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Appraisal of some ethnic milk products from minor milch animal species around the world: a review

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Abstract

Cattle and buffalo are the main species producing milk for human consumption. Minor milch species such as goat, sheep, camel, horse, yak, donkey, and reindeer make up a less significant portion of the total milk supply in the dairy sector as their production share is relatively small. However, in recent years, people have started to recognize the numerous health and nutritional benefits of milk from these minor milch species. There is a rich diversity of traditional dairy products in the world, among which the ethnic products made from the milk of minor dairy species have a solicitous place in their region of origin. The ingredients and composition of these products and the preparation methods impart their characteristic taste and flavour along with their typical nutritional and functional health benefits. Anti-microbial, probiotic, antioxidant, nutraceutical, and other health-promoting qualities are the few benefits of these products. However, lack of research and developmental activities, promotions and advertisements of ethnic milk products of minor milch species have led to their limited awareness among the consumers. In view of the above, the present review attempts to discuss some of the important ethnic milk products around the world from the milk of minor milch species.

Keywords Ethnic dairy products, Minor milch species, Functional foods, Minor dairy animals, Novel foods

Introduction

Milk is an ideal and universally accepted food. It plays a major role in human culture and has been a fundamental component of existence since ancient times [1]. In 2020, global milk production reached around 906 million tonnes, with an increase of almost 2% over the previous year [2]. Based on animals share in milk production, the world's milking species are categorized as "Major" and "Minor" milking species. For example, cattle and buffalo are classified as "Major milking species" (MaMS), whereas other milking species like sheep, goat, camel, yak, horse, donkey, and reindeer are classified in "Minor milking species" (MiMS) category. Many MiMS like camel, horse, donkey, and reindeer are even not frequently milked [3]. Sheep and goat contribute about 21% of MiMS milk, mainly in Africa, Asia, and Europe [4]. They contribute only a small percentage to the agricultural output and are of low-income dairy animals [5]. The data on milk production from these MiMS are scattered and are not always available for all these milking species. Nevertheless, data on global milk production by leading MiMS viz., goat, sheep, and camel are mapped (Additional file 1: S1) and presented in Fig. 1.

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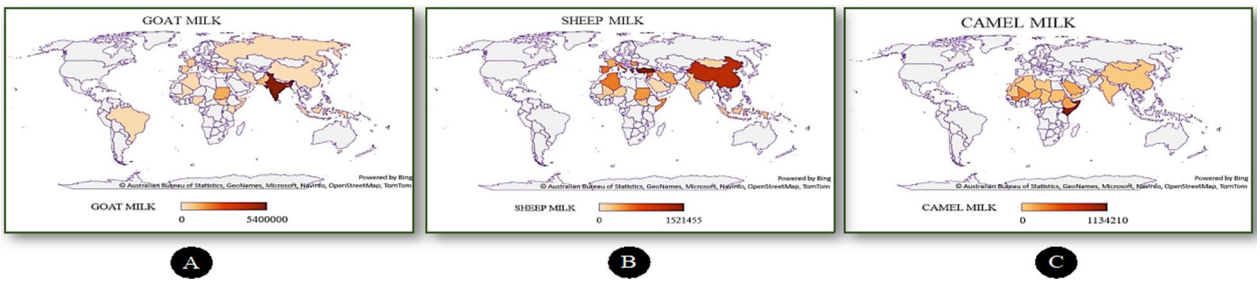

Fig. 1 Milk production (Metric tonnes) by leading minor milking species viz. **A** Goat, **B** Sheep and **C** Camel (Data source: FAO, 2019)

The milk from MiMS has numerous nutritional and functional health benefits. In the equatorial (tropical) and sub-tropical countries, goat, sheep and camel are the main livestock for marginal farmers. Goat and sheep are considered as "Poor man's cow" in these areas [6]. They use them for milk, meat and sometimes for skin and hairs. In semi-arid areas of world, local peoples use goat and sheep milk in regular diet. Goat milk contains antimicrobial properties and can be used to treat cardiovascular, gastrointestinal, and cancer disorders, as well as allergies like rhinitis and eczema [7]. Sheep milk improves absorption of micro-minerals and trace elements and improves bone structure. Conjugated Linoleic Acid (CLA) and orotic acid in sheep milk aid in the treatment and prevention of type 2 diabetes, cancer, and other diseases [8, 9]. In the extreme areas of high altitude, low temperature, hypo-oxygen level where cattle/buffalo cannot survive, yak (a mountain bovine) show tolerance to all these environmental extremes [3]. Yak milk is rich in probiotic bacteria, fatty acids, and several antioxidants [10]. Camel is very important in hot and arid countries in the sector of agriculture and also for dairy [11]. Camel milk has potent anti-inflammatory, probiotic, and antioxidant effects [12, 13]. Small body size, efficient grazing in short vegetation, survival with low appetite, having coarse to highly digestible grasses in diet make donkey a good livestock to rear in hilly areas for milk, meat, transportation, and agriculture [14]. Donkey milk contains higher lysozyme, has more antibacterial properties and anti-tumour properties, and is therefore better for manufacturing of functional foods and infant formula [15–17]. Deer is considered as comparatively better livestock than cow, sheep, and goat, in terms of feeding and management as their small body size makes them to survive at low diet also [18]. Deer milk has a greater fat, casein, protein, and minor element concentration [19]. Ability to utilize highly fibrous diet, even of low digestibility, make horse better option as a livestock under pleasing summer and extreme winter condition. Ethnic population of such region also use mare's milk for daily consumption [20]. Horse milk boosts the immune system, has low cholesterol, and reduces allergic reactions [21–23].

Milk is highly perishable when present in its natural form [24]. As a result, activities such as heat/cold treatment or the conversion of milk into various products and more recently numerous filtration techniques have been employed to extend the shelflife of milk and to keep the milk for longer duration [25]. Since ancient times, many dairy products have been produced worldwide. Most of these products were prepared from the milk of MaMS because of their high availability. Since ancient times, many dairy products have been produced worldwide. Most of these products were prepared from the milk of MaMS because of their high availability. Although the present article deals primarily about certain ethnic products of MiMS other than cattle and buffaloes, the interested readers may refer Vargas-Ramella et al. [26], Murtaza et al. [27], and Deb et al. [28] for some ethnic and area specific dairy products made from buffalo milk and Tenava-Angelevo *et* al. [29], Abdelgadir et al. [30], and Leksir et al. [31] for dairy products made from cow milk. On the Contrary, very few dairy products have been prepared using milk of MiMS because of their limited availability. The limited availability of ethnic milk products prepared from milk of MiMS is also due to restricted geographical distribution of these milking species [32]. Poor infrastructure and small scale of farming of MiMS are the main issue in arid and semi-arid countries [6]. Nevertheless, in addition to their conventional ethnic appeal in taste, flavour, aroma and other sensory attributes, products prepared from milk of MiMS are certain to provide all the excellent nutritional and health benefits to their consumers. Ethnic products reflect some connection with that particular region.

