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Traditional low-alcoholic and non-alcoholic fermented beverages consumed in European countries: a neglected food group

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Abstract

Fermented beverages hold a long tradition and contribution to the nutrition of many societies and cultures worldwide. Traditional fermentation has been empirically developed in ancient times as a process of raw food preservation and at the same time production of new foods with different sensorial characteristics, such as texture, flavour and aroma, as well as nutritional value. Low-alcoholic fermented beverages (LAFB) and non-alcoholic fermented beverages (NAFB) represent a subgroup of fermented beverages that have received rather little attention by consumers and scientists alike, especially with regard to their types and traditional uses in European societies. A literature review was undertaken and research articles, review papers and textbooks were searched in order to retrieve data regarding the dietary role, nutrient composition, health benefits and other relevant aspects of diverse ethnic LAFB and NAFB consumed by European populations. A variety of traditional LAFB and NAFB consumed in European regions, such as *kefir*, *kvass*, *kombucha* and *hardaliye*, are presented. Milk-based LAFB and NAFB are also available on the market, often characterised as 'functional' foods on the basis of their probiotic culture content. Future research should focus on elucidating the dietary role and nutritional value of traditional and 'functional' LAFB and NAFB, their potential health benefits and consumption trends in European countries. Such data will allow for LAFB and NAFB to be included in national food composition tables.

Key words: Fermented beverages: Low-alcoholic beverages: Non-alcoholic beverages: Europe: Dairy products: Local foods

Introduction

Ten thousand years ago, after the onset of agriculture, man's dietary adaptation to a few plant and animal species gave rise to new techniques in order to enhance the nutrient composition and, often simultaneously, rid their foodstuffs of their anti-nutritional effects[1,2]. At the same time, settlement forced humans to collect foods as a store of supplies to secure food availability during periods of bad weather, when fresh food and safe drinking water were not readily available[3]. Especially for alcoholic beverages, such as beer and wine, data from recent research support their contribution to the transition of our ancestors from hunter–gatherers to farmers[1–4]. Based on archaeological and archaeobotanical findings, it is generally believed that over 9000 years ago individuals of the globe were already fermenting beverages[5]. For instance, remnants in jars and vessels suggest that winemaking was popular in Neolithic Egypt and Middle East[1,2,6]. Overall, food fermentation stands as a remarkable benchmark in the history of human societies.

Historically, besides their role in human nourishment, fermented beverages have found other uses as well. They have been used as exchangeable products for labourers who worked in the construction of pyramids in Egypt and in royal cities and irrigation networks in ancient Central American cultures[1,2]. Furthermore, many ancient cultures have used alcoholic fermented drinks as medicines; in ancient Egypt, Rome and Greece as well as in ancient Mesopotamia and China, fermented beverages were used to relieve pain and to prevent or treat diseases[7]. *Koumiss*, a traditional alcoholic fermented beverage of Kazakh nomads made from mares' milk had been used by Russian doctors for the treatment of tuberculosis and diarrhoea[8]. Sorghum beer, a good niacin source, has helped to prevent pellagra in Southern Africa[1,2]. It has also been observed that children who consumed the dregs of sorghum beer were protected against the development of pellagra[9]. In the United Republic of Tanzania, it has been observed that children who consumed fermented gruels showed a decrease in the number of reports for diarrhoea by one-third as opposed to those who were fed with unfermented gruels; this difference was attributed to the inhibitory effect of the microbiota of fermentation towards pathogenic bacteria[1,2].

Fermentation contributes to food security, especially in agro-pastoralist societies. As an example, in Indonesia, the wastes of groundnut press cake and tapioca are often fermented to

Abbreviations: LAB, lactic acid bacteria; LAFB, low-alcoholic fermented beverage; NAFB, non-alcoholic fermented beverage.

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produce nutritious foods, namely *tempte-bongrek* and *ontjom*, foods that are important in the daily regimen of the poorest individuals[8], while *koumiss* had been used as a safe and easy to transport beverage for nomadic populations of Central Asia, who had to travel very often to places with variations in climatic and environmental conditions[9]. *Kawal*, a fermented product made of the leaves of a wild African legume, is believed to have helped children and adults in Sudan endure the 1983–1985 famine[8].

Fermentation enables the preservation of foods as well as the transformation of the raw material into a new product with unique sensorial properties[4,10–12] and enhanced nutritional value. Food and beverages that are prepared via a fermentation process represent an important part of human nutrition in practically every food culture around the world[4]. Fermented/pickled fruits and vegetables are very popular in many regions of Europe, Asia, America and Africa and Middle East[13]. Fermented fruit juices, tea leaves and products in brine are widely consumed in Asia. Fermented cereals, roots and tubes, such as pickles, porridges and gruels, make a major contribution to dietary staples in countries across Africa, Asia, Europe and Latin America[13], while fermented seeds and fish are also widespread in many regions around the globe[13]. With regard to fermented foods in liquid form, in Western societies, beverages made with alcohol-producing yeasts, such as beers and wines, are the dominant ones[3,14]. Alcoholic drinks played an important role throughout most of Western civilisation's history as a source for hydration and energy; however, in most recent history, they are responsible for many major health and social destructors. But fermentation need not always result in a beverage with alcoholic content. Low-alcoholic fermented beverages (LAFB) and non-alcoholic fermented beverages (NAFB) have been treasured as major dietary constituents in numerous European countries because of their keeping quality under ambient conditions and prolonged shelf-life, thereby contributing to food security and improving food safety[15]. The use of the terms 'alcoholic beverage', 'LAFB' and 'NAFB' is subject to varying regulations in different European countries. According to EU Regulation 169/2011 on the provision of Food information to consumers and the European Parliament Resolution 2015/2543 (RSP) an 'alcoholic beverage' contains an 'alcoholic strength by volume' (ABV; the number of litres of ethanol contained in 100 litres of wine, both volumes being measured at a temperature of 20°C) of more than 1·2 %, whereas a 'low-alcoholic beverage' refers only to beverages which have an ABV of 1·2 % or less. For the majority of the European countries, the limit of ABV for a 'non-alcoholic beverage' is considered 0·5 %.

The diversity of traditional fermented beverages in Asia and Africa has been well described in review articles and textbooks[4,5,11,15,16]. For example, the rich legacy and diversity of traditional fermented foods and beverages of the Himalayas have recently been recorded by Tamang & Samuel[17]. However, the scientific literature contains limited information on LAFB and NAFB prepared and consumed by European populations. Thus, the primary purpose of the present review is to provide an overview of the research regarding traditional LAFB and NAFB in European cuisines, including a documentation of the different types and a record of their modern and traditional names. Second, this review aims at comprehensively presenting information on the raw material undergoing the fermentation, the microbiota involved, as well as the health effects, dietary importance and cultural aspects of the endproducts. The results of this research are summarised in the tables, but selected traditional beverages are presented extensively. Finally, because in the last decades the food and beverage industry has focused on the revival and re-introduction of these indigenous beverages, their place in the European market and their perspectives and innovations are discussed.

Diversity of traditional low-alcoholic and non-alcoholic fermented beverages

Traditional LAFB and NAFB constitute an integral part of food culture of many European countries. They represent socially accepted products for habitual as well as ritual consumption. A diversity of traditional LAFB and NAFB[1,9] are produced from both edible and inedible raw materials in many European countries. Some of these beverages are well documented in the scientific literature, but for most of them, the existing information with regard to the names used (traditional and modern), the substrate and microbiota of fermentation involved, the spread of their consumption, the preparation method(s), the nutrient composition and perceptions on their nutritional value is incomplete. A wide range of substrates, including milk, cereals, fruits and vegetables, are used for the production of LAFB and NAFB. These substrates provide the criteria for the integration of traditional LAFB and NAFB into different categories. Representative examples of traditional LAFB and NAFB are presented in each category of these beverages.

Traditional fermented low-alcoholic and non-alcoholic milk-based beverages

Kefir. *Kefir* or *kefyr* (in Central Asia and Middle East) or *kephir/kiaphur/kefer/knapon/kepi/kippi* (in the Balkan–Caucasian region) is one of the oldest milk-based fermented beverages[9,17–19] (Table 1). It can be made from any type of milk (goats', sheep's, cows', camel, buffalo) and *kefir* grains[9,17]. Nowadays, novel varieties are also being made from milk substitutes, such as soya, rice and coconut milk[18,20–23]. The word '*kefir*' originates from the Turkish word '*keyif*', which means 'good feeling' and is believed to describe the sense experienced when consumed[20,24]. It has been traditionally prepared by shepherds in the Caucasus mountains[20,22,24,25] in bags made from animal hides, oak barrels or earthenware pots[19]. *Kefir*'s production and consumption originate from the countries of Eastern Europe, especially the Balkan–Caucasian region and Russia[9,11,18,22,25,26]. It has been widely consumed in Soviet countries for centuries; however, nowadays it is increasingly popular in Japan, the USA, the Middle East and Africa[9].

The type and amount of milk and the complex interactions between yeast and lactic acid bacteria (LAB) may influence the sensorial and textural properties of *kefir*[20]. Specifically, its

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Table 1. Examples of traditional milk-based low-alcoholic and non-alcoholic fermented beverages consumed in European countries

Name	Substrate	Sensory property and nature	Alcoholic content	Other metabolites	Nature of use
Kefir	Any kind of milk (goats', sheep's, cows', camel, buffalo) and milk substitutes, such as soya milk, rice and coconut milk[18,20–23]	Self-carbonated, viscous, uniform creamy and elastic consistency, sour, acidic and slightly alcoholic, tart flavour, perceptible yeast aroma, slightly foamy body and white or yellowish colour[9,17,18,20,21,24–26,166]	Usually below 2 %[18,20,21,25]	Lactic acid, ethanol, CO_2, volatile acids, acetaldehyde, diacetyl and acetoin, biogenic amines[18,20,21,24–26]	Easily digested, effervescent fermented milk beverage[24,27,28] with health-promoting effects[9,21,25], antimicrobial activity[18,20], reduction of symptoms of lactose intolerance and anti-tumour activity[18]
Ayran	Milk (cows' or other type)[22]	Low viscosity[20,21]	Non-alcoholic[20,21]	Lactic acid[20]	Drinkable fermented milk, easily digestible, consumed mainly during summer months[20,21]
Buttermilk or clabbered milk	Usually cows' milk, less often from buffalo milk[9,23]	Fluid with very low viscosity[19], acidic, sour taste[9], slightly yellowish colour[19]			Health drink[9,19], particular in summer[19], may be used in cooking the same way as sour cream[19]
Bulgarian or *Bulgaricus* buttermilk or Bulgarian milk[2,4,40]	Boiled goats' or cows' milk[4,9,23]	Acidic, sour due to high acidity, definitely impalatable[9,40]			Sour milk, a type of cultured buttermilk, a drink[2,9,18]
Acidophilus milk	Cows' milk[9,23,152]	Strong acid flavour, sour taste, viscous[9,18]			Traditional, medium acid-type fermented beverage or drink[9,152], poor table beverage due to its strong acid flavour[18], cultured milk[40]
Sour milk	Sheep's, cows', buffalo milk				Non-cultured fermented milk[19]
Tätmjölk	Whole or skimmed milk[19]	Extremely viscous in texture, very mild acid taste and low syneresis[19]		Lactic acid, ethanol, carbon dioxide[19]	Fermented milk product[18]
Surmjölk	Whole or skimmed milk[19]	Mild acidic taste, but more flavour than *tätmjölk*, viscous texture[19]			Traditional fermented milk, similar to *tätmjölk*[19]
Skyr[19]	Ewes' milk[2,19]	Rich and mild flavour due to lactic acid, acetic acid, diacetyl, acetaldehyde and ethanol[19,26], is still flavoured by Icelanders[19], concentrated texture[19]		Lactic acid, acetic acid, diacetyl, acetaldehyde and ethanol[26]	Yoghurt or yoghurt-like milk product[19,26]
Filbunke[19]	Whole milk[19]	Gel texture[19]			Traditional fermented milk and variant product of either *tätmjölk* and *surmjölk*[19,167]
Keldermilk	Milk[26]				Cultured milk[26]
Taette or Lapp's milk[2]	Cows' milk[169]				Viscous fermented milk, also known as cellarmilk[2]
Prokish	Sheep's milk[4]				Sour milk which later became yoghurt[4]
Laban	Animal milk[9]	Acidic, viscous[9]			Yoghurt-like, served as a cool drink[9]
Prostokvasha[2,39]	Sheep's milk				Sour milk[2]
Lyntyca[39]	Sheep's milk[39]				Whey-based fermented beverage
Žinčica (in Slovak)	Sheep's milk[39]				Whey-based fermented beverage, *kefir*-like beverage[39]

