

## Probiotic dairy dessert from camel milk – A review

Kianoush Khosravi – Darani<sup>1</sup>, Mahshid Jahadi<sup>2</sup>, and Abhishek Dutt Tripathi<sup>3</sup>, Alisha Nandan<sup>3</sup>, Veena Paul<sup>3</sup>, Adrija Chakraborty<sup>3</sup>, Tarun Verma<sup>3</sup> and Aparna Agarwal<sup>4</sup>

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**Abstract:** A staple food in many regions of the world, especially in the arid and semi-arid regions, is camel's milk. Health-promoting ingredients found in camel's milk include lactoferrin, zinc, lactoactive peptides, and mono- and polyunsaturated fatty acids. Some significant human ailments, such as TB, asthma, gastrointestinal disorders, and jaundice, may be treated with the use of these drugs. Compared to cow's milk, camel's milk has a more varied composition. In camels, nutrition, breed, age, and lactation stage have a greater impact on milk composition. The percentage of components in camel's milk varies greatly depending on the region and season. These whey proteins have distinctive qualities, such as physical, chemical, physiological, functional, and technical traits that are advantageous in the food application, in addition to their high nutritional value. Camel's milk proteins are hydrolyzed to create bioactive peptides, which have an impact on the body's primary organ systems and provide them physiological activities. The antidiabetic, antibacterial, antioxidant, and anti-cholesterol properties of camel milk are highlighted in this article.

**Keywords:** Autism, Anti-diabetic, Bioactive peptides, Camel milk

### Introduction

Functional foods are good for the human body and thus they are in demand. This evaluation demonstrates the worth of camel milk, its derivatives, and milk-based products. A probiotic dessert is a perfect example of a functional meal with sensory attributes

that the customer accepts, which may result in health-beneficial feedback (Valencia et al. 2016). The order Artiodactyl includes the family Camelidae, which includes camels. Numerous communities, notably those in the Middle East and Arabian Peninsula's arid regions, depend heavily on camels for their way of life (Kaskous, 2016; Sisay and Awoke, 2015). Camels could adapt to many environmental situations. They are used for transportation, recreation, and as sources of meat and milk, boosting the economy and ensuring that people have access to food (Suliman et al. 2019; Swelum et al. 2020). According to the latest Food and Agriculture Organization (FAO) figures, there are over 29 million camels in the globe, with about 95% of them being dromedary (one humped) camels (Sikkema et al. 2019). The amount of milk produced is influenced by a variety of variables, including breed, animal health, lactation stage, and living circumstances (Swelum et al. 2020). Even though camel udders are like cow udders in structure, camel milk output is smaller and more variable than cow milk yield. However, improved nutrition, water, and veterinary procedures may raise camel milk yield (Park & Haenlein, 2013). Milk is used every day by millions of people throughout the world because it has so many nutritional advantages, including helping young children's bones develop since milk is a strong source of calcium and vitamin D. It has been shown to be advantageous for older individuals, particularly for menopausal women where calcium shortage is a high-risk factor for osteoporosis development (El-Hatmi et al. 2015). For most individuals in underdeveloped nations, milk production not only provides nourishment but also a source of money and food security. The production of milk is a home activity in about 150 million families worldwide (FAO, 2012). Small-scale producers especially benefit from it because of the immediate financial flow.

<sup>1</sup>Department of Food Sciences and Technology, National Nutrition and Food Technology Research Institute, Faculty of Nutrition Sciences and Food Technology, Shahid Beheshti University of Medical Science, P. O. Box: 193954741, Tehran, Iran

<sup>2</sup>Department of Food Science and Technology, Faculty of Agriculture, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

<sup>3</sup>Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh, India

<sup>4</sup>Department of Food Technology and Nutrition, Lady Irwin College, Delhi University, New Delhi, India

Abhishek Dutt Tripathi (✉)

Email id: [abhishek.tripathi@bhu.ac.in](mailto:abhishek.tripathi@bhu.ac.in), Phone: +91-9450533651

Human sustenance is provided by camel's milk. Additionally, it has medicinal advantages (Bai et al. 2015). The review focuses on the physicochemical properties of camel milk versus cow milk, health benefits, bioactive peptides derived from camel milk protein fractions, and camel milk value added products.

