008). However, to date, information on the identification of LAB from shalgam and its microbiological quality remains limited. Shalgam varies in terms of chemical, microbiological, and sensory characteristics. Therefore, further studies on shalgam are required (Tangüler and Erten, 2013).

Table 3. Shalgam composition (adapted from Erten et al., 2008)

Biochemical composition	Values
pH	3.33–3.67
Titratable acidity as lactic acid g/L	5.94–8.91
Lactic acid, g/L	5.18–8.05
Volatile acidity as acetic acid g/L	0.57–1.16
Alcohol, g/L	1.32–6.41
Total solids, g/L	22.9–29.2
Protein, g/L	0.88–1.83
Ash, g/L	14.6–20.65
NaCl, %	1.37–1.97
CO_2, g/L	0.44–0.79
Color index (D520)	71–131
Anthocyanin as cyanidin-3-glycoside, mg/L	88.3–134.6
Total aerobic mesophilic bacteria	At most 1.0×10^5 CFU/mL
Coliform bacteria	At most 1100 CFU/mL

A standard method for commercial or home-scale shalgam production does not exist. Spontaneous fermentation is used in shalgam production; however, starter cultures for fermentation are used in controlled laboratory-scale production. In general, starter cultures are not preferred in commercial production. The addition of 15% (w/w) shalgam juice from a previous production is commonly used (Ekinci et al., 2016). Two processing methods for commercial shalgam production are traditional production and direct production. The traditional method involves first and second fermentation. The first fermentation is also called sourdough or dough fermentation (Erten et al., 2008). At this stage, primarily, LAB and yeast are enriched. First, bulgur flour with boiled or pounded wheat (3%), rock salt (0.2%), sourdough (0.2%), and adequate drinking water are mixed and kneaded to obtain a dough. On cold days, warm water must be used. The dough mixture is left to ferment at room temperature (25°C) for approximately 3–5 days. This fermented mixture is extracted with adequate water three to five times (Tangüler et al., 2020). The second fermentation that follows the first fermentation is also called the main or carrot fermentation. For the second fermentation, the extract from the first fermentation is combined in a tank with black carrot roots, rock salt (1–2%), and sliced turnip (1–2%) (if available), followed by the addition of adequate drinking water. Before the second fermentation process, the black carrots are washed, if necessary. All damaged carrots are removed and cut into 3–9 cm long pieces. The fermentation process is naturally performed for 3 to 10 days at room temperature (10–35°C). Finally, shalgam juice is filtered, packaged in suitable bottles, and stored in cold conditions until consumption (İncedayi et al., 2008). The direct or commercial method consists of single-stage fermentation. Dough fermentation is not performed in this method. Chopped black carrots, salt, baker's yeast or sourdough, sliced turnip (if available), and adequate water are mixed in a tank and allowed to ferment at room temperature. During fermentation, the characteristic flavor of shalgam is obtained from lactic acid, ethanol, acetic acid, and other organic compounds produced by LAB (Tangüler and Erten, 2013). In the traditional method, fermentation is completed over a long time (approximately 20–25 days), whereas in the commercial method, it takes a shorter time (approximately 4 days) (İncedayi et al., 2008).

Shalgam has a short shelf life of approximately 90–120 days in a closed plastic tank or a container at 4°C. Heat treatment such as pasteurization is not applied during shalgam production. A few shalgam manufacturers have introduced the pasteurization process to prolong the shelf life of shalgam. However, heat treatment may result in the loss of sensory properties, such as cooked carrot taste, in the final product. Therefore, heat-treated shalgam is not preferred by consumers. Non-thermal heat treatment, such as ultraviolet pasteurization, ultrasonication, and high-pressure processing pasteurization, is performed to increase the shelf life of shalgam. In addition to non-thermal heat processing, some chemical additives can be added to increase the shelf life of shalgam. According to the Turkish Food Codex-Food Additives Other Than Coloring and Sweeteners Directive, sodium and potassium salts of benzoic acid (Na-benzoate and K--benzoate; at a maximum concentration of 200 mg/L) may be used as a preservative to extend the shelf life of shalgam. Membrane filtration techniques may also be used for this purpose, and ready-to-drink shalgam produced using membrane filtration can be stored at 4°C and 20°C for 150–180 days (Tangüler et al., 2020).