Table 1. *Continued*

	Nutrition data	Microbiota of fermentation	Functional properties	Country of consumption in Europe	Status of fermentation (homemade/ industrialised)
Kefir	Per 100 g: protein 3·0–3·4 g, fat 1·5 g and lactose 2·0–3·5 g, lactic acid 0·6–1·0 ml/100 ml[19], vitamins B_1, B_{12}, B_6, K, ascorbic acid, folic acid, Ca, P, Mg, amino acids[21,28]	LAB, acetic acid bacteria, other bacteria, yeasts, probably moulds[9,17–20,22,24–28,36,166]	Potentially probiotic product[18,20,21,24,25,28,36]	Originated: Caucasus mountains[20,22,24,25] Consumed: Eastern Europe (Balkan–Caucasian region and Russia)[9,11,18,22,25,26], Soviet countries[9]	Homemade and industrialised[24,26]
Ayran	Total DM (1·07–11 %), protein (1·44–3·48 %), salt (0·17–1·75 %) and fat (0·1–3 %) and high content of vitamins and Ca[20]	LAB[22]		Turkey[20–22], Cyprus[26], Greece, Albania, Bulgaria, Former Yugoslavian Republic of Macedonia[26]	Homemade and industrialised[20,21]
Buttermilk or clabbered milk		LAB[9]		Russia, Bulgaria (*urgutnik* from sheep's milk), Ireland (*clabber*, from sheep's milk), southern Scandinavia (Finland, *kirnupiima* from sheep's milk) and Hungary (*savanyutez* from sheep's milk)[9,19,39]	Homemade[19]
Bulgarian or *Bulgaricus* buttermilk or Bulgarian milk[2,4,40]		LAB[2,9,18,23]		Originated: Bulgaria (500 AD)[2,4] Consumed: Yugoslavia, Greece, Turkey[4], Albania, Romania[9]	Homemade and industrialised
Acidophilus milk		LAB[9,18,23]	One of the first probiotic milks derived by Metchnikoff's observation[18]	Russia[26], East Europe, Greece, Turkey, Scandinavia[9]	Homemade and industrialised
Sour milk		LAB[19]		Iceland, Denmark, Southern Norway and the remaining parts of Sweden[19] *Kisela varenika* (Bosnia)[39] *Snezhanka* (Bulgaria) *Dickmilch* (Germany)[39] *Oxygala* (Romania)[39]	Homemade and industrialised
Tätmjölk		Mesophilic lactic starter cultures (e.g. *Lactococcus* spp. and EPS-producing *Leuconostoc* spp.)[19]		In most of Norway and the northern parts of Sweden, southern and Western Finland[19]	Homemade
Surmjölk		Similar to those present in *tätmjölk*, but using non-EPS-producing micro-organisms[19]		Sweden[19]	Homemade[19]
Skyr[19]		LAB, yeast and moulds[19]		Iceland[2,19,26]	Homemade and industrialised
Filbunke[19]		Without EPS strains[19]		Finland[9,18,19,26,167]	Homemade until 1950, nowadays very limited[19]
Keldermilk				Scandinavia[26]	Homemade
Taette or Lapp's milk[2]		LAB		Norway[2]	Homemade
Prokish				Thrace (Greece)[4]	Homemade
Laban		LAB, yeasts[9]		Turkey[9]	Homemade and industrialised
Prostokvasha[2,39]		LAB[2]		Soviet Union[2]	Homemade
Lyntyca[39]				Poland[39]	Homemade and industrialised
Žinčica (in Slovak)				Czechoslovakia, Poland[39] *Žinčice* (in Czech), *Żentyca* (in Polish)	Homemade and industrialised

LAB, lactic acid bacteria; EPS, exopolysaccharides.

flavour depends on the metabolism of LAB and yeast. Ethanol has little impact on flavour but may contribute to the aroma[19]. *Kefir* is a self-carbonated (some effervescence caused by carbon dioxide), slightly foamy and viscous beverage, with a uniform creamy and elastic consistency and sour, acidic and slightly alcoholic flavour[17,19,20,23,24]. It also has a perceptible yeast aroma and white or yellowish colour[17,23].

Kefir is regarded as an easily digested, effervescent fermented milk beverage and is esteemed for its nutritional value[24,27,28]. It typically contains (per 100 g) 3·0–3·4 g of protein, 1·5 g of fat and 2·0–3·5 g of lactose (after the fermentation stage). However, the lactic acid content may range between 0·6 and 1·0 ml per 100 ml of the final product[19]. *Kefir*'s vitamin and amino acid content increases during fermentation via biological enrichment[21,28]. The fermenting action of *kefir* bacteria and yeasts increase the biological value of milk, increasing the synthesis of B group vitamins. It has been proposed by many researchers that during *kefir* fermentation pyridoxine, vitamin B_{12}, folic acid and biotin are produced by the microbiota[29,30], but it depends on the type of milk and the microbiota composition[31]. The incorporation of *Propionibacterium freudenreichii* strains in the *kefir* microbiota may enrich the product with vitamin B_{12}[32]. Its alcoholic content is usually <2 % (<0·3 % (w/v) for Turkish *kefir*)[25].

Typically, the raw material used for the production of *kefir* is cows' milk, fortified with cheese whey (at homemade scale)[33] or ultrafiltered skimmed milk (at industrial scale)[19]. Two methods have been described for *kefir* production, the traditional (authentic) and the industrial (commercial)[24,26]. The type of fermentation observed in *kefir* is the result of a yeast–lactic fermentation. Traditionally, *kefir* grains are added to milk, left at room temperature for fermentation for 18–24 h; the grains are then removed and can be used in a new fermentation cycle. The resulting fermented milk is thus ready for consumption[24]. Commercial types of *kefir* may be blended with sugar and fruit juices or flavours[18].

Microbiota identification shows that *kefir* is a symbiotic combination of bacteria (about 83–90 % LAB and acetic acid bacteria), lactose-fermenting and lactose-negative yeasts (about 10–17 %), such as *Naumovozyma*, *Kluyveromyces*, *Kazachstania*, other bacterial groups and possibly moulds (*Geotrichum candidum*), bound within a polysaccharide matrix, known as *kefir* grains or *kefiran*, made of casein and complex sugars[19,21,23,24,27]. *Kefir* grains are filtered off after each use and reused for the inoculation of the next batch[26]. *Kefir* milk possesses a lower diversity of bacteria compared with *kefir* grains. Only four phyla have been identified in *kefir* samples, Actinomycetes, Bacteroidetes, Firmicutes, Proteobacteria, with Bacteroides traced only in *kefir* milks[34]. Bacteria involved in *kefir*'s production belong to the genera *Lactococcus*, *Lactobacillus*, *Leuconostoc* and *Acetobacter*[22]. *Lactobacillus* is the dominant genus in the *kefir* grains while *Lactococcus* and *Leuconostoc* are prevalent in *kefir* milk. Pyrosequencing analysis of *kefir* samples has revealed that the *Acetobacter* genus is not always detected, indicating that it is not required for the process of fermentation, contributing probably in other characteristics of the product. Bifidobacteriaceae were traced only in a minor number of *kefir* grains. High-throughput sequencing enables the detection of bacterial genera associated with the intestinal microbiota, rarely found in *kefir* samples and some of them (*Faecalibacterium*, *Allistipes*), identified for the first time in *kefir*[34]. Because many of the LAB in the *kefir* grains, such as *Lb. acidophilus*, *Lb. helveticus*, *Lb. casei*, *Pediococcus dextrinicus*, *P. acidilactici*, *P. pentosaceus*, etc.[20,35], are known to have probiotic properties, *kefir* is also being regarded as a potentially probiotic product[18,21,24,25,28,36,37]. The microbial counts of traditional and commercial *kefir* are different. The carbohydrate, fat and protein content of the milk used can affect the microbiota profile[20]. The main metabolites of the *kefir* fermentation are lactic acid, produced by LAB and ethanol, carbon dioxide, produced mainly by the yeasts but also by heterofermentative LAB. Carbon dioxide content increases during fermentation as the pH drops. If the fermentation is carried out for longer than 24 h, carbon dioxide production plateaus after 48 h. The concentration of carbon dioxide in traditional *kefir* varies between 0·65 g/l (grain free, 24 h)–1·33 g/l (grain fermented, 24 h)[38]. Also, volatile acids, acetaldehyde, diacetyl and acetoin (flavour compounds) are found in smaller quantities, while biogenic amines have been traced in *kefir* samples but in very low amounts, below the allowable limits[19].

Ayran. *Ayran* is a dairy NAFB (Table 1). It is a salt-containing yoghurt drink made from cows' milk or other types of milk[20,21]. *Ayran* is consumed in Turkey[20–22], Bulgaria, Macedonia, Kazakhstan, Kyrgyzstan and Azerbaijan[26]. Beverages that are similar to *ayran* include *ayrani* (Cyprus), *jugurt/eyran* (Turkey), *dhalle* (Albania), *ayryan* (Bulgaria) and *ariani* (Greece)[26]. *Ayran* is a low-viscosity drink, easily digestible and consumed mainly during the summer months[20,21]. Its composition depends on the type of milk used, the milk's fat content and the dilution rate used; for instance, its protein content by weight may range between 1·5 and 3·5 %[20].

Ayran is traditionally prepared by blending yoghurt with water (30–50 %) and salt (0·5–1 %), is produced daily and consumed fresh (homemade version)[20]. It can also be produced industrially by the addition of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* to standardised milk (industrial version)[20,21]. The resulting microbial composition of homemade *ayran* is generally similar to that of yoghurt[20,22]. Microbiota of fermentation consists of LAB bacteria such as *Lb. delbrueckii* subsp. *bulgaricus* and *S. thermophilus*, with microbial populations varying due to several factors, such as the increase of the acidity[20,22]. The population of yoghurt bacteria in industrially produced *ayran* is higher than in homemade *ayran*[20]. Some strains of *Lb. delbrueckii* subsp. *bulgaricus*, which are used as a starter culture, may produce bitter peptides[20]. Furthermore, lactic acid may be produced by the starter cultures, even during storage (post-acidification).