### Comparison of physicochemical properties of camel milk with cow milk

Colour of camel milk is opaque white, has a typical milky odour and combination of both taste salty-sweet with a high acid content. These characteristics of camel milk are mostly dependent on the type of fodder or flora present in the grazing region (Singh et al. 2017) and also depends on the phase of lactation (El-aziz et al. 2022). The ratio of components in camel's milk is considerably influenced by season and region is shown in Table 1 (El-Hatmi et al. 2015). The taste may vary according on the camels' habitat. On the American continent, camel milk stands out for its sweet flavour and creamy texture. In the Middle East, camel milk has a taste akin to hazelnut (Galali and Al-Dmoor, 2019; Abbas, 2013). After coagulation, camel milk whey is white in colour, in contrast to the greenish hue of cow milk whey. The presence of casein and tiny fat globules, which scatter light, may be the reason of greenish colour of cow milk whey. Due to the presence of carotene, cow's milk has an opaque white colour with a yellowish tint whereas Camel milk's white colour results from a lower level of -carotene (El-aziz et al. 2022). Camel milk has an average density of 1.029 g/cm<sup>3</sup> (Singh et al. 2017). When compared to cow's milk and human milk, camel milk has the highest viscosity, which ranges between 1.3 and 1.44 mPa.s. The fat globules of camel milk are like small floccules, and this is the reason for the high viscosity of camel milk (El-aziz et al. 2022). Specific gravity of camel milk depends on the breed of the camel and ranges from 1.028 kg. L<sup>-1</sup> and 1.033 kg. L<sup>-1</sup>. These values are comparable to values for both cow milk and human milk, which are varies from 1.026 kg.L<sup>-1</sup> and 1.034 kg.L<sup>-1</sup> (Sakandar et al. 2018). The pH varies from 6.2 to 6.5, which is lower than that of cow's milk (6.5-6.7) (El-Hatmi et al. 2015). Camel milk has a pH between 6.5 and 6.75, similar to that of cow milk, (Sakandar et al. 2018) but lower than that of human milk, which has a pH between 6.75 and 7.42 with a mean of 7.09.(El-aziz et al. 2022). Fresh camel milk has a pH between 6.4 to 6.7, which is comparable to sheep milk but somewhat lower in bovine milk (Singh et al. 2017). While skim cow milk has a maximum buffering capacity at about pH 5.65, skim camel milk

has a maximum buffering capacity of 4.95. This indicates that camel and cow milk have distinct compositions of components with buffering capacity (Sakandar et al. 2018; Sabahelkhier, 2012). Camel milk has an acidity that ranges from 0.14 to 0.15 percent, which is comparable to the 0.15% acidity of cow milk (El-aziz et al. 2022). Fresh camel milk has a titratable acidity that ranges from 0.13 to 0.16 percent lactic acid, which is slightly less than the average for cow milk of 0.17 percent and may vary by breed (Sakandar et al. 2018). The freezing point of camel milk varies from -0.57 °C to -0.61 °C (Singh et al. 2017). The freezing point of camel milk is lower than that of cow milk, which lies between -0.51 °C and -0.56 °C. Some physicochemical properties of camel milk are shown in Table 2. As the salt and lactose concentration of camel milk is higher in comparison to cow milk, this results in the lower melting point of camel milk (Sakandar et al. 2018). The calorific value of camel milk is 665 kcal/L, which is lower than the calorific value of cow milk, which is 701 kcal/L. The variation in calorific value may be due to differences in the concentration of fat, lactose, and protein contents. Camel milk has a steady lactose level that ranges between 3.5 and 4.5% (Devendra et al. 2016). In camel milk, the fat globule's average size is lower than that of globules seen in milk from cows, buffalo, and goats (Khalesi et al. 2017). Total milk solids in camel milk are comparatively low. The water content of camel milk lies between 87% and 90%. An inverse connection was observed between the total solids in camel milk and the camel's intake of water (Singh et al. 2017).

Compared to cow milk, camel milk has significantly less heat stability. Cow milk coagulates at 130 °C and heat coagulation time is about 40 minutes at pH 6.7, while camel milk coagulation time is 2-3 minutes at 130 °C and pH 6.7 (Sakandar et al. 2018). As the temperature increases, the heat stability of camel milk decreases when compared to cow milk and cannot sterilized at natural pH because of the casein-micelle size as well as lack of  $\beta$ -lactoglobulin ( $\beta$ -LG) (Hinz et al. 2012) and lesser percentage of k-casein (k-CN) in camel milk (El-aziz et al. 2022). The main problem of the camel milk preserved by ultra-high temperature (UHT) is sedimentation of proteins which need the use of selected additive to attain physical stability. Sterilized camel milk shows the maximum heat stability in the pH ranges of 7.0–7.2 and the minimum heat stability in the pH range of 6.5–6.8. Camel milk can be pasteurised well by the VAT or HTST methods of pasteurisation with zero precipitation of proteins (Felfoul et al. 2015). The proteins of camel milk classified into three wide-ranging

**Table 1:** Variability of physicochemical parameters of camel milk among different regions

Parameters	Irrigated Plains	Sandy Desert	Coastal Mangroves
pH	6.50	6.49	6.48
Titratable acidity (%)	0.165	0.169	0.178
Specific gravity	1.0319	1.0285	1.0301
Viscosity (cps)	1.7767	1.6500	1.6856
Conductivity (mS/cm)	5.0389	4.6971	4.8622
Refractive index	1.3452	1.3448	1.3450

Source: (Baloch et al. 2018)

classes, viz. caseins, whey proteins, and milk fat globule membrane proteins (Hailu et al. 2016). Total protein content of camel's milk fluctuates from 2.15 to 4.90% (Swelum et al. 2021). Casein composition in camel and cow's milk is comparable, however whey protein level varies. As a result, the ratio of casein to whey proteins in cow's milk is larger than in camel's milk (Park & Haenlein, 2013). The primary protein in camel's milk is casein, which accounts for 52–87% of the total proteins. Whey proteins make for 20–25% of the total proteins (Devendra et al. 2016). Compared to cow's milk, the whey proteins of camel milk were more heat stable. At a temperature of 80 °C for 30 min, the whey proteins of camel milk were 32–35% less denatured than the whey proteins of cow milk, which were 70–75% denatured. The denaturation temperature for sweet whey of camel milk was 73.8 °C and for acidic whey 60.50 °C, and 70.5°C for sweet whey of cow milk and 63.9°C for acidic whey of cow milk, indicating that whey proteins obtained from camel milk are more sensitivity towards acidity when compared to whey proteins obtained from cow milk (Felfoul et al. 2017).