Shalgam can be considered a functional food because of the various health benefits, namely toxin removal; diuretic effect; kidney sand and stone removal; lungs and bronchi cleaning; abscess, puberty acne, and eczema reduction; immune system strengthening through the enhancement of white blood cell function; digestion improvement; reduction of cardiovascular disease risk; reduction of cold severity and duration by lowering free radicals; and antioxidant properties (Üçok and Tosun, 2012). Shalgam is an excellent source of vitamin C, which has several health benefits, such as promoting bone health and enhancing iron absorption in the body. Shalgam is also rich in minerals such as potassium, calcium, magnesium, iron, phosphorus, sulfur, iodine, and sodium. Potassium positively affects human cardiovascular health and preserves the normal function of nerve, heart, and skeletal muscle cells. Carrots are rich in anthocyanin compounds, with several positive effects on human health, such as coronary heart disease risk reduction, antioxidant activities, and anticancer activities. Because LAB is employed in the shalgam fermentation process, shalgam is considered a probiotic food (İncedayi et al., 2008).

Hardaliye

Hardaliye has been widely consumed since ancient times in the Thrace region and the European part of Turkey. Hardaliye is a lactic acid-fermented beverage produced from either red grape or grape juice, with the addition of crushed mustard seeds, sour cherry leaf, and benzoic acid. Grapes are rich in phenolic compounds, such as flavonoids and anthocyanins (Coskun et al., 2018). The color of hardaliye is contributed by grapes (Coskun, 2017). First, the grapes are washed and crushed in a wooden jar or, preferably, a barrel. Subsequently, 0.3–0.4% of crushed raw black mustard seeds (*Brassica nigra* (L.) Koch) with or without 0.1% of benzoic acid are added as a preservative to protect against mold and yeast growth (Başyiğit Kılıç et al., 2016). Crushed cherry leaves (*Prunus cerasus* L.) and black mustard seeds enhance the aroma of hardaliye. This solution is left to ferment at room temperature for approximately ten days (Fig. 3) (Gucer et al., 2009; Coskun 2017). After fermentation, filtration removes sour cherry leaves and grape residues from the hardaliye (Amoutzopoulos et al., 2013). The LAB count ranges from 1 × 10^2 to 1 × 10^4 CFU/mL in hardaliye. *Lactobacillus paracasei* subsp. *paracasei*, *Lactobacillus casei* subsp. *pseudoplantarum*, *Lactobacillus pontis*, *Levilactobacillus brevis*, *Lactobacillus acetotolerans*, *Lactobacillus sanfrancisco*, and *Lactobacillus vaccinostercus* are predominant in hardaliye (Kabak and Dobson, 2011; Altay et al., 2013).

Hardaliye is stored at 4°C for 3 to 4 months and consumed either fresh or aged. This short shelf life limits the industrial production of hardaliye (Arici and Coskun, 2001). With aging, alcohol may be manufactured in hardaliye. Hardaliye's flavor is produced in three stages. In the first stage, a strong and bitter flavor is produced due to fermentation. In the second

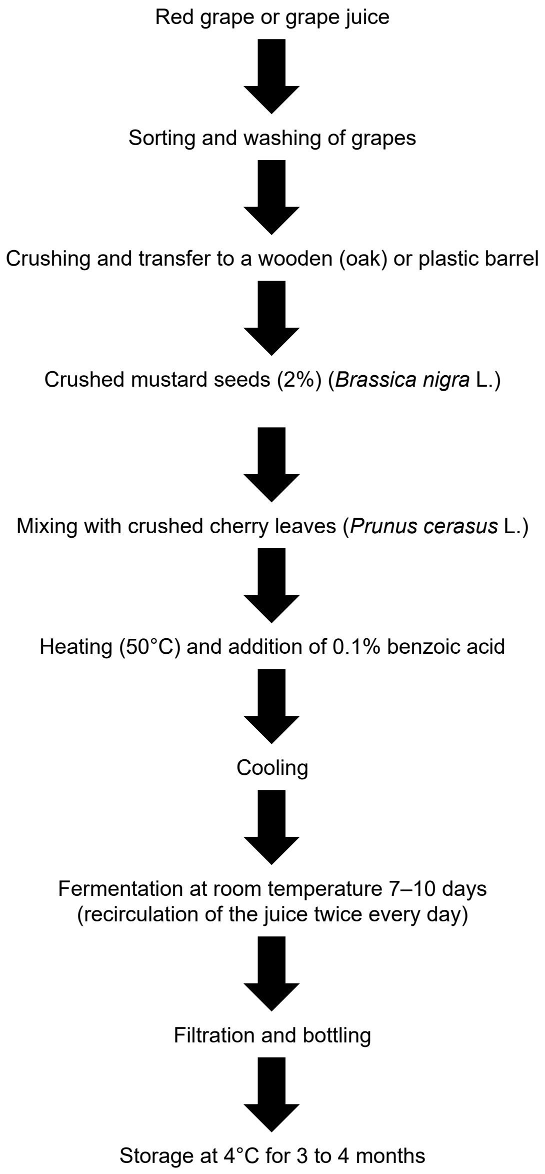

Fig. 3. Hardaliye production process (adapted from Gucer et al., 2009 and Aladeboyeje and Sanli, 2021)