Buttermilk. Buttermilk (or clabbered milk) can be classified as a LAFB and is usually made from cows' milk and, less often, from buffalo milk[9,23] (Table 1). Buttermilk's preparation has been always associated with butter production. For this reason, it is consumed in regions where butter-making is common[19], for example, Russia, Bulgaria (*urgutnik* made from sheep's milk), Ireland (*clabber* made from sheep's milk), Southern Scandinavia (the Finnish *kirnupiima* made from sheep's milk) and Hungary (*savanyutez* made from sheep's milk), particularly during the summer months[9,19,39]. It is also consumed in the USA, Canada, the Middle East, Egypt, Ethiopia, India, Australia and New Zealand[9]. Natural buttermilk is different from Bulgarian buttermilk or *acidophilus* milk[40]. Nowadays, buttermilk has been mostly replaced by its modern version, cultured buttermilk[18,19]. Buttermilk is a fluid of very low viscosity (due to the mechanical treatment, the churning of the cream)[19] and can be slightly yellowish in colour (usually due to the addition of a colouring agent during butter production). It has a sour taste[9]. Besides being used as a beverage, buttermilk can be used in cooking as well, in the same way as sour cream.

Traditionally, buttermilk is produced right after milk or cream is churned[18,40], as a part of the butter-making process[18], while the overall quality of buttermilk is entirely dependent on how the process of butter making is optimised[19]. The microbiota involved in the fermentation process includes mesophilic LAB[9]. The micro-organisms present in the starter culture are similar to those used for the production of *surmjolk*, a traditional fermented milk consumed mainly in the Southern and Western parts of Nordic countries[19]. The optimal temperature of buttermilk production is 17–22°C, while this range of temperature reassures the growth of mesophilic LAB[18].

Traditional fermented non-alcoholic or low-alcoholic cereal-based beverages

Boza. *Boza*, a cereal-based fermented beverage, is a type of millet beer. In this respect, its origin can be traced back to 8000–9000 years ago, when cereals were first fermented by man to produce beverages[41] (Table 2). The word *boza* derives from the Persian word *buze*[40], which means millet. It is made from wheat or rice semolina or from a combination of rye, oat, barley and millet flour for best quality and taste[22,41]. Maize can also be one of the raw materials[20,22,42–45] mixed with sugar[15,21,44,46]. *Boza* is widely consumed in Turkey[20–22,44–46] and in other countries of the Balkan Peninsula, such as Bulgaria (Sofia, Varna, Burgas)[20–22,42–44,46,47], Albania[21,44,46], Romania[21,43,44,46], South Russia, Fyrom[21], Anatolia, Middle East and Northern Persia[41]. *Braga* or *brascha* is a similar beverage consumed in East European countries, *Busa* is another similar beverage consumed in the Balkans (cocoa is included in the standard *boza* recipe), while *bouza* is also a similar beverage consumed in Egypt[41]. It is produced both at an artisanal and industrial scale[22,45]. In several Balkan countries, *boza* may be consumed on a daily basis[47], mainly in winter time[21]. In Turkey, *boza* is considered to be beer's ancestor and is sometimes served with cinnamon and roasted chickpeas[41,45].

Boza is a viscous beverage with a form of colloid suspension[21], with a slightly sour or sweet flavour (depending on its acid content)[40,42,43,47], an acidic–alcoholic odour and pale yellow or from light to dark beige colour[20,41]. Its odour and taste are affected by metabolites deriving via alcohol fermentation[20]. *Boza*'s variations in composition and nutritive value are the result, first, of the utilisation of different types and amounts of cereal products (raw materials) and, second, of spontaneous fermentation conditions[20]. The selection of raw materials is very important, as these affect the degree of fermentability, viscosity and DM content[20]. *Boza* is a source of, protein, carbohydrate, fibre and vitamins, including thiamine, riboflavin, pyridoxine and niacin[21,41]. *Boza*'s alcoholic content is either not detectable or up to 1·5 % (w/v)[15,20,21,43]. Turkish *boza*, in particular, has an alcoholic content of 0·03–0·39 % (w/v)[45] or lower than 2 % by volume in both the sour and sweet versions, according to the Turkish *Boza* Standard, TS 9778[41].

Boza's preparation involves six stages: preparation of raw materials, boiling, cooling, straining, addition of sugar and fermentation[41]. Another option for its production is the use of previously fermented *boza* as inoculum. The types of fermentation observed are lactic acid fermentation by LAB and alcohol fermentation by yeasts. Microbiota identification of *boza* shows that it mainly consists of LAB (most of them lactobacilli, such as *Lactobacillus plantarum*, *Lb. acidophilus*, *Lb. fermentum*, *Lb. coprophilus*, *Leuconostoc raffinolactis*, *Ln. mesenteroides* and *Ln. brevis*) and yeasts (such as *Saccharomyces cerevisiae*, *Candida tropicalis*, *C. glabrata*, *Geotrichum penicillatum* and *G. candidum*)[19,40,42,43,46]. Generally, LAB dominate; in the Bulgarian *boza* especially, the average LAB:yeasts ratio amounts to 2·4[44]. *Boza* is considered to be a rich source of probiotic bacteria, such as *Lb. plantarum*, *Lb. paracasei*, *Lb. rhamnosus* and *Lb. pentosus*[20]. Some of these bacteria are known to exhibit pronounced auto-aggregation properties as well as antiviral and antibacterial activity[47].

Kvass. *Kvass* is a cereal-based beverage, used mostly as a type of soft drink[22,48,49] (Table 2). Traditionally, it is produced from rye and barley malt, rye flour and stale rye bread[48]. Another version of *kvass*, *kvass* southern, is made from water, rye bread, sugar, yeast, juniper berries (*Juniperus communis* L.) and raisins[42,50]. Mint *kvass*, a traditional Russian drink, is another version, which is made from stale dark rye bread[49], to which water, sugar, dried yeast, fresh mint leaves and raisins or sultanas are added[49]. The mint can be omitted or replaced by honey or lemon peel. *Kvass* has normally a low alcoholic content, 1 % or even less; if it exceeds this concentration, then is considered spoiled[22,48]. *Kvass* is a very popular beverage in the countries of the former Soviet Union, especially in Russia[15,22,48,49]. In the past, it was also consumed in parts of Eastern Poland[41,47]. In Estonia, *kali*, a beverage similar to *kvass*, was produced in conjunction with beer, from the grain surplus after the production of beer[15].

Kvass is a sparkling, sweet or sour beverage with a rye bread flavour and golden-brown colour[15,22,48,49], while mint *kvass* is slightly carbonated[49]. Mint *kvass* is served chilled and it is popular in Russia 'fast food' restaurants[49]. *Kvass* contains carbohydrates (mainly maltose, maltotriose, glucose and fructose), proteins and amino acids, lactic and acetic acid, ethanol, minerals and vitamins originating from the raw materials or from the microbial metabolic activity[48].

Two main *kvass*-making techniques exist, which use as raw material either stale sourdough bread or malt[48]. In the first

Table 2. Examples of traditional cereal-based low-alcoholic and non-alcoholic fermented beverages consumed in European countries

Name	Substrate	Sensory property and nature	Alcoholic content	Other metabolites	Nature of use
Boza (millet ale)[42,50]	Wheat or rice semolina or a combination of rye, oat, barley, and millet flour, maize[20–22,41–46]	Viscous liquid, colloid suspension, slightly sour or sweet flavour, acidic–alcoholic odour, pale yellow or from light to dark beige in colour[20,21,41,43,44,46,50,168]	Non- or low alcoholic up to 1·5 %[20,21,43,168]	Lactic acid, ethanol, vitamins, antimicobials[22,41,45], biogenic amines like tyramine[45]	Healthy and popular beverage for all ages, high nutritional value[20,21,43–47], consumed mainly in the cold winter nights[21], on a daily basis (Balkan countries)[47], is regarded as the origin of 'beer'[41]
Kvass	Rye and barley malt, rye flour and stale rye (traditionally)[48]	Sparkling, sweet or sour, rye bread flavour[22], golden-brown colour[15,48,49]	Non- or low-alcoholic 1 % or less[22,48]	Lactic acid, acetic acid, ethanol, vitamins, minerals[48]	Popular beverage[22,48]
Hulumur	Sorghum, rice, millet[9]	Mildly acidic[9]			Drink[9]
Kaera, *kiesa* or *kaerapiim*[15]	Oat seeds				Sour liquor, drunk on the side of the meal[15]
Kile[15]	Oat flour mixed with water	Sour taste[15]			Filtered beverage, consumed instead of sour milk on the side of the meal[15]
Borș (*Borsh*)	Rye or wheat bran[15]	Sour taste[15]			Light summer beverage[15]
Taar	Rye and barley, rarely also oats[15]	Sour taste[15], may be flavoured with juniper 'fruits' (*galbula*)[15]			Drink[15]
Kali	Malted cereals[15]				Similar to *kvass*[15]

	Nutrition data	Microbiota of fermentation	Functional properties	Country of consumption in Europe	Status of fermentation (homemade/industrialised)
Boza (millet ale)[42,50]	Protein, carbohydrate, lactic acid, fibre and vitamins such as thiamine, riboflavin, pyridoxine and nicotinamide[21,41]	LAB, yeasts[20,21,22,41,43–47]	Strain ST284BZ is the best probiotic[47], rich source of probiotic bacteria, probiotic properties of *Lactobacillus plantarum*, *L. paracasei*, etc.[20]	Turkey, Bulgaria, Albania, Romania, south Russia, Former Yugoslavian Republic of Macedonia[2,21,41–47]	Homemade and industrialised[22,45]
Kvass	Carbohydrates (mainly maltose, maltotriose, glucose and fructose), proteins and amino acids, vitamins[48]	LAB and yeast[22,48]		Countries of former Soviet Union, especially Russia[15,22,42,48,49] In the past in eastern Poland[15]	Industrialised[15,22,48], homemade (very rare)[15]
Hulumur		LAB[9]		Turkey[9]	Homemade
Kaera, *kiesa* or *kaerapiim*[15]				Estonia[15]	Homemade
Kile[15]				Estonia[15]	Homemade
Borș (*Borsh*)				Hungary and Hungarians living in other surrounding countries (for example, Romania)[15]	Homemade
Taar				Estonia[15]	Homemade
Kali				Estonia[15]	Homemade

LAB, lactic acid bacteria.

technique, the sugars needed for the yeast fermentation derive from the bread, while in the second, rye malt and rye flour (boiled with excess water) are the raw materials and gelatinised starch is cleaved by malt enzymes. In case the rye bread is not stale, it should be placed in the oven in order to be dried slowly[42,48]. Before the addition of starter and sugar, the *kvass* batter is diluted in boiling water and clarified by sedimentation. *Kvass* southern preparation methods are baking and boiling[42]. The main stages of the preparation method of mint *kvass* are: preparation of raw materials, drying in an oven, boiling, cooling and straining, sugar addition and fermentation[49]. When made at home, a sourdough stock culture is used as a starter/inoculum for the fermentation. *Kvass* is produced on an industrialised scale, using starters and the final product is often pasteurised and supplemented with preservatives[15,22,48]. *Kvass* is very rich in microbiota consisting of viable yeasts and LAB[48]. Its microbiota of fermentation consists of LAB (*Lb. casei*, *Ln. mesenteroides*) and yeasts (*Saccharomyces cerevisiae*), but the composition on a species level is variable, due to differences in fermentation techniques and feedstock[22,48].