These ethnic dairy products if explored and propagated properly by developing standardized process for enhancing quality and shelf life may have the acceptance of wider consumer groups around the world. Therefore, in this review, an attempt has been made to appraise manufacturing processes and nutritional and functional health

attributes of some ethnic milk products prepared from milk of minor milch animal species around the world.

Ethnic dairy products from goat milk

Goats are the earliest domesticated minor milking animal species. Very first proof of goat domestication was found in Mesopotamia, an oldest known civilization. After that many evidences were found in the history of different countries in Asia, Africa, and in Europe as well. Wide environmental adaptability, long distance walking, low-cost management, good disease resistance, etc., make it better livestock under dry or semi-dry climatic conditions [33]. In 2017, the global population of goats was 218 million and accounted for 2.25% of global milk production [34, 35]. The average chemical composition of goat milk is 87.5% water, 12.2% TS, 4.0–4.5% Fat, 3.2% Protein, 4.6% Lactose, 0.85% Ash and Calorific value of 70 kcal per 100 g milk [36]. Goat milk offers numerous health benefits, including better iron and copper absorption than cow milk, as well as being a better alternative for preventing cow milk allergy and gastrointestinal problems [37, 38]. Goat milk is used in a variety of regional products. Various ethnic goat milk products like Cajeta, Mursik, Matzoon, and Kaymak have been covered in this section.

Cajeta

Cajeta (Fig. 2A) is a Mexican dessert made with caramelized goat milk. Also known as "Milk Jam," and it is used as ice cream and in cake fillings [39]. It is used for the preparation of Alfajores, a sandwich cookie in North-American countries such as Argentina, Uruguay, Peru, and Chile. The classic candies prepared with goat milk Cajeta in Mexico were Glorias and Queso de Nunez (with nuts) and Chongos zamoranos (with cinnamon flavour) [40]. Cajeta has better nutritional value (Table 1) and improved shelf life than goat milk as it is minimally processed for condensation and caramelization without any addition of preservatives. It has the potential to aid in the treatment of fatty liver disease and to slow down the ageing process [41].

In Argentina, Dulce de leche is a cow milk product very similar to Mexican cajeta. Peoples of Argentina says that the cajeta is a copied version of Dulce de leche. They consider cajeta as an offensive word. Which product is creamier and have rich flavour and better texture is a topic of debate over there [55].

Cajeta is available in various tastes, including vanilla, coffee, and chocolate. Producers sometimes add alcohol to it at a temperature of around 104 °C to give it a spirit flavour. Many producers also use baking soda to improve the texture of cajeta by altering the pH, which lowers protein aggregation. Its preparation can take up to 5–6 h because of high water content (Table 2), and the prolonged heat enhances the Maillard Browning Reaction, which results in caramel flavour. As it is a caramelized product, protein content of milk has most significant effect on its flavour and texture. High protein content causes aggregation and forms curd-like texture in caramel. Cajeta maker named it protein graining. Use of baking soda helps to resolve this problem [55]. Ultra-filtered (UF)-cajeta contains less lactose, potassium, and sodium and more protein, calcium, and phosphorus. Sensory qualities of the UF-cajeta after storage are superior as the UF process prevents the formation of bigger crystals and the development of sandiness in the product. A cajeta-flavoured whey beverage supplemented with inulin has a large consumer acceptance due to its beneficial functional characteristics and appealing sensory attributes [39]. Similarly, Ramirez and Vélez developed a novel cajeta milk beverage that provided consumers a potentially healthy product with reduced fat content and a fresh flavour [41].

Fig. 2 Ethnic dairy products prepared from goat milk.: **A** Cajeta (source: Cook's illustrated); **B** Mursik (source: Atlas Obscura; **C** Matzoon (source: alchetron.com); **D** Kaymak (source: basilgrocery.com)

Table 1 Chemical composition of ethnic dairy products manufactured from milk of minor milch animal species

Name of the product	Average chemical composition (%)							pH	Source
	Water	Total solid	Fat	SNF	Protein	Carbohydrate	Ash		
Goat milk									
Cajeta	18.17	81.83	7.52	74.33	7.50	66.70	0.13	–	[41]
Mursik	83.16	16.84	5.42	11.42	6.39	3.95	1.77	4.2	[42]
Matzoon	87.56	12.44	1.47	10.97	5.33	3.71	0.75	–	[43]
Kaymak	28.79	71.21	66.65	4.56	–	–	–	6.67	[44, 45]
Sheep milk									
Tzatziki	81.32	18.68	6.30	12.40	7.92	3.33	1.15	–	[46]
Cuajada	60.57	39.43	21.00	18.43	15.44	1.10	1.89	6.14	[47]
Zincica (acid)	88.20	11.80	4.90	6.90	2.40	2.60	0.40	–	[47]
Zincica (sweet)	87.80	12.20	5.10	7.10	2.60	3.80	0.41	–	
Saganaki	62.00	38.00	–	–	21.00	–	22.00	4–6	[48]
Camel milk									
Chal	95.50	4.50	2.30	2.20	1.70	0.10	0.40	4.5	[49]
Suusac	87.50	12.50	4.00	8.50	3.00	4.72	0.78	–	[50]
Horse milk									
Kumiss	95.34	4.76	1.70	3.60	2.20	1.10	0.30	–	[51]
Yak milk									
Kurut	12.35	87.65	50.00	37.65	24.50	2.80	10.35	4.2	[52]
Chhurpi (soft)	70.33	29.67	10.16	19.51	12.76	5.14	1.23	4.89	[53]
Chhurpi (hard)	10.22	89.77	7.20	82.57	63.33	23.17	6.31	4.32	
Reindeer									
Leipajuusto	41.30	58.70	25.30	33.40	22.46	8.77	2.17	6.11	[54]

Mursik

Mursik (Fig. 2B) is a spontaneously fermented milk product prepared by the Kalenjin community of Kenya, an Eastern African country. Kalenjin tribe originated before sixteenth century, and it includes eight different subtribes. Nandi is a highly civilized subtribe among all. This community raise livestock and cultivate some cereals [70]. Mursik is a major type of diet whose production and consumption constitute more than half of the daily food consumption in Kenya. The milk is fermented in gourds, *sotets* for 3–5 days or longer, depending on sensory preferences of the consumer. Locally, blood is also added in milk during preparation [71]. A blue or red layer is formed on the surface of mursik when it is ready to consume [72]. In addition to being commonly consumed after meals, it is also occasionally served in combination with other staple foods. The daily diet of Kalenjin tribe includes a mixed paste of cooked maize or millet flour with sorghum flour, mursik, and meat as a supplementary food. Mursik has high nutritional compositions (Table 1). Due to its high nutritional value mursik is considered superfood by these tribes and is generally an essential product fed to breast feeding mothers and initiates [56, 71, 72]. Kalenji females consume mursik instead of fresh hot milk during pregnancy [71].