Both camel and cow milk have similar casein contents, but they have different whey proteins content. Hence, casein to whey proteins ratio of cow milk is greater than that of camel milk. This affects the firmness of coagulum. Camel's milk forms softer gel than cow's milk. Camel's milk casein has four fractions ( $\alpha_{s1}$ ,  $\alpha_{s2}$ ,  $\beta$ , and k-casein) (Jilo, 2016) and presents in the ratio of  $\alpha_{s1}$  to  $\alpha_{s2}$  to  $\beta$  to k-casein- 22:9.5:65:3.5 respectively (Swelum et al. 2021). Composition of casein in camel and bovine milk is shown in Table 3. Along with having many soluble proteins, camel's whey protein contains native proteases such chymotrypsin A and cathepsin D. (Alhaider et al. 2013). As a result, camel's milk proteins may be bioactive on their own or act as building blocks for bioactive peptides. As  $\beta$ -casein and  $\alpha$ -casein were discovered to be 28.6 kDa and 35 kDa, respectively, it has been claimed that camel's milk caseins had greater molecular weights than bovine caseins. While in cattle,  $\beta$ -casein is 24 kDa and alpha-casein is 22–25 kDa (Al Haj et al. 2018). Camel's milk contains more  $\beta$ -casein (65%) than  $\alpha$ -casein (21%). Compared to cow milk, camel's milk has nearly the same  $\beta$ -casein and  $\alpha$ -casein concentration i.e., 36 and 38%, respectively and higher percent of k-casein i.e., 13%, which is around 4 times lesser in camel's milk i.e., 3.47% (Devendra et al. 2016). The  $\alpha$ -casein is more digestible in human body and has less allergic effect, as it is more susceptible to peptic hydrolysis in the gut. The presence of higher  $\beta$ -casein makes camel's milk more beneficial for human health. (Swelum et al. 2021). Casein micelles in camel's milk range in size from 20 to 300 nm, whereas those in cow's milk range from 40 to 160 nm (Park & Haenlein, 2013). Overall, camel's milk has casein micelles with a greater average diameter and a higher mineral charge (Attia et al. 2001). The primary whey protein in camel's milk is called  $\alpha$ -lactalbumin ( $\alpha$ -LA).  $\alpha$ -LA from camel milk is preferred over  $\alpha$ -LA from cow's milk because it is more easily digested and has more antioxidant action (Park & Haenlein, 2013).

Camel milk lacks  $\beta$ -lactoglobulin, which makes it less allergenic, but contains other whey proteins such lactoferrin and immunoglobulins (Devendra et al. 2016). The primary immunoglobulin in camel milk is immunoglobulin G (IgG), whose molecular weights are different from those of IgG from cattle, sheep, goats, and humans (Alavi et al. 2017). The primary component in bovine whey (50%) is  $\beta$ -LG, which is absent in camel's whey (El-Agamy et al. 2009). Camel's whey proteins offer a unique source of proteins that may produce bioactive peptides that have the potential to improve health.

Camel's milk varies in its overall mineral concentration between 0.60 and 0.90 percent. The increased chloride content gained from the feed the animals eat can be used to explain why camel's milk has a salty flavour (Devendra et al. 2016). calcium, phosphorous, magnesium, sodium, and potassium content in camel milk are comparable to that in cow milk in terms of minerals (Kaskous, 2016). zinc, copper, iron, and magnese content make up most of the difference since camel's milk contains greater levels of these minerals. The prevention of iron-deficiency anaemia may be helped by camel's milk's higher iron content. Additionally, because lactoferrin requires low amounts of citrate to be effective, camel milk has a lower concentration of citrate than cow milk, which boosts lactoferrin's antibacterial action (Park & Haenlein, 2013).

Vitamin and mineral salt concentrations in camel milk vary depending on the breed, diet, amount of water consumed, and stage of lactation. It also has a high vitamin C content—up to ten times that of cow milk and a high vitamin E content level (Benmeziiane–Derradji, 2021). As a result, it may boost the antioxidant and antiradical properties and lengthen shelf lives (Izadi et al. 2019). The fundamental distinction between camel

**Table 2:** Physicochemical properties of camel milk and camel milk whey

Parameters	Camel Milk	Camel Milk Whey
Acidity (%)	0.21	0.3
Ash (%)	0.97	0.9
Fat (%)	3.4	0.4
pH	6.5	5.4
Protein (%)	3.3	1.5
Total solids (%)	9.9	3.3

Source: (Ahmed NNA, 2011)