Table 4. Nutrient composition of hardaliye (per 100 mL) (Adapted from Coskun, 2017)

Biochemical composition	Values	Biochemical composition	Values
Energy, kcal	75.54	Iron, mg	0.91
Moisture, g	88.51	Zinc, mg	0.24
Ash, g	0.23	Vitamin B_1, mg	0.003
Fat, g	0.20	Vitamin B_2, mg	0.01
Total dietary fiber, g	0.98	Vitamin B_6, mg	0.05
Carbohydrates, g	17.53	Niacin, mg	0.31
Fructose, g	9.51	Vitamin C, mg	0.24
Glucose, g	9.43	Folate, µg	1.01
Total sugar, g	18.91	Pantothenic acid, mg	0.08
Potassium, mg	94.14	Magnesium, mg	13.59
Calcium, mg	13.45	Phosphorus, mg	24.50

stage, the biological degradation of mustard seeds is completed, leading to the disappearance of the strong and bitter flavor and the attainment of the characteristic hardaliye flavor. Although the flavor development of hardaliye is not well understood, it may be attributed to the transformation of glucosinolate into allyl isothiocyanates. The final aroma of hardaliye is developed after 30 days (Coskun, 2017). The nutrition composition of hardaliye is listed in Table 4. Glucosinolates containing sulfur compounds are present in mustard seeds. These compounds are enzymatically broken down into isothiocyanates. The specific flavor of mustard seeds is obtained from allyl isothiocyanates. Therefore, the desired aroma is obtained in the final product. Hardaliye is a non-alcoholic beverage. Allyl isothiocyanates also reduce alcohol production in hardaliye by completely inhibiting the growth of yeasts such as *Aspergillus flavus*, *Penicillium commune*, *Penicillium corylphilum*, *Penicillium discolour*, *Penicillium polonicum*, and *Penicillium roquerforti* (Amoutzopoulos et al., 2013; Coskun, 2017). Moreover, alcohol production is inhibited by benzoic acid (Arici and Coskun, 2001).

Children, vegetarians, and people with lactose intolerance and high cholesterol levels widely consume hardaliye because of its palatable, non-alcoholic, non-dairy, and low-fat properties (Amoutzopoulos et al., 2013). Grape beverages are widely consumed because of their positive effects on human health. Grapes are rich in phenols, such as anthocyanins. Anthocyanins possess antioxidant properties (Tena et al., 2020). Red grape juice contains flavonoids at more than 500 mg/L. Antioxidant flavonoids are supported by human enzyme systems and exhibit protective effects against cardiovascular diseases, cancers, and other age-related diseases. Flavonoids have anti-inflammatory, anti-allergic, anti-viral, and anti-carcinogenic properties. In addition, flavonoids scavenge oxygen-derived free radicals and reduce the risk of arteriosclerosis by inhibiting low-density lipoprotein oxidation. Resveratrol is present on grape skin and grape juice. Resveratrol decreases skin tumors and regulates blood pressure and blood glucose (Coskun, 2017).

FERMENTED MEAT PRODUCTS

Meat and meat products are one of the most important nutritious foods available to humans. Several raw cured and ripened meat products (different kinds of sausages and smoked cured meat products) are produced traditionally using the fermentation process (Kilic, 2009). Traditionally, raw meat products are produced through the fermentation of natural or added carbohydrates by LAB present in meat or its environment. Several substances, such as lactic acid, acetic acid, alcohols, aldehydes, ketones, and bacteriocins, are produced during fermentation, thereby affecting the quality, safety, and storage stability of meat products (Kołożyn-Krajewska and Dolatowski, 2012). Sucuk, pastırma, döner kebab, kavurma, çiğ köfte, and kokorec have been the most popular traditional meat products in Anatolia for several years. Of these, sucuk is a fermented food; therefore, only sucuk is summarized in this review.