The leaf extracts of African senna (*Senna didymobotrya*), African cherry (*Prunus africana*), Olive (*Olea europaea*), and Lippia (*Lippia kituiensis*) are added while preparation. Different tree species used in its preparation are very specific to the biogeographical and ecological conditions of that area. They are used either for addition in mursik or for pre-treatment of sotets. [73]. African senna extract addition imparts aroma and other attributes such as nutraceutical properties, antibacterial and antipyretic properties. The African cherry extract has antifungal, anti-diabetic, and anti-inflammatory properties; and the olive has high antioxidant and fatty acid content, cardioprotective activities. Charcoal from African cherry or olive plant is used to preserve milk, which also imparts milk colour and aroma in addition to providing health benefits. The effectiveness of *Lippia kituiensis* in chronic joint pain, malaria, and other diseases has been known well [74–79]. It also has a larvicidal effect on *Rhipicephalus appendiculatus* larvae [80]. Being a fermented dairy product and supplemented with important herbal extracts, Mursik has a number of health benefits such

Table 2 Ingredients and preparation protocol of ethnic dairy products manufactured from milk of minor milch animal species

Ethnic product	Ingredients and culture	Preparation protocol	References
Cajeta	Goat milk, sugar and nuts	Preheating goat milk to 40–50 °C Addition of 20% sugar on milk basis Concentrating the product to 70% TS Cooling, packaging and storage	[55]
Mursik	Milk, LAB starter culture (*Lactobacillus*, *Lactococcus, Streptococcus* and *Leuconostoc* species are used), gourd, burnt *Senna didymobotrya* sticks (as charcoal)	Gourd container for fermentation of the product is prepared by taking a clean dried gourd and cutting its top and removing the seeds These gourds are pre-treated with the smoke and charcoal of certain species of trees Pasteurize the gourd Boiling and cooling of milk. The cooled milk is poured into the specially prepared gourd Addition of starter culture The gourd is then capped and placed in a cool dry place to undergo spontaneous fermentation for at least 3–5 days through the action of lactic acid bacteria	[56]
Matzoon	Goat or sheep milk, matzoon culture (mainly lactic acid bacteria; *Lactobacillus acidophilus*, *Streptococcus thermophilus*, and *Lactobacillus delbrueckii subsp. Bulgaricus*)	Pasteurization of milk Cooling and inoculation of starter culture Filling to containers Incubation at 41–43 °C for 2–3 h Cooling and storing	[57, 58]
Kaymak	Goat milk	Receiving milk and separation of milk fat by using separator Standardization of milk fat (60% fat ratio) Pasteurization (80–85 °C, 5–10 min) Cooling (23–25 °C) Packaging and storage	[59]
Tzatziki	Sheep milk, yoghurt, cucumber, sour cream, olive oil, garlic, lemon juice, pepper, salt, xanthan gum	Homogenization and pasteurization of fresh milk Inoculation of yoghurt culture and incubation Cooling Straining of yoghurt and mixed with cucumber in a ratio of 4:1 Addition of garlic, lemon juice, dill, parsley or mint (if needed) and salt as per taste Packaging and storage	[60, 61]
Cuajada	Sheep milk, rennet, sugar or honey, fruits, and walnuts	Receiving sheep milk and heating to boiling temperature Cooling and addition of rennet Curdling Removal of whey from curd Addition of sugar or honey, walnuts, or fruits into curd Cooling, packaging and storage	[62]
Zincica	Sheep milk, LAB culture	Pasteurization of milk Cooling and addition of culture Coagulation The curd portion is filtered out The filtered whey is zincica Packaging and storage	[63]

Table 2 (continued)

Ethnic product	Ingredients and culture	Preparation protocol	References
Saganaki	Sheep milk, starter culture or rennet, cooking oil or ghee, lemon juice	Receiving sheep milk and preheating Cooling and addition of starter culture or rennet and letting it coagulate Preparation of cheese and frying of cheese using cooking oil or ghee Packaging and storage	[48]
Chal	Camel milk, culture (*L. lactis* & *S thermophilus*)	Receiving, filtering, and preheating fresh camel milk and then cooling to 30 °C Addition of sour milk or culture Incubation at 30 °C for 8 h or at 10 °C for 72 h Remove the thick layer of cream, known as agran, formed during the fermentation After the removal of the agran, the leftover liquid is called as Chal Cooling, packaging and storing	[64]
Suusac	Camel milk, LAB culture (*Lb. curvatus*, *Lb. plantarum*, *Lb salivarius*, *Lb. raffinolactis*, and *Leuconostoc mesenteroides* subsp. *Mesenteroides)*	Receiving camel milk and heating to 85 °C for 30 min Cooling to ambient temperature of 22–25 °C Inoculating with 2–3% starter culture and incubating at 27–30 °C for 24 h Packaging and storage	[65]
Kumiss	Mare or sometimes donkey milk, LAB and yeast strain. *Lactobacillus delbrueckii, Lb. bulgaricus, Lb. acidophilus, and lactose-fermenting yeasts (Torula koumiss and Saccharomyces lactis)*	Receiving mare's milk and heating to 90–92 °C for 5–10 min Cooling to 26–28 °C Addition of culture at an inoculum rate of 10–30% to give an initial acidity of 0.45% lactic acid Incubation at 28 °C till an acidity of 0.7–0.8% is achieved Agitating for every 1–2 h Cooling and stirring at 20 °C Packaging and storage (at 4 °C for 24 h)	[51]
Kurut	Yak milk, yoghurt culture, salt, cream	Receiving raw milk and heating to 90 °C for 10 min followed by rapid cooling to 40 °C Addition of 1–2% of yoghurt culture Incubation for 5–8 h. and store in low temperature (4 °C for 24 h.) Filtering the curd by cloth bag Addition of salt and cream with proper mixing Transfer the curd to different moulds for giving different shapes Drying in shades for 2–3 days then drying in sun for 3–5 days Final drying in shades for 2–3 months Packaging and storage	[66]
Chhurpi	Yak milk, LAB culture or Dahi (curd)	Boiling of milk for 10–15 min. and then cooling it for 20–30 min Addition of 50–80 g of old inoculum (curd) into milk (approximately 500 mL) Keep at room temperature for fermentation and curdling. This *Dahi* is locally known as *zho* Removal of fat from zho (*dahi*) After separating the fat from curd, the remaining buttermilk which is locally known as *tara* is boiled for coagulation Pressing and keeping for 1 h. for complete drainage of the whey part Mixing the curd mass and drying Shaping by pressing in between the fingers onto a clean cloth This is Soft *chhurpi;* when it is sun dried for 5–7 days, and it is called hard *chhurpi (used for long term storage)*	[67]

Table 2 (continued)

Ethnic product	Ingredients and culture	Preparation protocol	References
Pule cheese	Donkey and goat milk, rennet	Receiving fresh Donkey milk and goat milk and mixing in the ratio 60:40 Heating, cooling, and addition of rennet After fermentation drain the whey and place the cheese into 50 g mould to age for few days Packaging and storage	[68]
Leipajuusto	Reindeer milk, rennet, and salt	Receiving Reindeer milk and heating Cooling and addition of rennet The milk is curdled and set into a round cylindrical form with a thickness of 2–3 cm After this, the cheese is baked, grilled or flamed to give a distinctive brown or charred marks	[69]

as probiotic effects, gastrointestinal microecology stabilization by secondary metabolites production [81].