**Table 3:** Composition of casein in camel and cow milk

Protein	Camel (g/l)	Bovine (g/l)
$\alpha_{s1}$ -casein	5.3	9.5
$\alpha_{s2}$ -casein	2.3	2.5
$\beta$ -casein	15.6	9.8
k-casein	0.8	3.3
Total casein	24.0	25.1

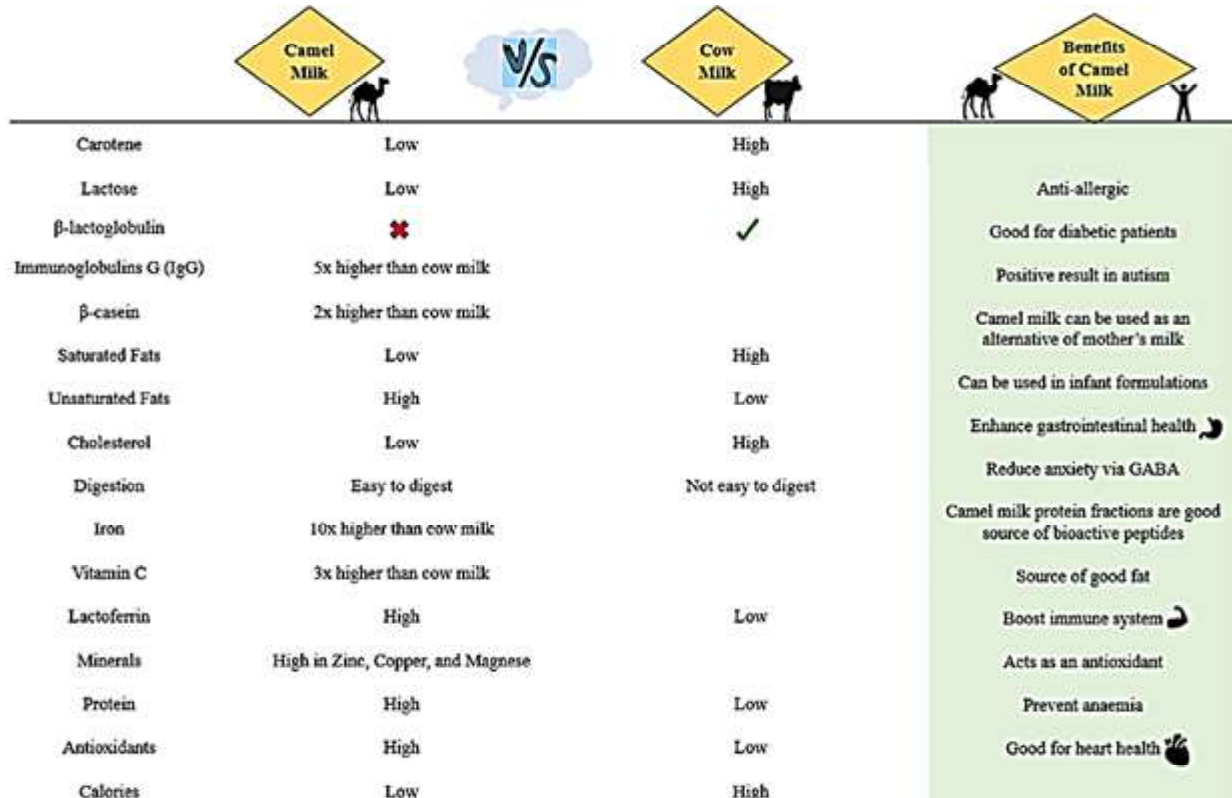
Sources: (Hailu et al. 2016 ; Swelum et al. 2021)

milk and other milks is that camel milk has a low lipid and saturated fatty acid content, which results in a low cholesterol level (Benmeziane–Derradji, 2021). However, it lacks folic acid, pantothenic acid, and thiamine, riboflavin, and retinol. Pyridoxine and Cyanocobalamin have about the same amounts in both camel and cow’s milk (Devendra et al. 2016; Elhosseney et al. 2018). Compared to cow’s milk, camel’s milk contains more inhibitory structures, particularly lysozyme and lactoferrins, which are significantly more abundant. Camels’ milk contains glycoprotein lactoferrin between 0.02 and 2.1 g/L. It possesses antibacterial, anti-inflammatory, immune-suppressing, and anticancer properties. Another milk antibacterial component called lysozyme is found in camel’s milk at a concentration of around 150 g/L, which is greater than that of cow’s milk (70 g/L) (Park & Haenlein, 2013). Fig. 1 represents the comparison between camel milk and cow milk