Traditional fermented non-alcoholic or low-alcoholic fruit-based beverages

Hardaliye. *Hardaliye* is a fruit-based NAFB (Table 3). It is made from red grape juice and crushed black mustard seeds, even though other ingredients, such as pomace and sour cherry leaves, can also be used[51,52]. Sometimes benzoic acid is added as a preservative (at the industrial scale)[21,53]. *Hardaliye* originates from Thrace, in the European part of Turkey, where it is widely consumed[52,53]. Its colour varies depending on the grape varieties used and the production methods[54]. It has an acidic taste[51,52].

Hardaliye is mostly homemade following the traditional method[20]. The ingredients are pressed and left to ferment for 5–10 d at room temperature[21,22]. The microbial population of *hardaliye* has been reported to be mainly composed of lactobacilli and unknown fungal species[22]. Bacterial species which have been identified in naturally fermented *hardaliye* samples include: *Lb. paracasei* subsp. *paracasei*, *Lb. casei* subsp. *pseudoplantarum*, *Lb. brevis*, *Lb. pontis*, *Lb. acetotoleran*, *Lb. sanfransisco* and *Lb. vaccinostercus*[53].

Gilaburu juice. *Gilaburu* juice is a traditional NAFB[55,56]. The basic ingredients for the fermentation are European cranberry bush (*Viburnum opulus L.*) and water (Table 3). European cranberry bush, known as gilaburu in Turkey, is a red-coloured fruit with a special astringent taste, grown mainly around Kayseri city in Turkey. Occasionally, sugar is added to avoid the astringent taste. *Gilaburu* juice is rich in acetic acid[55]. It originates from the Kayseri province, in the central Anatolia of Turkey[55,56].

For the preparation of the beverage, the fruits are left in water in a dark place and at room temperature for about 3–4 months to ferment[55,57]. Several LAB species have been identified, including mainly lactobacilli, in the fermenting microbiota, such as *Lb. plantarum*, *Lb. casei*, *Lb. brevis*, *Lb. hordei*, *Lb. paraplantarum*, *Lb. coryniformis*, *Lb. buchneri*, *Lb. parabuchneri*, *Lb. pantheris* and *Lb. harbinensis*, along with but also *Leuconostoc*, for example, *Ln. mesenteroides*, *Ln. pseudomesenteroides*[56].

Traditional fermented non-alcoholic or low-alcoholic vegetable-based beverages

Sauerkraut juice. Sauerkraut juice or Kraut juice is the juice produced from white cabbage fermentation[58] (Table 4). Sauerkraut juice is made from cabbage and salt, same as *Sauerkraut* (fermented cabbage) is[42]. Fermented cabbage juice is widely consumed in Germany (*Sauerkrautsaft*), Ukraine, Romania (*moare*), Serbia (*rasol*) and other regions in the Black Sea[42,50]. According to the common method of production, the cabbage is fermented and then the juice is pressed out. Typically, the final product contains a lot of salt. It has been shown that sauerkraut and sauerkraut juice could be prepared with a very low Na concentration as well as, with a low total mineral salt content. The sauerkraut juice, which is fermented with 0·5 % mineral salt is considered to have the best taste[59]. The natural fermenting microbiota includes mainly LAB, such as *Ln. mesenteroides*, *Lb. brevis*, *Lb. sakei* and *Lb. plantarum*[35,58,59].

Şalgam juice. *Salgam* (also spelled *Shalgam* or *Şalgam*) juice is a NAFB (Table 4). It is made from black or purple carrots (*Daucus carota*), turnips (*Brassica rapa*), bulgur (broken wheat) flour, sourdough, salt and water[60]. In India, a similar product, *kanji*, is produced via the natural fermentation of carrots and the addition of salt, chilies and crushed mustard. Both products owe their colour to the anthocyanins present in the black carrot[21]. *Salgam* comes originally from the Cukurova province of Turkey but nowadays is consumed throughout the country[61], especially in Adana, Hatay and Icel (the Mediterranean region of Turkey). Recently, it has become popular in urban centres, such as Istanbul, Ankara and Izmir, as well[62]. *Salgam* juice is typically produced on a home-scale; however, small quantities are being commercially produced[61].

Salgam juice is red-coloured, cloudy and has a sour taste. It is rich in minerals (Ca, K and Fe), vitamins (A, C and B group vitamins), and has polyphenols content[61,63,64]. Typically, *salgam* juice accompanies meals[21]. The indigenous microbiota of naturally fermented *salgam* juice is mainly composed of LAB, with the predominant species being *Lb. plantarum*, *Lb. brevis* and *Lb. paracasei* subsp. *paracasei*[62,65]. Yeasts, such as *S. cerevisie*, have been reported to contribute to the fermentation process[64].

Traditional fermented non-alcoholic or low-alcoholic herb, spice and aromatic plant-based beverages

Kombucha. *Kombucha* is one of the most popular LAFB in the world (Table 5). Black tea and white sugar are used for its production although green tea can also be used[66]. The drink was originally popular in China, but nowadays is consumed worldwide, showing an increasing popularity as a traditional

Table 3. Examples of traditional fruit-based low-alcoholic and non-alcoholic fermented beverages consumed in European countries

Name	Substrate	Sensory property and nature	Alcoholic content	Other metabolites	Nature of use	Nutrition data	Microbiota of fermentation	Functional properties	Country of consumption in Europe	Status of fermentation (homemade/ industrialised)
Hardaliye	Red grape juice and pomace[21,51–53]	The original colour of the grapes, acidic[51,52,54]	Non-alcoholic, 0·28–0·59 %[21]		Traditional non-dairy probiotic beverage, antioxidant properties[53]	Antioxidants[53]	LAB, uncharacterised fungal component[53]		Origin: Thrace in the Marmara region of Turkey Consumed: Thrace region of Turkey[52,53]	Homemade, small-scale local technologies[53]
Gilaburu juice	Cranberry bush (*Viburnum opulus* L.)[55]	Astringent without the addition of sugar	Non-alcoholic[55]	Acetic acid[55]	Traditional, may be a health-promoting beverage[55]		LAB	Possible probiotic potential	Regions in Central Anatolia of Turkey, Kayseri[169]	Homemade
Juniper beer (called *psiwo kozicowe* or *piwo jałowcowe* in Poland)[170]	Juniper berries (*Juniperus communis* L., Cupressaceae[15]	Sweet and sour taste[170]	Low[170]		Traditionally served at weddings[170], baptisms and funeral parties[171], nowadays sold at folklore events, village fêtes, culinary festivals[170]				Northern Poland Similar drinks: countries in the Baltic Sea (for example, Estonia, Finland, Sweden)[15,170]	Homemade, not mass produced, sold upon request[170]
Wild apple and cherry vinegars	Fruits of wild apple (*Malus sylvestris*) and Cornelian cherry trees (*Cornus mas*)[15]				Health properties[15], drunk as a preventive beverage[15], anti-obesity product and externally against bruises, fever and headache[172,173]				Istro-Romanians in Croatia[172], South Kosovo, north east Albania, Hungary[15]	Homemade[15]
Beverage from fruit pickles	Wild apples, pears, plums, blackberries (*Rubus caesius*), raspberries (*Rubus idaeus*), lingonberries (*Vacciniumvitis idaea*), medlars (*Mespilus germanica*)[15]	Acidic taste[15]				Valuable source of vitamins during the winter months[15]			Devin area (South Bulgaria, Rhodopes Mountains)[15]	Homemade
Fermented fruit and roots	Fruits or roots from wild Cornelian cherries, gentian roots (*Gentiana lutea*), sloe (*Prunus spinose*), wild apples, juniper berries (*Juniperus communis*), cultivated apples, plums, damsons, cherry-plums (*Prunus cerasifera*)[173]	Carbonated, sour, sweet[173]	Low- or non-alcoholic[173]		Perceived 'health' benefits (such as influenza remedy, diarrhoea remedy, hypertension remedy), 'good for the heart', nutritious, potable, culturally appropriate (Islamic faith)[173]		LAB[174]		Slavic Gorani minority living in north east Albania and South Kosovo[173]	Homemade

LAB, lactic acid bacteria.

Table 4. Examples of traditional vegetable-based low-alcoholic and non-alcoholic fermented beverages consumed in European countries

Name	Substrate	Sensory property and nature	Alcoholic content	Other metabolites	Nutrition data	Nature of use	Microbiota of fermentation	Country of consumption in Europe	Status of fermentation (homemade/ industrialised)
Sauerkraut juice or kraut juice	Cabbage, especially white cabbage[59,174]			Lactic acid, acetic acid, biogenic amines[59]		Lactic acid-fermented beverage, claims that it helps digestion and normal function of the intestinal tract and the stomach, antimicrobial properties, health and nutritional benefits[59]	LAB[59]	German (*Sauerkrautsaft*) Ukraine (Odessa) Romania (*moare*) Serbian (*rasol*)[59]	Homemade and industrialised[59,174]
Şalgam or *şalgam* juice	Black (purple) carrot (*Daucus carota*), turnip (*Brassica rapa*)[60]	Red-coloured, cloudy, sour[61]	Non-alcoholic: 0·1–0·641 %[61,63]		Vitamins (A, C, and B group vitamins), minerals (Ca, K, and Fe)[64], amino acid and polyphenol content[61,63]	Lactic acid-fermented beverage, soft drink, widely consumed with food[62]	LAB, yeasts[62,64,65]	Origin: Cukurova province of Turkey Consumed: all over Turkey (Adana, Hatay and Icel – the Mediterranean region of Turkey) Popular in metropolises such as Istanbul, Ankara and Izmir[62]	Homemade, commercially on a small scale[61]
Turshiena chorba	Hot peppers or horseradish roots[15]	Salty, pungent, spicy and acidic[15]				Healthy for conditions like gastritis and ulcers, especially during the winter[15]	Lactic acid fermentation[175]	Bulgaria[175]	Homemade[175]

LAB, lactic acid bacteria.

soft drink[22,67,68]. *Kombucha* has a slightly sweet, carbonated, acidic taste resembling sparkling apple cider[67,69,70]. Traditionally, it was a homemade drink and the preservation and supply of the symbiotic colony of bacteria and yeast was included in the process[69], but nowadays it is also commercially available[67].

For the preparation, tea leaves are added to boiling water and left to infuse for 10 min. A small amount of sugar is then added in the hot tea and the preparation is left to cool. Tea fungus is added to the mixture, which is left to ferment for 1–8 weeks. 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[69]. Regarding the metabolites of the fermentation, the final product contains mainly acetic acid[67,71] but also gluconic and glucuronic acids, ethanol and glycerol[68,72].