Matzoon

Matzoon (Fig. 2C) is an ethnic milk product, generally prepared by using goat or sheep milk and is considered to be originated in Armenia, a Western Asian country, and subsequently spread to Georgia. Matzoon is the national acido-lactic product of the Caucasus region and is known by different names viz., 'Matsoni', 'Matsun', 'Matsoun', etc. [82]. It has deep roots in the history of the country. Its history is as old as Armenian medical practices, near about 260 AD to 301 AD. Grigor Magistros (990–1058 AD) was a prince of Armenia and a researcher as well. He denotes matzoon as a "glue like" drink. Its mention was found in Holy Bible (before 33 AD) as yoghurt, in Holy vedas of Hindu culture (before 500 BCE) as a curd, and as Matsun in ancient Armenian literature (eleventh century) [83]. Different uses of matzoon are in bakery as a starter, in meals with cereals, acid-milk products in different forms and in butter making. Matzoon has significant iron-dependent antioxidant activity, which is mostly mediated by rod-shaped *lactobacilli*. Protease-resistant bacteriocins produced by lactobacteria predominate in the microbiota of this organism. It also falls into the category of items that exhibit symbiotic communities of lactobacteria and yeast that reflect the extreme diversity of ecological circumstances in the Matzoon region [84]. High palatability of matzoon results in its exclusive consumption in Armenia and is commonly used instead of cow milk [57].

Matzoon is fermented mainly by using thermophilic culture of *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, commonly known as Matzoon culture at 42–45 °C. Culture used is usually from previously prepared matzoon [58]. *Saccharomyces kefir*, a yeast is also presents in matzoon which primarily do not take part in the main fermentation process of Matzoon formation but produce little quantity of alcohol during fermentation, and also after consumption in digestive tract [85]. Well prepared matzoon tastes like high butter milk. Texture resembles to frothy and very fine granular curd [57]. It has a better chemical composition with good energy (54 kcal), glucose (1.0%), galactose (0.61%), and lactic acid content (8.69 g/L), which makes it nutritious and wholesome [43]. Other parameters of chemical composition of matzoon are presented in Table 1. Matzoon provides a number of health benefits, including improving and enhancing appetite, managing intestinal function, speeding up digestion, toning the body, lowering cholesterol, the risk of diabetes, heart attacks, and kidney stones [86]. The presence of lactobionic acid (which improves calcium absorption during intestinal digestion) due to lactose oxidation by *Acetobacter orientalis* in "Caspian Sea yoghurt/matzoon," a fermented product in Japan, has been reported [87].

Kaymak

Kaymak is a traditional dairy product manufactured mostly in eastern Turkey and central Anatolia (particularly in the region of Afyonkarahisar). The first reference of kaymak was found in the dictionary "Dīwān Lughāt al-Turk" compiled by Mahmud al-Kashgari in 1072-74. In several nations in the Middle East, Central Asia, India, and the Balkans, kaymak is also referred to as "kajmak", "kaimak", "gemagh", or "geymar". [88]. It occupies a prominent position in Turkish culinary tradition [89]. Kaymak is a clotted cream made using goat milk (Fig. 2D) and also from buffalo or cow milk. The process of making kaymak begins with the separation of the cream, followed by the fermentation and ripening period. Archaeological survey reported some micro-organisms used in fermented beverages production in 7000 BC [90]. Kaymak has a faint acidic flavour, depending on the ripening season, and a creamy, thick consistency. Consumption of kaymak was started in Kadayif and Baklava desserts in Turkey. Nowadays, it is an integral part of breakfast and is consumed with milk, sugar and honey.Different forms of kaymak have been produced in different regions of Turkey. 'Afyon kaymak' from Afyonkarahisar region, 'Ispir kaymak' from Ispir village of Erzurum region, and 'Kuru kaymak' from Erzincan, Nvesehir, Sivas, and Erzurum province [59, 91]. Ispir kaymak prepared with goat's milk is preferred over cow's milk kaymak and is distinguished by its high content of esters. Characteristic honey comb structure of final product and its flavour are the most important criteria for its acceptance. It must be consumed after few hours of making due to its low shelf life. Refrigeration enhances shelf life but compromises with taste and flavour [59]. Afyon kaymak is usually made up of water buffalo milk [92]. Kuru kaymak is quite different because of additional steps of foaming and drying. These two steps help to produce crispy texture and prolong shelf life [91]. Kaymak is also utilised in the production of silivri yoghurt, a sheep milk product [93]. Qeymer is an Iraqi milk product similar to kaymak but is typically produced with fat-rich cow or buffalo milk and served with fresh bread, jam, or honey.

Ethnic dairy products from sheep milk

Sheep was domesticated 11,000 years ago by early humans and is the next farm animal to have been domesticated after goat. After that it has been used primarily for meat (South-west Asia) followed by wool, and milk. Sheep was easy to adapt because of their non-harming behaviour, and wider acclimatization [94, 95]. Mostly

wild sheep are found in Iraq, Iran, and Syria, as well as the eastern part of Turkey. Sheep milk accounts for approximately 1.9% of global milk production [96] and contains 7.62% Fat, 10.33% SNF, 3.7% Lactose, 6.21% Protein (5.16% casein and 0.81% whey protein), and 0.90% Ash [97]. It contains a high concentration of bioactive peptides with antioxidant, antibacterial, antithrombotic, and antihypertensive properties [98]. Tzatziki, Zincica, Cuajada, and Saganaki are some of the ethnic products chosen for discussion among the many regional products prepared using sheep milk.

Tzatziki

Tzatziki (Fig. 3A) is a Greek salad, also known as Greek deli salad, made of strained yoghurt. It is prepared by blending veggies with yoghurt primarily derived from sheep or goat milk. This product is a common meal in Greek cuisine and most noticed item in a menu of any Greek restaurant [99]. People in Van province of Turkey use tzatziki in their breakfast [100]. It is thought to have originated in a region between Southeast Europe and the Middle East and is popular in Greece and other countries of the world, including the United States. Recipe books of ancient Greek around 3100 BC had mention of tzatziki [101]. It's made with plain yoghurt, cucumber and sour cream and spiced with olive oil, garlic, lemon juice, salt, pepper, and xanthan gum [102]. Hanging cheesecloth was the part of Greek household kitchens for removing excess moisture [103]. Cucumber in yoghurt breaks down the protein network, which increases the rate of syneresis. It is recommended that more moisture should be added to yoghurt before fermentation for optimal consistency [104]. Ready to eat without cooking or other processing [103]. At 4 °C, tzatziki can be stored either aerobically or under vacuum with a shelf life of 3–4 weeks and 6–8 weeks, respectively. Tzatziki is a low pH food due to the presence of yoghurt and the acid(s) produced by fermentation and has a low salt concentration, making it a healthy snack option. Salmonella and coliform bacteria which are major microbial contaminants survive to a lesser extent in tzatziki than other salads like Melitzanosalata (an aubergine puree salad); Rossiki, (Russian salad); Tyrosalata, (cheese salad), Tyrokafteri (cheese salad with extra spice), Tarama salad (cod roe paste), Eggplant salad and Hungareza (Hungarian salad) [60, 61]. Tzatziki has high and diverse nutritional profile than plain yoghurt. A 100 g of sample contains 90–110 kcal of energy, 2.3% carbohydrate, 5.2% cholesterol, 82 mg Ca, 105 mg K and 0.8 mg Fe (Table 1) [104]. Copper, iron, zinc, and potassium are all higher in cottage cheese supplemented with tzatziki [105].