**Nutritional benefits of camel milk**

Camel’s milk has high level of digestibility (Meena et al. 2014). Vitamin C, which is three to five times more than in cow’s milk, is crucial for nutrition (Bai et al. 2015; Kamal & Karoui, 2017). Comparable to human milk, camel milk has a high amount of β-casein; this casein is more easily digested and results in fewer new born gastrointestinal sensitivities. Camel’s milk offers a variety of nutrients and medicinal qualities, including antibacterial, anticancer, antioxidant, anti-hypertensive, and anti-diabetic

effects (Ayoub et al. 2018; Sharma and Singh, 2014; Bakr Shori, 2015). During storage or processing, native protease enzymes such as milk plasmin can hydrolyse proteins and liberate bioactive peptide fragments (Mohanty et al. 2016). In addition to enhancing the bioactive qualities of milk proteins, enzymatic hydrolysis is known to boost their functional properties (Jrad et al. 2014). Making bioactive hydrolysates from camel’s milk proteins and examining their potential bioactivity in in vitro and in vivo settings are the main topics of recent study (Mudgil et al. 2018). The probiotic bacteria can manufacture these beneficial components from milk proteins during the fermentation process (Devendra et al. 2016). Due to its high content of anti-inflammatory proteins, polyunsaturated fatty acids, and vitamins that speed up carbohydrate metabolism, it has a positive impact on stomach and intestinal illnesses (Kaskous, 2016). Due to the presence of lactoferrin, lysozyme, lactoperoxidase, hydrogen peroxide, and immunoglobulins, camel’s milk possesses antibacterial and antiviral characteristics. These substances can inhibit both gram-positive and gram-negative bacteria, such as *Escherichia coli*, *Listeria monocytogenes*, and *Staphylococcus aureus*. Lactoferrin in camel milk suppressed the growth of *Salmonella typhimurium* by binding iron and preventing it from being used for its growth. Camel milk has more antimicrobial ingredients than cow milk does. However, milk’s beneficial characteristics are fully rendered inactive after being exposed to 100°C for 30 minutes. Additionally, camel milk’s whey proteins improve the anti-rotaviruses’ capacity to treat non-bacterial gastroenteritis. Camel’s milk has a



**Fig 1.** Comparison between camel and cow milk and health benefits of camel milk

therapeutic impact on drug-resistant tuberculosis (TB) due to the number of antibacterial components in it. (Devendra et al. 2016). Hepatitis C viruses can be inhibited and their multiplication in cells prevented by the lactoferrin and IgG found in camel's milk. When human IgG cannot detect the presence of the virus, the Camel milk's IgG can recognize hepatitis C viral peptides. Saltanat et al. (2009) reported that consumption of camel milk for 1 year can help treat hepatitis B because it controls the expression of type 1 helper T cell/ type 2 helper T cell (Th1/Th2)-type cytokines and balances the Th1/Th2 cytokine network, thus strengthening cellular immunity, preventing virus deoxyribonucleic acid (DNA) replication, and enhancing the recovery of chronic hepatitis B patients.

Milk proteins, like many other dietary proteins, have angiotensin converting enzyme (ACE)-inhibitory peptides as part of their main structure. The fermented camel milk also contains ACE-inhibitory peptides (Moslehisad et al. 2013). Proteins are broken down into peptides and amino acids by probiotic bacteria used in fermentation. The bioactive peptides in camel milk that has undergone fermentation may help to reduce cholesterol. From camel's milk, certain probiotic strains of *Lactobacillus*, *Bifidobacterium*, *Enterococcus*, and *Streptococcus* were identified and employed in the dairy business (Shori & Baba, 2014). Orotic acid, which is present in camel's milk, is known to lower cholesterol levels in people (Devendra et al. 2016). El Hatmi et al. (2017) compared the physicochemical and sensorial characteristics of fermented camel (dromedary) milk (FDM) and fermented cow milk (FCM) by fermenting milk with *Enterococcus faecium* (W1), *Streptococcus macedonicus* (W2), and by the combination of W1 and W2. More viscous and acidic fermented milks were produced by the combination of W1 and W2 than by a single strain. The advantageous fatty acids were unaffected by the fermentation process. Both FDM and FCM milks included 19 aroma components, the majority of which were ethanol, acetoin, and diacetyl. When fermented by the W1 strain, FDM had the highest radical scavenging activity. In contrast to peptide fractions produced by imitating gastro-intestinal digestion, El-Hatmi et al. (2016) found that peptide fractions made following fermentation with *Streptococcus thermophilus* exhibit a higher level of free radical scavenging activity.

Due to the tiny size of the immunoglobulins and the presence of insulin and compounds like insulin e.g., half cysteine, camel's milk can be utilized to treat both type 1 and type 2 diabetes (Devendra et al. 2016; Malik et al. 2012). Limon et al. (2014) reported that the camel and goat milks can activate GABA (gamma-aminobutyric acid) receptors and contain much more bio accessible GABA than cow and human milks. There are 52 units of insulin per litre in camel milk, which is a high concentration (Ayoub et al. 2018). Additionally, these substances have an impact on the liver and pancreas, which improves insulin production, lowers the amount of insulin needed to control blood

sugar level, lessens insulin resistance, and enhances lipid profiles (Kaskous, 2016; Ayoub et al. 2018).