The microbiota of *kombucha*'s fermentation has been examined by many research groups, which concluded that both LAB and yeasts are present during the fermentation[70], while some have reported that acetic acid bacteria also take part in the fermentation process[22,71]. Recently, different *kombucha* samples were analysed using high-throughput sequencing and five bacterial phyla were revealed: Actinobacteria, Bacteroidetes, Deinococcus-Thermus, Firmicutes and Proteobacteria. The most abundant were Proteobacteria and the dominant genus was *Gluconacetobacter*, while *Acetobacter* was traced in lower populations. The Firmicutes were represented mostly by the *Lactobacillus* genus and *Lactococcus* was found mainly in *kombucha* pellicles. The genera *Leuconostoc*, *Enterococcus* and *Allobaculum* were detected for the first time in *kombucha* samples. Actinobacteria were not found in all samples but *Propionibacterium* and *Bifidobacterium* strains were detected in early stages of *kombucha* fermentation, for the first time. Culture-dependent techniques do not permit the detection of micro-organisms living in extreme thermophilic conditions like *Thermus* spp. (Deinococcus-Thermus), which was detected in the same study. Regarding yeasts, *Zygosaccharomyces* was the dominant genus but also *Pichia*, *Dekkera* and *Kazachstaniagenera* were found in tea[73].

Ginger beer. Ginger beer, also known as ginger ale, is a LAFB[74,75] (Table 5). There are many different recipes for the production of ginger beer; however, the basic ingredients used are ginger, lemon, sugar and yeast[74]. Other ingredients used to improve its taste are mainly sugar, cream of tartar, dried ale or bread yeast, juniper berries (*Juniperus communis*), liquorice (*Glycyrrhiza glabra*) and chili (*Capsicum annuum*)[74]. At first, ginger beer was homemade, but soon it became commercialised and nowadays is consumed worldwide[49,74–76]. It is a sparkling soft drink with acidic taste and due to its low alcoholic content, it has become popular among children[74].

The production of ginger beer began in England in the mid-1700s[74], while the first written recipes date from the early 19th century[77]. The micro-organisms responsible for the fermentation of ginger beer are LAB and yeasts[78]. In particular, strains of the following genera have been identified in ginger beer samples, as

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Table 5. Examples of traditional herbs, spices and aromatic plant-based low-alcoholic and non-alcoholic fermented beverages consumed in European countries

Name	Substrate	Sensory property and nature	Alcoholic content	Other metabolites	Nature of use	Microbiota of fermentation	Country of consumption in Europe	Status of fermentation (homemade/industrialised)
Kombucha	Sweetened tea (black or green, but best black)[66,67,70,71]	Slightly sweet, carbonated, acidic[67,70], tasting like sparkling apple cider[69]	Low[68]	Mainly acetic acid[67,71], gluconic and glucuronic acids, ethanol, glycerol[68,72]	Health[69] and antimicrobial properties[22,70]	LAB, acetic acid bacteria, yeasts[22,70,71,129]	Origin: China Consumed: worldwide[22,67,68]	Homemade[69], industrialised[67]
Mursalski chai (mursal tea)	*Sideritis scardica* Griseb.[42,50]				Tea drink[50], medicinal tea[176,177]		Bulgaria (Smolian, Devin)[42,50,178] and Former Yugoslavian Republic of Macedonia[176]	Industrialised
Socata (elderberry soft drink)	Flowers of elderberry (*Sambucus nigra* L.)[42,50]		Low or non-alcoholic[42,50]		Soft drink[50]	*Sambucus nigra* L., yeasts[42]	Romania (Transylvania)[42,50,178]	Homemade[50]
Çay (black tea)	Leaves of *Camelia sinensis*[42,50]						Turkey (Black Sea, coastal area)[42,50,178]	Homemade, industrialised
Ginger beer	Ginger[49,74]	Acidic taste, sparkling[74]	Low[74,75]		Healthy, carbonated soft drink, counterirritant, easily digested, popular among children[76,77]	LAB and yeasts[78,79]	Origin: England[49,74,75] Consumed: worldwide	Homemade (past), commercial[49,74,75,76]
Birch beer	Sap of birch trees (usually sweet or black birch)[179–182]	Less sweet and carbonated than root beer[18,181]	Non-alcoholic[179,181]		'Family' drink, health-promoting[179], healing properties[183]		Mostly Scandinavia, East Europe (Russia, Lithuania, Ukraine)[181,183]	Homemade (past), commercial[179]
Root beer	Various roots (for example, hops, burdock, sarsaparilla)[184,185]	Sweet taste, flavoured with a mixture of herbal essences[76]	Low[77]		Sweet soft drink, health beverage in centuries past[76,77]	Yeasts[76]	England[49]	Homemade (past), commercial[49,77]
Fermented tree saps	Birch (*Betula pendula*, *B. pubescens*)[15,183]		Low[15]		Hay-time drink, usually consumed in the summer[15,183]		Russia, Belarus, Ukraine, Estonia, Poland[15], Hungary[15] Scandinavia (especially in Sweden)[183]	Homemade

LAB, lactic acid bacteria.

a result of industrial fermentation: *Lactobacillus*, *Leuconostoc*, *Bacillus*, *Staphylococcus*, *Candida* and *Saccharomyces*[79].

Traditional fermented non-alcoholic or low-alcoholic sucrose-based beverages

Sima. *Sima* is a sucrose-based LAFB, consumed in Finland. The ingredients used for its preparation include water, lemon, raisins, white and brown sugar and dried ale or bread yeast. *Sima* is a fermented soft drink of sweet taste and murky appearance. Typically, it is used to mark special occasions, such as May Day celebrations[49]. Due to its low alcoholic content, it is suited for consumption by children. The preparation method consists of six stages, the preparation of raw materials, boiling, cooling, straining, sugar addition and fermentation[49].

Water kefir. Water *kefir*, also known as sugar *kefir* or *tibicos*, is a sucrose-based LAFB. The main ingredients used for its production are water *kefir* grains (a symbiosis of bacteria and yeast contained within grains), a sucrose solution, dried fruits (most commonly figs) and lemon[80–82]. The most prevalent theory as to the origin of water *kefir* claims that water *kefir* grains are formed as granules fermented from sap on the pads of the *Opuntia* cactus in Mexico, but the drink is nowadays consumed worldwide[22]. Water *kefir* is mostly a homemade beverage, while the grains for its preparation are usually passed from household to household[82].

Fermentation of water *kefir* lasts for 1 or 2 d at room temperature and results in a cloudy, carbonated and straw-coloured drink[81]. The product is lightly carbonated and acidic[81,82]. The micro-organisms responsible for water *kefir* fermentation are LAB, acetic acid bacteria and yeasts[80,83]. Recently, two research groups published the microbiological analysis of water *kefir* samples, using high-throughput sequencing techniques[82,84]. Interestingly, the microbiota analysis has given different results probably due to the different origin of the samples. In the samples from the UK, USA and Canada three bacterial phyla were identified: Actinobacteria, Firmicutes and Proteobacteria. Proteobacteria were predominant in the grains, while Firmicutes were more abundant in the fermentates. The *Zymomonas* genus was dominant in all the samples, with the next common being the *Lactobacillus* genus. *Leuconostoc* was traced, but lactococci were not found. *Acetobacter* and *Gluconacetobacter* were also present. Bifidobacteriaceae were identified in small amounts but they could not be identified to the genus level[82]. Gulitz[84], analysed water *kefir* samples from different regions of Germany and according to their results *Lactobacillaceae* were the most abundant bacteria, followed by *Bifidobacteriaceae*. *Acetobacteriaceae* were traced in all the samples but in low amounts. They focused on the bifidobacteria analysis and identified *Bifidobacterium psychraerophilum* as the main species, which was also isolated[84]. As for the yeasts, different species have been associated with water *kefir* natural fermentation. Specifically, *Saccharomyces*, *Hanseniaspora/Kloeckera*, *Zygotorulaspora* and *Candida* strains have been found in water *kefir* samples[85], whereas other researchers report *Dekkera* spp. (*D. anomola*, *D. bruxellensis*), *Hanseniaspora* spp. (*H. valbyensis*, *H. vineae*), *S. cerevisiae*, *Lachancea fermentati*, *Zygosaccharomyces* subsp. (*Z. lentus*, *Z. florentina*) and *Meyerozyma* subsp. present in the beverage[22,82].

Health benefits of traditional low-alcoholic and non-alcoholic fermented beverages

The notion that the consumption of traditional LAFB and NAFB is associated with health benefits is widespread; for example, *kefir* has a reputation for beneficial effects on gastrointestinal disorders[18]. However, health claims are mostly based on personal experiences and testimonials of individuals who habitually drink these beverages while the experimental evidence is still fragmentary, as the ideal methodology for research, for example, randomised controlled clinical trials, is not easy to apply. Most of the studies which investigated traditional LAFB and NAFB and their impact on health have focused on two beverages, *kefir* and *kombucha*. Thus, the association between traditional LAFB and NAFB and health has not been scientifically proven yet. Nevertheless, as their alleged health-promoting properties are deeply rooted in the respective cultures, they deserve to be further examined via controlled clinical studies in other cultural origins and in current conditions of living.

Besides the nutrients of the raw unfermented ingredients, LAFB and NAFB also contain micro-organisms, as well as metabolites and protein breakdown products[86]. The primary metabolic actions of the starter cultures in food and beverage fermentations include their ability to predominantly ferment carbohydrates and, to a lesser degree, degrade proteins and fats in the raw material. This leads to the production of a broad range of metabolites, mainly organic acids (for example, lactic, acetic, formic, propionic), peptides, amino acids and NEFA, along with many volatile and non-volatile low-molecular-mass compounds, such as ketones and esters. Other metabolites, such as antimicrobial compounds (for example, carbon dioxide and ethanol as well as antimicrobial peptides and proteins known as bacteriocins), exopolysaccharides, enzymes (for example, amylases) and vitamins are also often produced. This way, starter cultures enhance the product's shelf-life and microbial safety[6].

In recent years, a special category of starter or adjunct micro-organisms, the so-called probiotics, have been recognised to be involved in food fermentations[87]. Probiotic foods and beverages are considered as health-promoting foods and belong to the so-called functional foods with large and expanding commercial interest. As presented in the above section, many traditional NAFB and LAFB are good sources of probiotics. Probiotics mainly belong to the LAB group and when taken up in adequate amounts confer a health benefit on the host[37]. Even if it is not easy to declare health-promoting effects, probiotics have been implicated in the management of gastrointestinal tract diseases, alleviation of lactose intolerance, reduction of the risk for certain types of cancer, treatment of ulcerative colitis and *Helicobacter pylori* infection, whereas they have been suggested to exert antihypertensive and hypocholesterolic effects[87–89]. Some of the aforementioned effects are supported by clinical studies;

however, issues such as the site and mode of action, viability, effectiveness after food handling and storage and the minimum quantity necessary to promote a health effect are still under examination[90]. Attributed and evidence-based health benefits of the various categories of LAFB and NAFB are presented in the following sections.