Cuajada

Cuajada (Fig. 3B) is a traditional fermented semi-solid dairy product prepared from sheep milk and is originated in the northern part of Spain. It is more popular in Central American countries such as Honduras, Nicaragua, Costa-Rica and El Salvador. In Basque country (Basque Autonomous Spanish community), it is called as 'mamiya' [62, 106]. Cuajada is beneficial for health as it has a high nutritional profile (Table 1). It is made from pasteurised or ultra-heat-treated milk that has been coagulated with rennet and stabilized sometimes with stabilizers like gelatin and refrigerated below 8 °C [62]. In some part of Spain, Mushroom has been used for fermenting milk for preparation of cuajada [107]. In ancient Spain, cuajada was made during months of January to May using Kaiku—a wooden utensil—by adding sheep rennet into warm milk [106]. In the Central American country Nicaragua, people consume cuajada by adding salt in it and by dipping *"Guirilas"* a tortilla prepared by using maize flour in it [62]. It has a shelf life of 20 to 28 days. Nisin, reuterin and lactoperoxidase combination, which is used for inhibition of *Listeria monocytogenes* and *Staphylococcus aureus*, enhances the shelf life of cuajada [108]. Cuajada is beneficial for health as it has a high nutritional profile (Table 1). [62].

Fig. 3 Ethnic dairy products prepared from sheep milk; **A** Tzatziki (source: bloglovin.com); **B** Cuajada (source: cheese.com); **C** Zincica (source: nikos.sk); **D** Saganaki (source: pappaspot.com)

Zincica

Zincica is a whey beverage (Fig. 3C), made as a byproduct of "Bryndza" cheese production [109]. It is a pure and pasteurized sheep milk cheese produced in Slovakia and Poland. Bryndza cheese is a soft spreadable cheese [110]. It has been produced from fourteenth century at household level and been commercially produced from seventeenth century. After preparing the cheese, the coagulum in the whey is extracted by heating; the coagulum was then stirred vigorously back into the liquid until thoroughly blended. After the addition of salt, the mixture was consumed either warm or cold. By using spontaneous souring, sweet type zincica can be converted into sour type zincica [63]. During country festivals like sheep festival, haluska festival and bacova route, etc., bryndza cheese and zincica gave popularity and pride to the native dairy products [111]. Bryndza cheese and zincia are developed by actions of diverse types of microorganisms. In total, 29 types of bacteria, 23 types of yeast and fungi were found in the sample of "Bryndza cheese" [112] and among these only 7–8 strains were of lactic acid bacteria [113]. *L. plantarum* found in May Bryndza cheese, a variant produced at start of summer using *L. plantarum*, showed traits of antibacterial activity, probiotic functions, and helps in preventing cancer and is known by the name 'White gold' [111, 114]. The nutritional profile of zincica is presented in Table 1 [63].

Saganaki

Saganaki (Fig. 3D) is a variety of Greek dish prepared in a small frying pan, the best-known being an appetizer of fried cheese and contains around 18% salt. In the local language, sagani means a two-handled frying pan. The nutritional values of saganaki are shown in Table 1 [48]. The cheese used in its production may vary from region to region. In Arachova region of Greece, saganaki is prepared from Formaela hard cheese; in Cyprus, it is prepared from Haloumi, a semi-hard and unripened cheese; and in Metsovo, Greece, prepared from Vlahotiri, a hard cheese made from goat milk. Shrimp saganaki and Mussels saganaki are the popular varieties of saganaki.

Ethnic dairy products from camel milk

According to current estimates, the global camel population totals around 39 million animals. Camel milk contributes for approximately 8% of total milk production in Sub-Saharan Africa. Kenya, Somalia, and Mali are the top three countries in the world for producing camel milk. Milk production by camel may range from 3.5 to 40 L per day, depending upon breed and management practices. Other members of the camelids viz. llama and alpaca are also used for milking in some regions [3]. The chemical composition of camel milk also varies with management practices. Fat, protein, lactose, ash, water and SNF content may range to 2.9–5.5, 2.5–4.5, 2.9–5.8, 0.35–0.95, 86.3–88.5 and 8.5–14.3%, respectively, with 1.03 specific gravity [115]. Calorific value per litre of camel milk is 665 kilocalories. Camel milk is less allergic than bovine milk, contains high quantity of protective proteins, and the fermentation process in camel milk increases the number of bioactive peptides which helps to cure gastrointestinal disorders, diabetes and also reduce cholesterol content [116, 117]. Camel milk is high in minerals such as iron, zinc, copper and magnesium, as well as vitamin C and Niacin [118]. In camel milk, lower concentration of β-casein the absence of β-lactoglobulin and the presence of protective proteins strengthen the immune system and brain development. Camel milk has a greater and more potent lactoferrin concentration than other types of milk. Antiviral properties of camel milk contribute to fight against virus infection and to the treatment of virus-related illnesses [119]. Two popular ethnic fermented dairy products prepared from camel milk, *Chal* and Suusac are discussed here.

Fig. 4 Ethnic dairy products prepared from camel and horse milk **A** Chal (source: Dreamstimes); **B** Suusac (source: foodyoushouldtry.com); **C** Kumis (source: indyguide.com)

Chal

Chal is a traditional camel milk fermented beverage (Fig. 4A) with origins in Central Asian countries such as Uzbekistan, Kazakhstan, Turkmenistan, and Iran. People in Kazakhstan and Turkmenistan consume similar products like *Chal* which they call "Shubat" [120]. It is prepared from either complete raw milk or raw milk that has been diluted with warm water in a 1:1 ratio. Milk is fermented by inoculating it with one-fifth to one-third of previously fermented milk after it has been stored in goat skin or ceramic vessels. Incubation requires 3–4 h at a temperature ranging from 25 to 30 °C [64]. The final product in skin bag showing sparkling effect is *Chal* [121]. Nutritional value of *Chal* is presented in Table 1 [49]. When *Chal* is made with highly sour milk, a thick layer of fermented fat appears on the surface. The fat layer that rises is known as *agaran*. Once that layer is removed, the remaining component is *Chal* or *doogh*. The fermented camel milk has higher antioxidant activities and better radical scavenging properties as compared to fermented bovine milk [122]. As a result of the fermentation process, camel milk *Chal* contains more amino acids, organic acids, and fatty acids [123]. Starter culture of *Chal* includes a variety of lactic acid bacteria such as *Lb. plantarum, Leuconostoc lactis, L. kefiri,* and *Weissella cibaria,* etc. [124].