Decreased allergenicity, particularly in kids with cow's milk allergies, is another potential health advantage of camel's milk. This allergy is brought on by the presence of  $\beta$ -lactoglobulin as well as the high concentration of  $\alpha$ -casein and low content of hypoallergenic  $\beta$ -casein. The immunoglobulins in camel milk resemble those in human milk hence, it is safe for infants to drink (Devendra et al. 2016; Izadi et al. 2019). Also, camel's milk is safe to drink for those who are lactose intolerant. Compared to cow's milk, which is high in D-lactate, camel's milk has more L-lactate. L-lactate reduces the allergenicity of milk. Because camel milk immunoglobulins do not react with the immunoglobulin E (IgE) of children who are allergic to cow's milk, they reduce allergic symptoms (Kaskous, 2016). Furthermore, those who have autism may benefit from drinking camel's milk.  $\beta$ -Casomorphin, a potent opioid peptide that is formed by the incomplete metabolization of casein protein in the intestine, causes diarrhea and alter appetite. This opioid peptide may also cause brain damage in youngsters. Cow's milk has a high concentration of  $\beta$ -casein and  $\beta$ -lactoglobulin, which increases the likelihood that opioid peptides will develop (Devendra et al. 2016; Kaskous, 2016). Al-Ayadhi and Elamin (2013) examined the effects of the consumption of 500 mL of camel milk by autistic children for a period of two weeks. The results showed that by changing the levels of antioxidant enzymes and nonenzymatic antioxidant compounds, camel milk may have a significant impact on reducing oxidative stress and improving autistic condition.

Additionally, the protective proteins lactoferrin, lysozyme, and immunoglobulins in camel's milk may help with brain development (Devendra et al. 2016). Another camel's milk advantage is the treatment of breast, lung, liver, and blood cancer (Kaskous, 2016). It prevents the growth of human hepatoma (HepG2) and human breast (MCF7) cells as well as the activation of cell-line-specific death receptors and oxidative stress-related processes (Korashy et al. 2012). The drinking of camel's milk contributes to the development of a larger abundance of *Allobaculum*, *Akkermansia*, and *Bifidobacterium*, which enhances the gut microbiota. According to a study by Wang et al. (2018), camel's milk may increase the amount of *Allobaculum*, which may have a good impact on the organism's physiological function. Short-chain fatty acids produced by this species help to reduce inflammation, prevent obesity, and promote colon health. A mucin-degrading probiotic known as *Akkermansia* is well known for its advantages against obesity, metabolic diseases, diabetes, and inflammation. Abdel-Salam et al. 2016 study the impact of a diet including Camel whey protein on wound healing in malnourished mice. They discovered that the ability of malnourished mice supplemented with camel whey protein to heal wounds improved due to a reduction in oxygen free radicals and an increase in glutathione levels (an antioxidant). Ayyash et al. (2018) in his

study showed the health-encouraging benefits of water-soluble extract (WSE) of fermented camel milk. They found that WSE of fermented camel milk has ACE-inhibition antiproliferative and antioxidant activities.

**Camel milk proteins:** The concentration of amino acids in camel milk are high except for lysine, glycine, threonine, and valine (Shamsia 2009). Recently, increasing attention has been paid to the components of MFGM (Milk Fat Globule Membrane), especially to their protein components (Yang et al. 2015). MFGM proteins, which account for 1–4% of the total milk protein, depending on the breed of the animal. The proteins of camel MFGM are mainly involved in protein processing, bio-synthesis of fat, and actin cytoskeleton organization (Sabha et al. 202). The main MFGM proteins are fatty acid synthase, xanthine oxidase, butyrophilin, lactadherin, and adipophilin (Bakry et al. 2021; Saadaoui et al. 2014).

**Camel milk fat:** Camel milk ranges in fat content from 1.2 to 4.5% (Devendra et al. 2016). However, camel's milk has a fat level that may reach up to 6.4%, according to (Park & Haenlein 2013), and its fatty acid composition is characterized by the presence of unsaturated and long-chain fatty acids like linoleic acid in greater concentrations. Short chain fatty acids in camel milk are low. The amount of lipids in human serum is decreased as a result of this. Ninety-two to ninety-nine percent of the fatty acids are long-chain, and between 35 and 50 percent are unsaturated (Izadi et al. 2019). Because of these structural variations, the camel's milk fat has a "waxy feel

**Camel milk water content:** The most important factor in camel milk is water content. The total solid content is similar to that of human milk. Unlike other animals the water content of camel milk increases during dehydration. When water is easily available the water content of the milk is 86 percent, but when water is restricted the water content of milk rises to 91 percent (Rahim et al. 2020). This is useful as water source for dehydrated calf and the humans in area where water is scarce. The reasons for increment of water content of milk of dehydrated camel are antidiuretic hormone (ADH) secretion is elevated in the dehydrated camel, a decrease in the fat content and type of forage eaten by the animal (Ahmed, 2015).

**Camel milk carbohydrate:** The major carbohydrate fraction in camel milk is lactose sugar with range between 3.3 to 5.80 percent. The nature of vegetation eaten by the camels in desert areas could be a significant factor for extensive variation in lactose contents. Camels generally like to consume halophilic plants like *Celosia*, *Acacia* and *Atriplex* to fulfil their physiological necessities of salts intake. However, in some dromedary varieties of the camel lactose contents found to be changed slightly over a period. Lactose can be readily digested by human lactase with no signs of lactose intolerance. Additionally, it contains a modest number of various oligosaccharides that defend new born against viruses,

encourage the growth of *Bifidobacterium* environments, and aid in nervous system development (Park & Haenlein, 2013).