Traditional fermented low-alcoholic and non-alcoholic milk-based beverages

Same as milk, fermented milk products are also good sources of proteins, lipids and carbohydrates; in addition, they contain bioactive compounds, most importantly immunoglobulins, bioactive peptides, hormones, cytokines and growth factors[85]. This complex mixture of substances influences many biological functions, such as the stimulation of cellular proliferation and gastrointestinal function and maturation in the postnatal state, contributing to the adaptation of the newborn child[85]. Fermented milks are also rich in exopolysaccharides, such as kefiran in *kefir*, which are considered to have a beneficial impact, especially as antioxidant, anti-tumour, antimicrobial and immunomodulating agents[37,91]. Thus, the superiority of fermented against non-fermented milk stems from its microbiota and bioactive compounds.

Fermented dairy products help in the alleviation of lactose intolerance, not only because they have a reduced lactose content compared with milk, but also due to the secretion of bacterial lactase from LAB stains into the stomach and intestine[87]. In children with acute diarrhoea and carbohydrate malabsorption, the gastrointestinal diseases and, most importantly, the decreased duration of acute diarrhoea and stool frequency, were shown to be associated with the feeding of yoghurt, while the cessation of diarrhoea and weight gain of these children were similar to either yoghurt or milk feeding groups[92]. Fermented milk can also be valuable in complementary feeding, targeting the prevention of Fe-deficiency anaemia and also the prevention and shortening the length of gastrointestinal infections via the action of probiotics. Furthermore, fermented milk can contribute to the prevention of malnutrition in young children living in regions with limited access to animal-origin foods, high prevalence of parasites, low hygiene levels in food handling and unsafe drinkable water[93,94].

Natural fermented milks have been examined for a number of health-promoting effects. *Kefir* in particular has been accredited with the ability to normalise the intestinal microbiota and reduce the symptoms of lactose intolerance[9,18,21,24,25,95]. With regard to gastrointestinal diseases, in Russia, *kefir* has been routinely administrated for the treatment of peptic ulcers[96]. The administration of *kefir* in an animal model was associated with a significantly increased number of LAB and reduced number of enterobacteria and clostridia[97]. *Kefir*'s antimicrobial activity against a wide variety of Gram-positive, Gram-negative bacteria and fungi, some of them being considered as food-borne pathogens or food spoilage micro-organisms, is related to compounds such as lactic acid, carbon dioxide, volatile acids and bacteriocins[18,20]. Similarly, *ayran*, a salt-containing yoghurt drink, is a vehicle of viable LAB such as *Lactobacillus delbrueckii* subsp. *bulgaricus* and *S. thermophilus*[98]. Yoghurt's potential to alleviate symptoms of lactose intolerance has been well documented and is considered to be a species-related trait of LAB[37]. In men with chronic malabsorption, the consumption of a fermented dairy product (yoghurt) was associated with alleviated symptoms and decreased breath hydrogen status[99]. Other strain-specific health properties of traditional yoghurt living cultures are the immunomodulatory impact of a *L. bulgaricus* specific strain supported by both *in vitro* and *in vivo* studies[100]. The endproducts of *kefir* fermentation, namely the peptides derived from a mild proteolysis of the milk caseins, have been found to be associated with immunomodulating activity on the gut and stimulation of the immune system in mice[101]. For the case of antibiotic associated diarrhoea, however, a clinical trial, the *Kefir* (MILK) Study, failed to show a positive impact on its prevention when *kefir* was administered[102].

Besides the effects related to the normalisation of the intestinal microbiota, natural fermented milks have been examined for their potential to protect against cardiovascular risk factors[37,70]. In an animal study in hypercholesterolaemic rats, the oral administration of *kefir* resulted in reductions of VLDL-cholesterol, LDL-cholesterol and TAG levels and increased HDL-cholesterol levels[103]. Similar results emerged from another study with cholesterol-fed hamsters, in which *kefir* was associated with lowered levels of TAG, total cholesterol, cholesterol accumulation in the liver and non-HDL fraction[104]. Furthermore, kefiran, the exopolysaccharide of *kefir*, has been associated with the prevention of atherosclerosis in rabbits fed with a high-cholesterol diet[105]. On the contrary, a clinical study with mildly hypercholesterolaemic men, who consumed *kefir*, did not result in low levels of plasma lipids[106]. Apart from natural fermented milks, functional fermented milks with strains isolated from naturally fermented dairy products have also been used in order to improve serum lipid levels[91]. Recently, it has been shown that the addition of a *Lactobacillus helveticus* strain isolated from fermented cows' milk in the diet of hypercholesterolaemic mice was associated with the reduction of the serum total cholesterol level, while a significant decrease in the LDL-cholesterol level was also observed[107].

Furthermore, an antihypertensive effect of fermented milks has also been shown *in vivo*, in both human studies and animal models (rats); this effect is believed to be mediated by the production of angiotensin-converting enzyme (ACE)-inhibitory peptides (antihypertensive bioactive peptides) released during fermentation[108]. Beltrán-Barrientos *et al.*[109] reviewed seven different clinical trials that assessed the effect of fermented milk consumption on blood pressure and concluded that significant decreases of blood pressure were noticed and that they can be attributed to the use of *Lactobacillus helveticus* strains[109]. On the contrary, a clinical trial among type 2 diabetes patients who were randomly assigned to receive daily a fermented milk with *L. helveticus* for 12 weeks failed to show any significant reduction in blood pressure after the consumption of this 'functional' milk[110].

Some experimental evidence exists for other purported health benefits of milk-based NAFB and LAFB, such as their

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impact on obesity. An *in vitro* study has shown that *kefir* could act as a regulator for obesity, due to the inhibition of the adipocyte differentiation[111]. Another study using genetically obese mice (ob/ob) suggested that oral administration of *kefir* was associated with the suspension of lipogenesis and, thus, protection against non-alcoholic fatty liver disease[112]. With regard to yoghurt's effect to prevent weight gain, the Seguimiento University of Navarra (SUN) cohort study has shown that there is an inverse association between its consumption and the incidence of overweight and obesity in adults, especially when yoghurt is part of a healthy dietary regimen and is accompanied by high fruit consumption[113]. Furthermore, an observational, cross-sectional study that was conducted among adolescents in eight European cities (HELENA) showed that consumption of dairy products, including milk, yoghurt and fermented milks, was inversely associated with total and abdominal excess body fat[114].

The impact of the consumption of fermented milks on bone metabolism and bone mineral density has also been investigated. In a double-blind cross-over study, the consumption of fermented milk with *Lactobacillus helveticus* by twenty postmenopausal women had a positive acute effect on their Ca metabolism, compared with milk consumption and with juice containing peptides formed by the same strain[115]. A recent clinical trial measured the effects of *kefir* supplemented with calcium bicarbonate on bone mineral density and metabolism in forty osteoporotic men and women for 6 months, and compared them with unfermented raw milk also supplemented with calcium bicarbonate. The *kefir* consumption was associated with improved bone mineral density and with significantly increased serum parathyroid hormone[116]. In a study with an ovariectomised rat model having postmenopausal osteoporosis, it was observed that a 12-week treatment with *kefir* could be beneficial to the prevention or treatment of osteoporosis[117].

Another health effect that has been attributed to fermented milk products is their antioxidant capacity. In this respect, an *in vitro* study using human colon cells has found that both *kefir* and *ayran* have an antioxidant potential that may prevent DNA damage[118]. When administered in diabetic rats, *kefir* was associated with reduced oxidative stress, and improved renal function, one of the main diabetic complications[119].

From the above it can be concluded that the published evidence on fermented milks provides substantial grounds for supporting the potential of these beverages to modulate gut microbiota and, thus, improve the gastrointestinal function. The evidence on other health benefits, such as the impact on CVD risk factors and osteoporosis, is weak and therefore these claims require further evaluation.

Traditional fermented non-alcoholic or low-alcoholic cereal-based beverages

The impact of the consumption of traditional cereal-based LAFB and NAFB on health has also received attention. These beverages are sources of nutrients and other substances, such as minerals, vitamins, fibres, flavonoids and phenolic compounds, which could protect from oxidative stress, inflammation, hyperglycaemia and tumorigenesis[120]. Moreover, their microbial content and metabolites may also contribute to their health-promoting effects. In particular, *boza* has been found to have probiotic properties[20,21,43–47], while the various metabolites of LAB that it contains, such as lactic acid, confer antimicrobial properties and positive effects on digestion and intestinal microbiota[41,45].

Traditional fermented non-alcoholic or low-alcoholic fruit-based beverages

The data concerning the potential health effects of traditional fruit-based LAFB and NAFB are scarce. Recent research has found that the European cranberry bush (*Viburnum opulus* L.), the main ingredient of *gilaburu* juice, is rich in antioxidants and has antimicrobial properties[56,121,122]. Furthermore, its juice may be chemopreventive at the early stages of colon cancer, as reported from the treatment of mice after 1,2 dimethylhydrazine (DMH)-induced colon cancer[123]. Furthermore, because it contains several LAB species, *gilaburu* juice is deemed to have a probiotic potential[55,56]. According to the results of a randomised controlled clinical trial, *hardaliye* exhibits antioxidant activity[124].

Traditional fermented non-alcoholic or low-alcoholic vegetable-based beverages

Among the various vegetable-based LAFB and NAFB, data exist only for sauerkraut juice. More specifically, research has been conducted to test its role in helping digestion, normalising the function of the stomach and gut, as well as in providing antimicrobial, antioxidant and anti-tumour effects[37]. The health-promoting components of sauerkraut juice and its impact on health have been studied in a few *in vitro* and *in vivo* animal studies[58]. An *in vitro* study has shown that sauerkraut juice, which was produced via short and prolonged fermentation by LAB, had a more pronounced antioxidant effect compared with non-fermented cabbage[125]. Also, an animal study has indicated that the chemoprotective properties of sauerkraut juice may be attributed to the activation of the detoxifying enzymes[126]. Another animal study which examined rat liver and kidneys has shown that sauerkraut juices may have anticarcinogenic and chemopreventive effects via the inactivation of carcinogens/xenobiotics[127]. However, the above evidence needs to be enriched with additional data, in order for the health claims about sauerkraut juice to become substantiated.

Traditional fermented non-alcoholic or low-alcoholic herb, spice and aromatic plant-based beverages

The proposed health effects of *kombucha*, a fermented sweetened tea, have been attributed first to the protective impact of tea itself, and second to the products formed during the fermentation, namely its content in glucuronic acid, acetic acid, polyphenols, phenols and B-complex vitamins, including folic acid[69,128]. The acid content of *kombucha* resulting in reduced pH, in conjunction with antimicrobial substances produced by the bacteria and the alcohol (although it is not always detected), may have an antimicrobial and curative potential[22]. Glucuronic acid, an endproduct of *kombucha*'s fermentation, is thought to be one of the key components for its proposed health effect on liver and gastrointestinal function and also on immune stimulation[128]. D-Saccharic acid-1,4-lactone (DLS), which is produced from *Gluconacetobacter* sp. A4 (a micro-organism found in *kombucha*), may facilitate glucuronic acid to exert detoxifying, antioxidant and anti-tumour properties. Wang *et al*. have found that the hepatoprotective properties of *kombucha* are attributed to the presence of DLS in it and also that *Gluconacetobacter* sp. A4 is the key functional strain responsible for these protective effects[128].