Suusac

Suusac is a fermented milk product (Fig. 4B) that is originated in Kenya and prevalent in Somalia, Eastern Africa and Kenya. Low viscosity, smoky fragrance, and astringent flavour characterise this product. Fresh milk is poured into pumpkin vessels (gourd) that have already been smoked and fermented at a temperature of 25 to 30 °C for two days [65]. The starter culture used for the preparation of *Chal, Suusac,* and *Gariss* is very similar. These includes *Lb. salivarius, Lactococcus raffinolactis, L. plantarum, Lb. curvatus* and *Leuconostoc mesenteroides subsp. mesenteroides* [124]. The resulting product is white in colour and has a low viscosity exhibiting a range of flavours and aromas and the characteristic smoky taste [125]. For smoking, an ember from a certain wood, such as *Acacia busia* or *Olea Africana*, is used. The smoke improves the product's colour and flavour and also increases its shelf life to 20 days. Farah et al. (1990) evaluated the possibility of incorporating mesophilic dairy culture into traditional Suusac. In this example, milk is boiled to 85 °C for 30 min, and temperature reduced to 22–25 °C, 2–3% dairy cultures is then inoculated before being incubated for 24 h at 27–30 °C [126]. The nutritional values of suusac are listed in Table 1 [50]. It has been useful for long journeys in dessert where water is scarce and because of its high moisture content, it has been used as a substitute for water [127].

Ethnic dairy products from horse milk

In recent years, considerable interest in horse milk has been ignited by the discovery that it includes a wide range of important nutrients having beneficial impact on health. Milking practice for mare has been carried out mostly in steppe grassland area of central Asia, and it contributes to less than 1% of total global milk production. The composition of horse milk varies considerably from the milk of other breeds. Despite this, it is highly prized for its chemical compositional similarities to human milk, which allows it to use in the infant feeding as a mother's milk substitute. Horse milk has a low fat and protein level, as well as a high lactose concentration. It contains 88.4% Water, 3.2% Fat (37.5–55.8% SFA, 18.9–36.2% MUFA, 12.8–51.3% PUFA), 4.2% Protein (casein: whey = 52:48), 7.2% Lactose, 0.5% Ash, 5.0–8.8 mg/100 ml cholesterol [128]. α-lactalbumin and β-lactoglobulin present in milk improves heat stability than bovine milk [129]. The fat-soluble vitamins (A, D_3, E) in horse milk are comparable to those in cow's milk, while the vitamin C content is higher, but it is lower as compared to human milk [130].

Along with the beneficial amount of essential nutrients, horse milk benefits include the existence of health-enhancing substances like orotic acid, lactoferrin and lysozyme. Lactoferrin is a transferrin glycoprotein having antifungal, anti-inflammatory, antiviral, antibacterial and immunomodulatory effects [131, 132]. In a regular diet, it is quite difficult to obtain orotic acid (referred as vitamin B_{13}). It is one of the few vitamins that can aid in the prevention of fatty liver disease, cirrhosis and skin ageing. Additionally, lysozyme possesses antimicrobial capabilities and also involved in one of the mechanisms of immune response [130, 131]. Horse milk benefits patients suffering from cardiovascular disorders by enhancing calcium absorption. It aids in wound healing and granulation tissue formation in skin diseases. Its use in diabetics helps to reduce insulin doses and improves the glycaemic index. Additionally, it is used in cancer therapy, post-chemotherapy and post-radiotherapy recuperation and to treat anaemia [133].

Horse milk has been used in very few dairy products in eastern Asia. A very popular ethnic dairy product from mare's milk, Kumiss has been described here.

Kumiss

Kumiss (Fig. 4C) is a traditional fermented beverage produced from mare's milk. Sometimes, this product is also prepared from donkey's milk. It is a milk beverage made from lactose and lactic acid bacteria and yeasts

[134]. Its colour is milky-bluish-white with a rosy tinge. It has a slightly tangy, sour flavour, a faint sweetness to the aftertaste, and a distinct aroma. After intake, it imparts an almond flavour in the mouth. The drink continues to remain popular among the Turkish, and Mongol people of Central Asia's steppes [135]. Genghis Khan (1162–1227 AD), the Mongol king, fed his huge army with kumiss in their staple diet. They actually believed that kumiss make warriors healthy and braver [136]. Kumiss is rich in electrolytes and other mineral profile like Na, Ca, Mg, etc. (Table 1). In the dry land of Asia, kumiss is prepared as a carbonated drink with an alcohol content of about 2% [51]. The alcohol level of kumiss varies from 1 to 3% depending on the length of the fermentation period [137].

Over a 150-day period, the total daily production of mare's milk per animal is 5–10 L. (May to September). The milk is placed in barrels made of wood or leather called 'Chanach' or 'Saba,' which contain 10%–20% fermented milk from the previous day ('Korongo'). The wooden barrel is covered with a wooden lid and has a 'Bishkek' mixing device [138]. A 'Bishkek' is used to stir mares' milk several times a day for aeration. After that, it should be stored at a temperature of 15–20 °C. Koumiss is ready for consumption once it develops a distinct alcoholic odour [138, 139]. In Kazakhstan, variety of kumiss consumed by local peoples associated with their culture and customs. It may be 'Uyz kumiss' from first milk of mare, 'Sary kumiss' in yellow colour, 'Qunan kumiss' under three-night fermentation, and 'Besti kumiss' under five-day fermentation [140].

Kumiss consumption may lower cholesterol levels and help to prevent tuberculosis infection. It aids in the treatment of pulmonary, cardiovascular, respiratory, urinary, and digestive system diseases. People with ADHD, depression, cancer, insomnia, AIDS, herpes, and cases of meat poisoning and scurvy are advised to take this supplement [141]. Its consumption could lower the cholesterol level and prevent tuberculosis infection. Kumiss has a good amount of Vitamin B_{12} and C, which can aid in the treatment of ulcers, typhoid, and paratyphoid [51, 140, 141].

Ethnic dairy products from yak milk

Animal domestication began approximately 11,000 years ago in Middle Eastern countries and then, spread throughout the world. In the case of Yak, this process was started before 6000–12,000 years [142]. The Himalayas of India, Bhutan and Nepal, Tian Shan Mountains of Northern China and the Tibetan Plateau, Northern and Western Mongolia, and neighbouring parts of Russia and certain Central Independent States of the former USSR all have a large population of domestic yaks [143]. China has more yaks than any other countries across the globe. 90% of the total wild yak population, which is around 22,000 individuals, is found in China, among 14 million domestic yaks, 92% population found in China and the remaining in Mongolia and other parts of Asia [144]. The survival of Tibetan nomads is heavily dependent on yak milk, and its derivatives account for the majority of their regular diet [145].