### Bioactive peptides

Potential amino acids (bioactive peptides) are encoded in milk proteins as inactive sequences that are liberated from milk proteins either naturally during digestion, through proteolysis using enzymes, or by fermentation. Bioactive peptides found in camel milk have a wide range of potential uses, including anti-bacterial (gram positive and gram negative), anti-hypertensive, ace inhibition, anti-inflammatory, mineral binding, cytotoxicity, antioxidant, and immunomodulatory effects (El-Salam and El-Shibiny, 2012; Zibae et al. 2015; Soleymanzadeh et al. 2016). As a result, interest in bioactive peptides derived from camel milk proteins is increasing nowadays. Three methods are used to generate peptide fractions from camel milk proteins (i) fermentation with different proteolytic bacterial strains (ii) enzyme hydrolysis using purified proteases and (iii) a combination of pepsin and pancreatin to mimic gastrointestinal digestion (Mati et al. 2017). Ibrahim et al. (2018) isolated bioactive antioxidant peptides from camel milk's protein fractions. Their findings suggest that the casein and whey protein fractions of camel milk both contain bioactive peptides with significant radical-scavenging activities. This opens a fascinating possibility for their potential use as nutraceuticals or therapeutic peptides for the prevention and treatment of diseases linked to oxidative stress. Fourteen peptides with masses ranging from 913.12 to 2,951.68 m/z were derived from the casein hydrolysate. From casein hydrolysate, most of the peptides were generated by  $\beta$ -caseins in comparison to  $\alpha_{s1}$ ,  $\alpha_{s2}$  and  $\epsilon$ -casein. There were eight peptides derived from the whey hydrolysate, with masses ranging from 1,168.52 to 1,861.14 m/z. In the whey hydrolysate few peptides were derived from lactophorin and cysteine-rich proteins, but most of the peptides were derived from lactoferrin. Kumar et al. (2016) Compared to alcalase and papain,  $\alpha$ -chymotrypsin hydrolyzed camel milk whole casein displayed higher antioxidant activity. According to Mudgil et al. (2019) study, camel milk proteins are an intriguing source of antihypertensive and anti-inflammatory peptides. Also, it was revealed that the type of enzymes and the timing of the hydrolysis had a significant impact on the bioactivities of the peptides generated during enzymatic hydrolysis, which released powerful antihypertensive and anti-inflammatory peptides. Alcalase and papain enzyme hydrolysis of camel milk proteins for 6 hours increased ACE inhibitory action, while 9-hour enzyme hydrolysis resulted in a decrease in this activity, demonstrating the significance of controlled hydrolysis. Al-Shamsi et al. (2018) verified that the performance of camel milk protein hydrolysates (CMPH) was impacted by the type of enzymes utilised in their production. Alcalase and bromelain both had lower hydrolysis efficiency than papain. The foaming capacity and protein solubility were increased by all the enzymes, with papain having the most activity. After papain hydrolysis, antioxidant activities were also elevated. Nongonierma et al. (2018) identified nine