Other recent *in vitro* and *in vivo* experimental studies, mainly in mice and rats, have also reported that *kombucha* may exert health prophylactic and recovery effects, through immune stimulation, detoxification, antimicrobial activity, as well as antioxidation[69,103,129,130]. One study has shown that *kombucha* was more efficient to revert the CCl_4-induced hepatotoxicity in rats when compared both with black tea and with enzyme-processed tea with tea fungus; this was attributed to the antioxidants produced during the fermentation process[131]. Furthermore, the antioxidant capacity of polyphenols, mainly flavonols and catechins found in *kombucha*, may prevent the development and inhibit the progression of many chronic human diseases, including cancer, CVD, diabetes and neurodegenerative diseases. The availability of B-complex vitamins and especially folic acid in *kombucha* may also contribute to the normal central nervous system function at all ages and help towards the prevention of disorders related to the central nervous system[69,103,129,130]. As the majority of the data on *kombucha*'s effects arise from *in vitro* and *in vivo* (animal) studies, human clinical studies are needed in order to clarify its health benefits and the mechanisms of action.

Apart from *kombucha*, advocates of ginger beer have attributed health benefits to this beverage, especially counter-irritant properties and a capacity to alleviate the symptoms of an upset stomach[76,77]. However, its impact on health has not been evaluated yet.

Traditional fermented non-alcoholic or low-alcoholic sucrose-based beverages

The evidence on the two sucrose-based LAFB and NAFB, water *kefir* and *sima*, is very fragmentary and limited to water *kefir*. Water *kefir* is believed to be a health-promoting beverage. It contains strains from species, such as lactobacilli and bifidobacteria, which are generally considered to have probiotic properties[84]. To date, however, the research on water *kefir* is very limited and its health benefits have yet to be investigated[82]. Evidence on the health-promoting effects of *sima*, another traditional sucrose-based LAFB, is completely missing.

Potential health risks of traditional non-alcoholic or low-alcoholic fermented beverages

Even though the consumption of non- or low-alcoholic fermented beverages is generally considered safe, there are some aspects arising from toxic compounds traced in fermented milks and cereal-based fermented products. The main substances found with toxic activity, depending on their concentration, are biogenic amines, such as tyramine, putrescine, cadaverine, spermidine and tyramine. They are produced by LAB of *Enterococcus*, *Lactobacillus*, *Leuconostoc* and other genera, via the decarboxylation of amino acids. The consumption of foods containing biogenic amines might represent a health risk for patients with neurodegenerative diseases treated with monoamine oxidase inhibitor drugs[132].

In a survey conducted in *kefir* samples from different producers, a number of biogenic amines were traced. Total amines varied from 2·4 to 35·2 mg/l, and tyramine was the predominant, traced in almost all the samples. Putrescine, cadaverine and spermidine were also detected. Based on the current knowledge, their concentrations in the examined samples do not seem to be of great concern[25]. In another study searching biogenic amines in *boza* samples from different producers, putrescine, spermidine and tyramine were found in all samples. Total biogenic amines concentration varied between 25 and 69 mg/kg; tyramine was the dominant amine[45]. As there are no data regarding the association between the consumption of these beverages and toxicity, more experimental evidence is required. Furthermore, the attributed toxic activity of biogenic amines poses the need for regulatory authorities to adequately standardise their concentration limits in traditional non- or low-alcoholic fermented beverages.

For *kombucha*, there are a few reports associating daily consumption with stomach upset, or allergic reactions. The mechanism connecting the causality of *kombucha* consumption to these adverse effects has not been yet proposed, but the cessation of its intake ameliorated the health status of these patients[133,134]. A case of cutaneous anthrax has also been associated with unhygienic *kombucha* tea exposure in Iran[135]. Some health disorders, such as hepatotoxicity and severe metabolic acidosis, have been linked to *kombucha* consumption, possibly after chronic or excessive consumption[129,136]. Recently, a case of hepatotoxicity related to *kombucha* consumption was published[137]. Finally, a pilot study in mice reported some adverse effects, such as splenomegaly and hepatomegaly, after chronic *kombucha* injection[136].

Regarding *kvass*, a cereal-based beverage popular in Russia and other countries, concerns have been published for its possible contribution to chronic alcoholism in the former Soviet Union. *Kvass* content of alcohol is generally below 1·5 %, but due to its low price has been massively consumed even by adolescents and children[138].

Commercialisation of indigenous non-alcoholic or low-alcoholic fermented beverages

Traditional non-alcoholic or low-alcoholic fermented beverages and their place in the market

Non- and low-alcoholic fermented beverages have gained consumers' acceptance worldwide. Their demand stems from long-rooted established practices, as well as their sensorial

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properties. In the past, NAFB and LAFB were found mainly in rural markets, such as small- and large-scale farms and local village markets, but recently have become available in urban markets as well. A variety of LAFB and NAFB are commercially available in many cities[139] (Tables 1, 2, 3, 4 and 5). Most of them are dairy products, for instance *kefir*[140]. Examples of other than dairy NAFB, which are commercially available in European markets, are *kvass* and *kombucha*.

In countries where a standardised production for NAFB and LAFB exists, their consumption has exhibited an increase over the past decades. Dairy fermented beverages, with fermented milks and yoghurt-like drinks being the most representative, comprise the majority of the health-promoting fermented beverages. Dairy NAFB and LAFB are widely consumed in northern European countries, such as Denmark, Sweden and Finland[141] (Fig. 1), but are less consumed in other countries such as France, German, Spain and the UK[139]. Based on a series of studies focusing on the level of consumption of commercially produced fermented milk products in different countries, Finland had the highest level, with 91·6 % of the participants reported consuming sour milk[22,142]. Thus, the implementation of standards in the manufacturing of traditional NAFB and LAFB not only ensures the identity and quality of these products, but also helps in promoting their consumption in the general population.

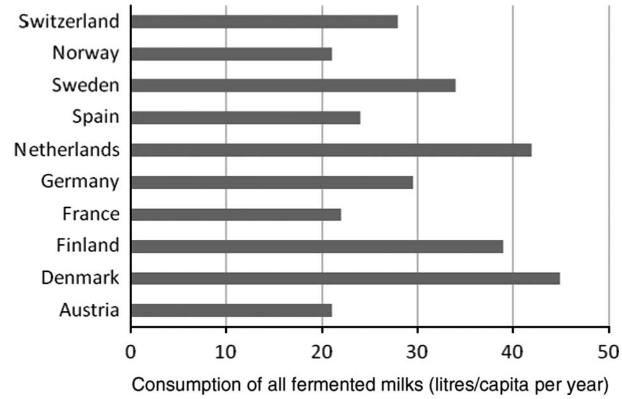

Fig. 1. Annual per capita consumption of all fermented milks only in selected countries in Europe. Data were taken from Saxelin (2008)[166].

Innovations and perspectives of traditional non-alcoholic or low-alcoholic fermented beverages

Over the last decade, an increasing demand for health-promoting foods and beverages has been reported in many parts of the world[139]. This resulted in the expansion of 'functional' foods throughout the market, with a wide range of products, including beverages. Generally, there is no unanimously accepted international definition of 'functional' foods. From a science-based view, the European Commission Concerted Action on Functional Food Science in Europe (FuFoSE) describes a food as functional 'if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease'. It also states that '"functional" foods must remain foods and they must demonstrate their effects in amounts that can normally be expected to be consumed in the diet: they are not pills or capsules but part of a normal food pattern'[143]. This prerequisite represents a challenge when attempting to formulate legislations for regulating the market of functional foods[139].

Dairy foods are estimated to account for almost 43 % of the functional foods market, the largest proportion of which is comprised of fermented products[144]. The majority of fermented milks and yoghurt-like drinks fall within the category of probiotic beverages, the largest proportion of the functional food market[22,139]. These beverages often contain strains of *Lactobacillus* spp. and *Bifidobacterium* spp., as well as other species. In their novel versions, *Lb. acidophilus*, *Lb. rhamnosus*, *Lb. casei* and *B. bifidum* are the most commonly added probiotics[139,144,145], while peptides, phytosterol, minerals and milk whey are the most commonly added bioactive compounds (for examples, see Table 6). In some cases, species of *Saccharomyces* and *Candida* may be added in commercially prepared fermented milks[146], but only *Saccharomyces boulardii* is considered as a yeast with probiotic properties. More recently, the production of probiotic fermented beverages from whey has received much attention[147]. A representative example of a fermented whey-based drink is Gefilus® (Valio Ltd) (Table 6). Whey is an endproduct of cheese manufacturing (a fermentation process), which retains almost half of the milk nutrients and is low in fat (0·36 %). A fermented whey-based drink can be produced by the addition of LAB, such as *Streptococcus* and *Lactobacillus*, on whey. These probiotic bacteria can survive and ferment whey[148]. Furthermore, it has been shown that the addition of starter cultures, such as *kefir* grains, can also result in the production of a fermented whey-based beverage[147].

The prospect of manufacturing non-dairy fermented beverages is currently very appealing, mostly as an alternative way to traditional dairy-based fermented beverages for delivering probiotics. Non-dairy beverages containing probiotic strains have recently been launched in the European market. Made of fruits, vegetables and cereals, these beverages are suitable for individuals allergic to milk, hypercholesterolaemics as well as for vegans, while they are good sources of antioxidants, fibres, vitamins and minerals[46]. At the same time, they are free from substances found in dairy products, such as pesticides, oestrogen and insulin-like growth factor I (IGF-I) which might be responsible for a negative association between dairy products and health problems[139]. In particular, cereals serve as alternative substrates for the industrial production of non-dairy fermented beverages which contain probiotic and prebiotic ingredients[148]. Proviva® (Skane Dairy) was the first non-dairy fermented probiotic beverage, made of oatmeal gruel with the addition of LAB[46] (Table 6).