Because of its high fat, protein, and lactose content during the main lactating period, yak milk is known as natural concentrated milk [146]. Yak milk is produced in small quantities but has a good chemical composition, with 16.9% TS, 6.12% Fat (64.62 g/100 g of SFAs, 31.48 g/100 g of MUFAs, 3.90 g/100 g of PUFAs), 4.95% Protein, 5.03% Lactose and 0.8% Ash [147]. In general, yak milk is more nutritious than dairy cow milk. As compared to the most popular milk-producing Holstein cattle, concentrations of fat, protein and total milk solids in yak milk are approximately two times higher [145]. Mao et al. [148] reported that certain active casein peptides found in yak milk show inhibitory effect against the angiotensin-I-converting enzyme. This indicates that yak milk casein contains a naturally occurring antihypertensive component that may have commercial potential in the realm of functional foods. Yak milk protein is particularly high in methionine content [149]. As a result, methionine increases the antioxidant capacity in Tibetan nomad's diet [150]. Yak milk fat and its derivatives have less saturated fatty acid, greater total unsaturated fatty acids (UFA), total polyunsaturated fatty acids (PUFA), and the omega-3/omega-6 Fatty Acids ratio than cattle, sheep, and goat milk fat [146]. Recent research has found that the proportions of rumenic acid, vaccenic acid and total CLA in the fat of yak milk, cheese and butter are at least double that of cattle milk. Antioxidant and vitamins are also found in higher concentrations in yak milk products [151]. Kurut and chhurpi are important ethnic dairy product obtained from yak milk.

Kurut

Kurut is a conventional Chinese dairy product and is also available in Turkey and some Middle Eastern countries [52]. Herder's process fresh milk into kurut to enable storage because it is difficult to ship fresh milk to a milk processing factory in some pasture regions of China in a timely manner. Since centuries, Tibetan people prepare kurut by their traditional method and use it as a staple food [66]. Although kurut is sometimes referred to as dried yoghurt [148], most researchers classify it as a hard cheese due to the whey draining step and high dry matter content [152, 153].

Kurut is a dried, fermented dairy food that is light yellow or white in colour and has distinct acidic

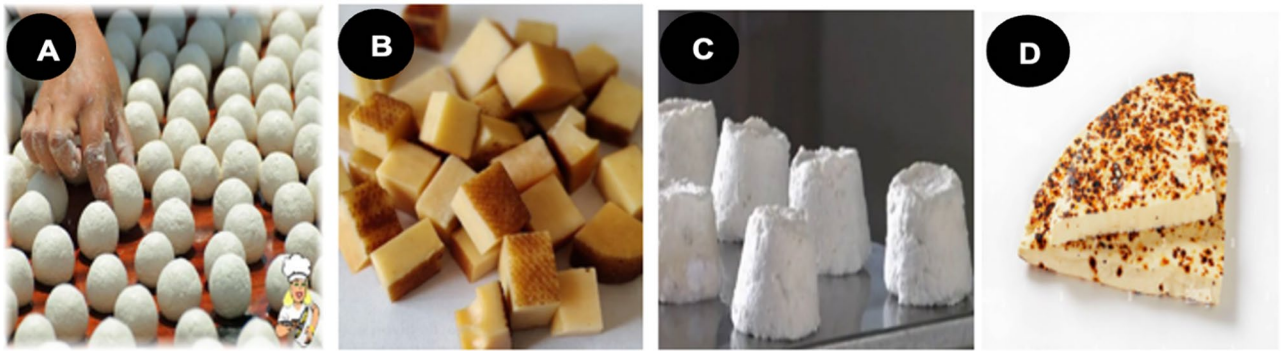

Fig. 5 Ethnic dairy products prepared from Yak, Donkey and Reindeer milk: **A** Kurut (source: facebook.com); **B** Chhurpi (source: techeblog.com); **C** Pule cheese (source: luxurylaunches.com); **D** Leipajuusto (source: alamy)

organoleptic sensations (Fig. 5A). Kurut is traditionally made with ayran or low-fat yoghurt. It is then transferred into a cotton bag and allowed to drain for one day. The strained yoghurt is then cut into small pieces of 30–60 g weight and 4–5 cm diameter in round, oval, or conical shapes in a large pot. 1.5 to 3% (wt/wt) salt is added to the kurut curd to preserve it [154]. Finally, the pieces of kurut are sun-dried for 5 to 10 days. The final product has a pH between 4.0 and 4.3.

Although the composition of kurut varies considerably, typical values include 12.1–13.4% moisture, 15.5–45.9% fat, 25.5–49.7% protein, 9.9–11.9% ash, 1.83–2.91% titratable acidity and 6.7–12.9% salt (Table 1) [52]. Due to its high protein and mineral content, which includes calcium, potassium, and phosphorus, the nutritional value of kurut is high [44]. The product can be stored at room temperature for up to a year.

Chhurpi

Chuurpi (Fig. 5B) is a cheese made from yak milk that is popular in Himalayan regions, particularly Nepal and India's Leh and northeastern region. It has a firm texture, and as a result, it can be chewed like gum. There are two forms of this cheese: hard and soft cheese, based on their processing time [155, 156]. Hard chhurpi had a greater total solid content (89.77%) than soft chhurpi (24.8%). Fat, protein, carbohydrate, and ash content of soft and hard chhurpi samples are reported to be 8.8 and 7.2%, 60.78 and 63.33%, 24.52 and 23.17%, and 5.9 and 6.3%, respectively (Table 1) [53].

Both the hard and soft varieties are produced in hilly and terai regions. Soft Chhurpi, alternatively referred to as Kachcha Churpi, is prepared from both cow and yak milk. The milk is boiled and kept at room temperature for 24 h in a wooden vat. The cream is separated manually, and the milk is curdled by heating. The casein curd is tightly wrapped in muslin cloth and let aside to drain for 3 to 5 h. Finally, the cloth is taken out from the dish and softened chhurpi is cut into appropriate pieces before serving [67]. Soft chhurpi is generally used to prepare pickle, momos, curry, chutney, etc., in villages around India-Bhutan borders. In Sikkim, it is a replacement of non-vegetarian food [67, 157].

Durkha or hard chhurpi is made from yak milk. Centrifugation is used to remove the cream from the milk, and the skimmed milk is heated and curdled with *fitkiri* (alum) or *mahi* (buttermilk). Following filtering, the casein curd is tightly wrapped in cloth and cured for 2–3 days at room temperature (15–20 °C) under heavy stone pressure. Sliced cheese is cured in the sun or over a wood-fire oven. Due to the low moisture level of this variety of Churpi, it hardens and may be preserved for an extended period. Chhurpi has a delicate sweetness and a chewy texture. The Dhurkha comes in a range of colours, from white to smoky grey [158].

Ethnic dairy products from donkey milk

Donkey is a domesticated mammal that has received less research than other domesticated animals [159, 160]. Around 44 million donkeys were recorded in 2012, an increase of 10% over the previous decade. Asia (43.3%) and Africa (37.5%) make for the great majority of the world's population, and about 17.3% and 1.8% in America and Europe, respectively [161]. Around 2500 BC, in Egypt first species of donkey was found and from there its milk started to get acknowledged for its health benefits. Use of donkey milk for cosmetics has been reported in several texts of ancient era like Medicamina Faciei Femineae, Naturalis Historia and De Materia Medica from Ovid, Pliny the Elder and Dioscoride, respectively [12]. Donkey milk is more comparable to human milk than any other dairy animal milk (e.g., cow, goat, sheep, buffalo and camel). Lactose, total protein, and whey protein levels in donkey and human milk are comparable.