Sucuk

Sucuk is the Turkish name for a traditional fermented meat product that has been produced since ancient times. It is the most popular semi-dry fermented meat product in several regions of Anatolia (Stajić et al., 2011). Sucuk is manufactured through natural fermentation and is consumed with or without cooking. In the production of sucuk, beef, water buffalo, camel, lamb, bovine, and/or ovine meats are commonly used as raw materials. The procedure is performed in the open air and takes 15 to 20 days, depending on the ripening conditions (Kaban and Bayrak, 2015). Traditionally, smoking and heat treatment are not applied in the production of sucuk; however, in recent years, some manufacturers heat sucuk to an internal temperature of 45–70°C after a short fermentation period. Heating has the advantages of ensuring a shorter production time, inactivated microorganisms, and economical production. Moreover, compared with traditionally produced sucuk, heat-treated sucuk has a different flavor and aroma. This is because heat inactivates desirable microflora in the final product (Temelli et al., 2005; Kabak and Dobson, 2011).

Traditionally, starter cultures are not used in the production of sucuk. First, fat, bone, tendon, fascia, cartilage, lymph ovules, and large nerves and veins are separated from bovine and ovine meat, followed by mincing using a meat grinder or cutter. The minced meat is mixed with salt, red pepper, black pepper, cumin, body fat, internal fat, tail fat, kidney fat, and one or more additives. This mixture is filled in natural or artificial small intestines of cattle and hung for fermentation (ripening period) at 22–23°C by either using microorganisms naturally present in the mixture or by adding starter cultures. The mixture is hung till maturation or drying (Kilic, 2009) in open areas called Çardak throughout the fermentation process. Sucuk is exposed to heat (10–15°C), humidity (80–90%), and wind (1–1.5 m/sn) in Çardak for 15–20 days. Sucuk dries and ripens through microbial fermentation, thereby influencing both internal and external characteristics of the product. Fermentation occurs spontaneously because of traditional sucuk microflora, mainly composed of LAB, molds, and yeasts. *Lactobacillus*, *Staphylococcus*, and *Micrococcus* genus play the most important role in sucuk fermentation and ripening (Nazli et al., 2017). LAB decreases the pH by producing lactic acid and bacteriocins that have several beneficial properties, such as inhibiting the growth of some pathogenic and spoilage organisms (such as *Listeria monocytogenes* and *Staphylococcus aureus*), providing diverse sensory properties by the modification of raw material, contributing to flavor, color, and texture development, and improving the overall quality and shelf life of the final products (Ozdal, 2020).

The final pH and moisture of sucuk range between 4.7–5.4 and 4.2%–6.3%, respectively, (Gagaoua and Boudechicha, 2018). Sucuk produced through natural fermentation and without heat treatment is nutritionally valuable because of its high-quality protein contents, B group vitamins, minerals, trace elements, and other bioactive compounds. In recent years, probiotic meat products have increasingly been used by both consumers and manufacturers because of the high numbers of LAB. To improve the shelf life and safety of fermented meat products (including sucuk), the use of a single or mixture of probiotic cultures is gaining the interest of scientists. Therefore, the application of probiotics in the production of fermented meat products such as sucuk should be further explored (Kilic, 2009).

CONCLUSION

From ancient years, Anatolia, as a bridge region, has been home to several civilizations with different cultures, religious beliefs, and languages. This rich cultural heritage is reflected in the dietary habits of Anatolians, and traditionally produced fermented foods and beverages have been part of the culture throughout history.

Fermentation has mainly been associated with food safety, the transformation of perishable and indigestible raw materials into pleasant foods and drinkable beverages with rich in flavors, nutritional value, and textures; formation of inhibitory metabolites (lactic acid, acetic acid, formic acid, propionic acid, ethyl alcohol, carbon dioxide, diacetyl, reuterin, and bacteriocins); detoxification and elimination of undesirable substances in raw foods, such as cyanide, phytates, tannins, and polyphenols; and the inhibition of food pathogens are the other advantages of fermented foods.

In this review, we considered the historical perspective, microbiological and nutritional characteristics, and traditional and commercial production processes to follow these traditional fermented foods. We grouped these foods into certain groups, such as dairy-based, cereal-based, fruit/vegetable-based, and meat-based foods. These foods have several positive effects on human health that have been proven scientifically. These health benefits are attributable to the bioactive compounds that are formed during lactic acid fermentation. In Anatolia, several traditional fermented foods and beverages are produced by using LAB, yeasts, or mixtures of both. Addressing these traditional foods in a scientific framework is valuable for isolating both potential probiotic and starter culture strains. Recording both the microbiological and chemical compositions of these foods in the scientific history of their traditional production will contribute to transferring them to new generations in the ancient Anatolia lands.

CONFLICT OF INTEREST

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