Ongoing research for developing new formulas for dairy and non-dairy LABF and NAFB products results in an expansion of the types available, beyond the traditional ones[46]. Further evidence, which will substantiate their preventive or/and therapeutic health benefits, mode of action, optimal intake,

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Table 6. Examples of commercially available functional low-alcoholic or non-alcoholic fermented beverages in European countries[139,144,145]

Product	Substrate	Producer, country	Functional culture
Acidophilus milk	Milk	Sweden, several countries	*Lactobacillus acidophilus*
Acidophilin	Milk	Probiotic, Russia	*Lb. acidophilus*, *Lactococcus lactis* subsp. *lactis*, *kefir* culture
Diphilus milk	Milk	France	*Lb. acidophilus*, *Bifidobacterium bifidum*
Biomild	Milk	Germany	*Lb. acidophilus*, *B. bifidum*
AB milk products	Milk	Denmark	*Lb. acidophilus,* bifidobacteria
Bifighurt	Milk	Germany	*B. longum* (CKL 1969) or *B. longum* (DSM 2054)
Bifilak©t	Milk	USSR	*Lb. acidophilus*, bifidobacteria
Biokys (= Femilact)	Milk	Czechoslovakia	*Lb. acidophilus*, bifidobacteria and *Pediococcus acidilactici*
Acidophilus yeast milk	Milk	Russia (former USSR), Western European countries (a very limited volume)	*Lb. acidophilus*, lactose-fermenting yeasts (*Saccharomyces cerevisiae*, *S. boulardii*)
Bifidus milk	Milk	Germany	*B. bifidum or B. longum*
Arla A-38 (A-38 fermented milk)	Milk	Denmark	*Lb. acidophilus*, *B. bifidum*, *Leuconostoc mesenteroides* ssp. *cremoris*, mesophilic lactococci
AKTFIT plus	Milk	Switzerland	*Lb. acidophilus*, bifidobacteria*, Lb. casei* GG and *Streptococcus thermophilus*
Verum® (*filmjölk* variant)	Milk	Essum AB, Sweden	*Lc. lactis* L1A, *Lb. rhamnosus* LB21
Gaio®	Milk	MD Foods, Denmark	*Enterococus faecium*, *S. thermophilus*
Actimel®	Milk	Danone, France	*Lb. casei* Immunitas™
Vifit Drink®	Milk	Mona, The Netherlands	*Lb. casei* GG, *Lb. acidophilus*, *B. bifidum*
CHAMYTO®	Milk	Nestlé, France	*Lb. johnsonii*, *Lb. helveticus*
Cultura®	Milk	Arla Foods, Sweden	*Lb. acidophilus*, *B. bifidum*
ProCult Drink®	Milk	Müller, Germany	*B. longum* BB536, *S. thermophilus*, *Lb. delbrueckii* subsp. *bulgaricus*
Gefilus® (fermented whey drink, fermented milk, fruit drink, drinking yoghurt)	Milk	Valio Ltd, Finland	*Lb. rhamnosus* GG Vitamins C and D
Proviva®	Cereal (oat)	Skane Dairy, Sweden	*Lb. plantarum* 299v
Evolus®	Milk and fruit	Valio Ltd, Finland	Bioactive peptides
Flora Pro-Activ	Milk	Unilever, UK	Phytosterol
Zen	Milk	Danone, Belgium	Mg
Milone	Milk whey	Poland	Whey and *kefir* bacteria
Serwovit	Milk whey	Poland	Whey

selection of specific strains for a targeted outcome and mode of delivery, is needed. Also, information regarding the viability, metabolic activity and thus efficacy of probiotic bacteria in a beverage till the end of its shelf-life has to be considered. New product development requires detailed knowledge of the products' details as well as the customers' needs and behaviour[149,150].

Discussion

LAFB and NAFB are important constituents of the human diet all around the world. Their value stems from their cultural significance, as their production has been interwoven with ecosystems and social structures of local communities[150,151]. In Europe, LAFB and NAFB produced from milk are the most abundant, with *kefir*, *ayran* and buttermilk being among the most representative ones. LAFB and NAFB made of cereals (such as *boza* and *kvass*), herbs, spices and aromatic plants (such as *kombucha* and ginger beer) as well as, sucrose-based (such as *sima* and water *kefir*) are also popular in some countries; LAFB and NAFB made of fruits (such as *hardaliye* and *gilaburu* juice) and vegetables (such as sauerkraut juice and *salgam* juice) are generally less well known.

By applying the process of fermentation, the nutritional value of the substrates of fermentation, milk, fruit, cereals and vegetables, can be modified via a spontaneous biological enrichment with essential amino acids, vitamins and bioactive compounds[70]. For example, in fermented milks, via the process of biological enrichment, most of the lactose is converted to lactate and proteins to free amino acids, both of which are readily absorbed, thus enhancing the digestibility of the product[152]. However, although consumption of LAFB and NAFB has received attention, information on their nutrient content is generally lacking. Thus, compiling information on the composition and nutritional value of LAFB and NAFB is important in order to properly update[42,50]. Furthermore, this knowledge will allow government authorities to compile scientifically based regulation requirements, beverage industries to promote these beverages based on information, nutritionists and dietitians in dietary planning and consultation, and finally scientists in research designing and explaining study results. In addition, a robust knowledge of traditional LAFB and NAFB from European countries will assist in the promotion of regional biodiversity and sustainability.

LAFB and NAFB produced in European regions are usually from cows' milk (Table 1). However, at a global level, non-cows' milk has a growing importance in production, culture, economy and ecology[153]. Non-cows' milk is widely produced and consumed in Asia and Africa (approximately 50 % of the produced milk), mainly in emerging or developing countries and in remote areas[154]. In Europe the majority of the produced non-cows' milk comes from sheep[153]. Several of the milk-based LAFB and NAFB presented in Table 1 can be made from types of milk other than cows' milk, such as sheep's (sour milk, *skyr*, *prokish*, *prostokvasha*, *lyntyca*, *žinčica*), camel (*kefir*), buffalo (sour milk) or goats' milk (Bulgarian buttermilk). Thus, milk-based LAFB and NAFB may represent an opportunity in the direction of poverty alleviation and environmental sustainability by contributing to the increasing demand for food quantity and quality, especially in poor and underdeveloped countries.

In the past, alleged health effects had been sufficient for the consumption of LAFB and NAFB. Nowadays, their link to health benefits requires evaluation. Well-designed studies could investigate the impact that their consumption has on human health and elicit the role of their bioactive ingredients, type of microbes and their content and by-products of fermentation, as their health effects are probably the result of a synergistic process[22,139,151,155]. Many factors perplex the implementation of clinical trials: constrains of time and money, the required adherence by the participants to consume the prescribed beverage and the selection of appropriate placebos (both for LAFB and NAFB and diet regimen). However, the need for strict and standardised guidelines in designing and conducting experimental studies is necessary.

Generally, LAFB and NAFB are an under-researched group of foods. The great diversity observed in traditional LAFB and NAFB can be attributed to several factors, such as utilisation of different raw materials, variations in natural microbiota and fermentation conditions, and production methods applied[20]. Our understanding would be facilitated by establishing a consensus with respect to the specification of the natural microbiota, description of these particular micro-organisms that are essential for fermentation, as well as their contribution, either as a consortium or as a single strain to the final composition of each beverage[22]. Currently, the formulation of health drinks that are based on traditional LAFB and NAFB represent a challenging opportunity for the beverage industry.

Most of the LAFB and NAFB presented here have been only recently become available in the market. Thus, in order for the scientific and commercial food standards to be met, there is a need for improving their microbial and sensorial properties. The design and production of a second-generation LAFB and NAFB require the following actions: (1) the identification, quantification and standardisation of promising bioactive compounds; (2) the fingerprinting and characterisation of the indigenous microbiota of the artisanal products; (3) the selection of starters able to produce bioactive compounds; (4) the selection of strains with functional properties to enhance the health-promoting properties of traditional LAFB and NAFB; (5) the investigation of bioavailability and metabolism of ingredients with health-promoting potential; (6) the study of safety aspects related to the consumption of beverages with enhanced nutritional effects; and (7) the formulation of value-added products based on traditional LAFB and NAFB[20,155]. These developing actions in the health-promoting beverage market need to rely on a collaborative effort between industry partners and academia. This way, clinical trials and solid evidence will guarantee the production of LAFB and NAFB with enhanced nutritional effects and justified health claims[156].

However, many of the fermented foods are still produced in the traditional manner, i.e. either by natural spontaneous fermentations or by employing the back-slopping method[2,19,70,157]. Back-slopping results in a higher initial number of microbiota present in the raw material itself. The specific microbiota involved in the production of any particular LAFB/NAFB varies markedly from region to region, and even among households within small geographical regions. Furthermore, taking into consideration the existing variability in the processing parameters, which are also being employed between the different fermentation regimens and geographical regions, one may conclude that the achievement of a uniform LAFB/NAFB is an extremely difficult task. The above indicate that further research is needed in order to determine the microbiological and biochemical features of the traditional LAFB and NAFB in each European country. As industrialisation and urbanisation are currently the norm for European societies, there is a need for large-scale production that will result in traditional fermented beverages of a consistently high quality and safety[158]. The transition from a household procedure to an industrial-scale production is a complex process, which requires improvements in the process controls and overall quality and safety, such as the microbiological standpoint of the raw materials used in the production of these beverages.

Nowadays, many individuals in Western societies wish to follow a prudent lifestyle. LAFB and NAFB could be an integral part of this trend as they are linked to a traditional, sustainable food system while they may be capable of improving the nutritional status of many[159]. As the scientific knowledge on the role of probiotics expands, the need for alternative means of probiotic delivery also increases. The various dairy products are currently the vehicle of choice for delivering probiotics, and probiotics are responsible for the health benefits of many LAFB and NAFB. Furthermore, cheese whey is an inexpensive fermentation substrate with high nutritional value and some whey components, such as lactoferrin, growth factors and immunoglobulins are gaining commercial interest from the beverage industry[144]. Thus, whey-based fermented beverages could constitute a larger part of European commercial beverages[160,161]. In addition, LAFB and NAFB based on substrates other than milk, such as cereal and fruit juices, may also gain success among consumers. Cereal-based fermented drinks could be produced commercially in Europe and low-quality cereals could be used for the production of a highly nutritious product[43].

The interest of consumers for the preparation and consumption of traditional LAFB and NAFB depends on their potential to have a good taste, to prevent disease and ensuring healthy lives and well-being at all ages[144,155,162]. Full regulatory approval for claims requires the support of robust evidence[163]. The European Food Safety Authority (EFSA), in accordance with Regulation (EC) no. 1924/2006, has also set scientific requirements for substantiating health claims related to gut and immune functions[164]. However, in the USA and Japan a health claim that is suggested but not supported by robust evidence is known as a qualified health claim and is permitted. This heterogeneity in the required evidence has resulted in diverse health claims being accepted by the

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competent agencies among different countries even in the same continent and eventually creates confusion to the consumer. Currently, only in a few European countries, for instance, Sweden, the UK and the Netherlands, existing regulations allow for an official approval of health claims[165]. Once the constitution of the new regulation from the European Union is in place, the use of unauthorised claims and promises will cease, thus ensuring the development of accurate claims in regards to the health benefits of products that target specific health conditions[22,139,151,155].

Conclusion

Historically, LAFB and NAFB produced and consumed by European populations have been important for their nutrition and well-being. The present review revealed a considerable variety of traditional LAFB and NAFB across Europe. Although the dietary significance for some of these beverages is well known, there is still much to be elicited, especially about those of marginal use. Moreover, the stock of local knowledge on the natural preparation processes of these traditional beverages appears to be at risk, because of the overreliance on commercially produced beverages which currently prevails, even in rural regions. This trend, combined with a decline in the transfer of knowledge and lack of documentation on the remaining traditional know-how concerning local microbiota, ingredients of fermentation and fermentation processes, has resulted in the marginalisation and, in some cases, even disappearance of homemade LAFB and NAFB today.

From a commercial perspective, an increasing interest in beverages with enhanced nutritional effects has made selected traditional milk-based LAFB and NAFB, such as *kefir* and *ayran*, widely available in many European markets. The health beverage market will benefit from the increase of knowledge on less widespread traditional LAFB and NAFB, such as those that are presented in this review. Based on the improvements in science and technology, as well as consumers' increasing consciousness for healthy and sustainable diets, the future for LAFB and NAFB appears to be more promising than ever.

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