Donkey milk contains casein, but in far lower proportions than cow milk. Donkey milk consistently provides a balanced nutritional composition, which is beneficial for sensitive populations like elderly and infants. The total protein content of donkey Milk is lower (1.5–1.8 g/100 g) and is more comparable to human milk (0.9–1.7 g/100 g) than bovine milk (3.1–3.8 g/100 g). Whey proteins content is higher in Donkey milk, which account for 35–50% of total nitrogen component, compared to just 20% in bovine milk. α- La (22.56%), β-Lg (29.85%), and lysozymes (21.03%) are the three primary whey proteins found in donkey's milk [162–164]. In addition to these three, blood serum albumin (BSA) (6.2%), immunoglobulins (Igs) (11.5%), lactoferrin (4.5%) are also present [67, 159]. Donkey milk contains a higher content of serine, valine, arginine and glutamic acid than mare and cow milk. Donkey milk has a fat level varying from 0.28 to 1.82% [165]. So far, the main factors influencing donkey milk fat content appear to be breed, milking strategy, and technique. The saturated fatty acids (SFAs) content of the milk is low, whereas the essential fatty acid content is higher. Donkey milk contains between 6 and 7% lactose, which is greater than the lactose percentage of cow milk (4.1–4.4%) [166]. Compared to human and bovine milk, donkey milk contains a higher quantity of vitamin B_{12} (cobalamin), which assists in the synthesis of DNA and RNA and maintains healthy nerve cells. Apart from niacin (vitamin B_3), other B-complex vitamins like riboflavin (vitamin B_2) and thiamine (vitamin B_1) are also significantly greater compared to human milk. Donkey milk is deficient in vitamin A and E. Donkey milk has sufficient vitamin C that is advised for children of age group of 6–12 months to consume on a daily basis [68]. The antibacterial, hypoallergenic and immunomodulatory qualities of donkey milk are attributed mostly to the presence of milk ingredients like omega-3 fatty acids, lactoferrin, immunoglobulins, bioactive peptides, lysozyme and a favourable casein: whey protein ratio [166]. The antiproliferative properties of donkey milk help in preventing and treating lung cancer, make it less allergic, and act as a curative agent in case of cardiovascular diseases, etc. [161].

Pule cheese

It is one of the most recently prepared cheese in the market and the only one dairy product manufactured with a 60:40 blend of the donkey (mostly Balkan) and goat milk (Fig. 5C). It has been initially prepared in Zasavica natural reserve in Serbia and has since gained popularity in a number of European, Asian, and American countries. Pule cheese is one of the most expensive cheeses in the world. Its spicy, pungent, and powerful flavour is derived from the combination of the freshness of fragrant herbs with the warmth and salinity of the Serbian terrain where the donkeys graze. Pule has a granular texture and a more pronounced, robust flavour. It requires between 25 and 30 L of milk to produce one kilogramme of Pule cheese. Cheese made from donkey milk can be produced utilising a variety of specialised processes, including the use of certain rennets, elevated coagulation temperatures, fortification with milk from other species, and the use of transglutaminase to increase the crosslinking of milk proteins [68].

Donkey milk is packed with about 300 useful compounds for the human body, including omega-6 and omega-3 fatty acids, lipolytic enzymes, antioxidants, minerals and vitamins. Pule cheese retains all of the nutrients of Balkan donkey milk, making it a good source of vitamins D, E, A, B complex, and folic acid all of which are beneficial for the maintenance of neurological system and the enhancement of eyesight and hair structure. The calcium and potassium are also found in pule cheese. In addition to preventing the development of cardiovascular and ailments like asthma and bronchitis, pule cheese usage strengthens the skeletal system and teeth, and improves the skin's health [167].

Ethnic dairy products from reindeer milk

Domestication of reindeer began between 2000 and 3000 years ago in Siberia [168]. They survived in critical conditions of the arctic by both physical and cultural means [169]. During the Second World War, reindeer were served as a main source of numerous items, including food, skins, clothes, transport of soldiers from one place to another in the Northern part of Finland [170]. According to the 2018 Arctic Report Card, the global reindeer population has decreased by 56% in the last two decades with only about 2.1 million reindeer remaining. Reindeers are the only source of milk for Laplander populations in northern Scandinavia (e.g., Sweden, Norway, Finland, and Russia's Kola Peninsula), where no other dairy animals can survive the extreme cold [171]. Only 1% of the world's milk supply comes from reindeer, with a chemical composition that includes Water 75.2%, Fat 11.9%, Protein 9.2%, Lactose 3.8%, Ash 0.4%, Ca 0.32%, Al 0.5 mg/100 g P 0.27%, K 156 mg/100 g, Na 50 mg/100 g, Mg 19 mg/100 g, Zn 1.1 mg/100 g and Cl 68 mg/100 g [172, 173].

Typically, reindeer milk is utilised in three steps. Milk from the first half of lactation is normally consumed fresh, whilst milk from the second portion is primarily utilised for cheese making, and milk from the last part is

more suitably used for butter churning. Antidiarrheal and wound healing characteristics make reindeer milk and its derivatives a valuable medicinal resource for treating gastrointestinal disorders and repairing wounds. It is used to cure nursing pains, frostbites, and other injuries by heating and oozing the fat from reindeer cheese. Reindeer milk contains at least twice as many essential amino acids when compared to bovine milk [174]. Leipäjuusto cheese prepared from reindeer milk has been described here.

Leipäjuusto

The only cheese prepared from reindeer milk is leipäjuusto cheese which is originated in Finland, a country in Northern Europe. It is also known as "bread cheese" due to its hard texture. This unique cheese is the most popular cheese to drink with coffee in Finland. Kaffeost typically uses black coffee from a coffee maker and tops it with diced leipäjuusto cheese. This Kaffeost drinking culture has been inextricably linked to the culture of Finnish society [175].

Leipäjuusto cheese has a number of health benefits. People who have digestive issues with cow milk can consume deer milk in order to improve gut health [69]. Researchers reported that deer milk contains bioactive compounds that can help boost immunity [19]. Furthermore, deer milk, particularly that of the red deer species, contains twice as many solid compounds as cow's milk. Deer milk also contains more casein, protein, and fat than other types of milk (Table 1). It has a significant amount of calcium (680.17 ± 5.09 mg/100gm) which has numerous health benefits for the human body [54].

Conclusion

Minor species' milk and milk products are rich in nutrients and have diverse functionality. Yet, due to their limited production and utilization, minor milks and ethnic dairy products obtained from these milk types have remained unknown by the people outside their niche. The growing popularity of ethnic cuisines for their diverse functional and nutraceutical health benefits in addition to their appealing sensory attributes has potential to catch the larger market place and wider consumer groups if appropriately dealt. In this direction, exploring important ethnic dairy products developed from milk of minor milch species, validation of their functional and nutraceutical properties through scientific research and development activities, standardization of their manufacturing process for commercial production, followed by proper marketing and promotions will be critical to their success in the global market.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42779-023-00205-3.

Additional file 1. S1. Data for mapping milk production (Metric tonnes) by leading minor milking species viz. A. Goat, B. Sheep and C. Camel.

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Availability of data and materials
The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Declarations

Competing interests
The authors declare that they have no competing interest with respect to the research, authorship and/or publication of this article.

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