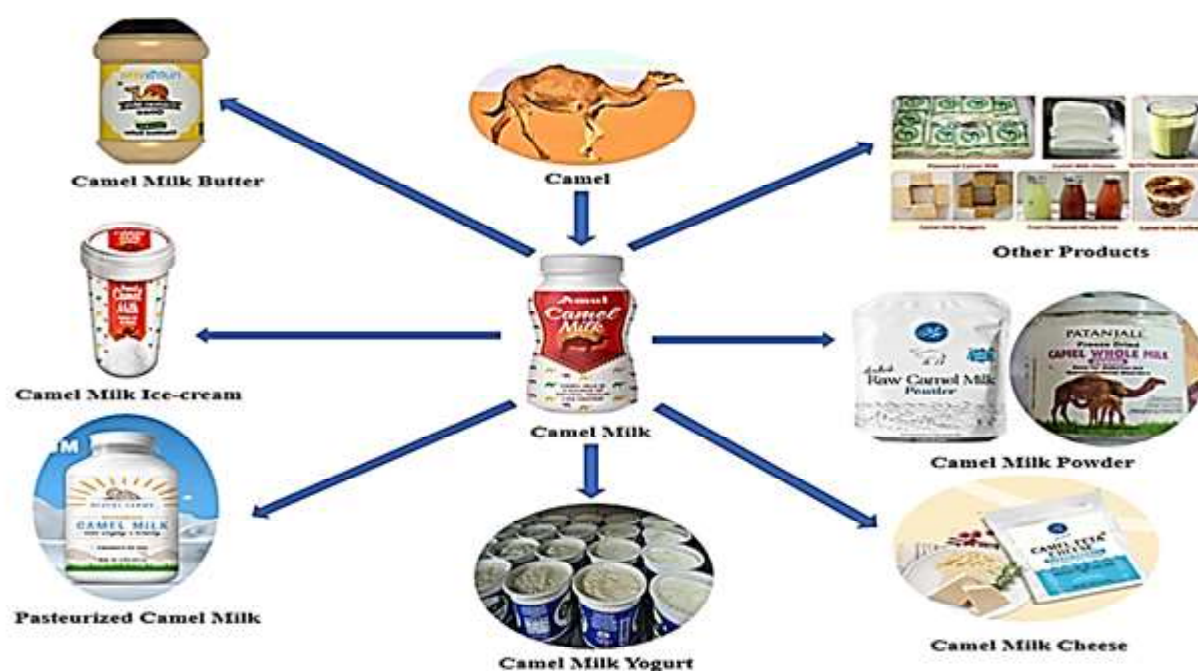


Fig. 2 Value-added camel milk products

unique camel milk peptides including FLQY, SPVVPF, ILDKGIDY, LQALHQQQIV, LLQLEAIR, LPVP, ILELA, MPVQA and FQLGASPY with high dipeptidyl peptidase (DPP-IV) inhibitory capability. The most potent anti-diabetic peptides were MPVQA and LPVP. Nongonierma et al. (2019) extracted Val Pro Val (VPV) bioactive peptide from camel whey protein hydrolysate that was reported to be the second most powerful DPP-IV inhibitor known to date after Ille Pro Ille (IPI) (Diprotin A), a commercial DPP-IV inhibitory. Mudgil et al. (2021) found that when camel milk caseins were hydrolyzed with enzymes alcalase and pronase E for 3 and 6 hours, followed by mimic gastrointestinal digestion, it resulted in the generation of potential anti-diabetic peptides that had a strong inhibitory effect against enzymatic markers that are involved in diabetes like DPP-IV,  $\alpha$ -amylase, and  $\alpha$ -glucosidase. Their findings indicated that the peptide FLWPEYGAL was the most effective inhibitor of  $\alpha$ -amylase, LPTGWLM, GPAHCLL, and MFE peptides were the most effective against  $\alpha$ -glucosidase; and the peptides HLPGRG, QNVLPLH and PLMLP were most effective against DPP-IV. Kamal et al. (2018) investigated the in-vitro anti-liver cancer potential of camel milk whey protein hydrolysates, which were produced by hydrolysing the protein using pepsin, chymotrypsin, and trypsin at varying times. Just 4.5–6.5% of the viable hepatoma G2 (HepG2) cells remained after the treatment with chymotryptic hydrolysates that are generated after 3 hours of hydrolysis, which had the highest anti-proliferative effect. Tryptic hydrolysates generated after 3 hours of hydrolysis and peptic hydrolysates generated after 3 and 6 hours of hydrolysis have both shown a notable antiproliferative effect by reducing the viability of cancer cells.

### Value added camel milk products

Large-scale camel milk production and processing facilities have recently been built in several nations as a result of the growing demand for camel milk, particularly from non-camel-producing communities (Seifu 2023). There is scope for manufacturing a variety of processed products from camel milk because, in terms of nutritional value, camel milk is superior to cow or buffalo milk and relatively similar to human milk. It has high quantities of a variety of bioactive substances that are vital for maintaining human health. Compared to bovine milk, the number of food products made from camel milk is still quite small, despite its significant nutritional and health benefits. To maintain the nutritional content of camel milk while obtaining desired qualities in the finished products, a thorough understanding of the composition, bioactive components, and thermal stability of camel milk is crucial (Ho et al. 2022). Value added products from camel milk is shown in Fig. 2

### Pasteurized camel milk

For camel milk, different countries use different pasteurization time-temperature combinations, like 63°C for 30 min., 72°C for 15 sec., and 80°C for 20 sec. Countries that produce camel milk do not have any specific regulations or standards for camel milk. As a result, camel milk is pasteurized in accordance with the same criteria as milk from cows. The best temperature to improve milk stability is thought to be 80°C for 20 seconds during pasteurization of camel milk. Camel milk undergoes separation issues at temperatures exceeding 80°C (Seifu 2023). Different time-temperature combinations for the pasteurization of camel milk

were reported in different scientific literatures, such as Rahman et al. (2012), reported 60°C for 30 minutes; Alhaj et al. (2013), reported 75°C for 15 seconds; and Oselu et al. (2022), reported 90°C for 30 minutes. Thus, in various studies, several time-temperature combinations varying from 50 to 95 °C were evaluated for the inactivation of microorganisms (Muthukumaran et al. 2022). Due to protein sedimentation, ultra-high temperature pasteurization (UHT) of camel milk was unsuitable. Only mild UHT processing, i.e., 150°C for 2 seconds followed by refrigeration, was needed to extend the shelf life of camel milk up to 5 weeks (Seifu 2023). To find an effective pasteurization indicator, Lorenzen et al. (2011) examined the alkaline phosphatase (ALP), gamma-glutamyl transferase (GGT), lactoperoxidase (LPO), lipase (LIP), and leucine aryl amidase (LAP) activities in raw and pasteurized camel milk. They concluded that in pasteurized camel milk, GGT, ALP, and LIP were still present, but lactoperoxidase (LPO) might have been a better indicator of pasteurization.

### Camel milk powder

Food and dairy industries may have a wonderful opportunity to expand their product lines by using camel milk powder to promote new milk and milk products. Camel milk powder are relatively recent consumable product in international dairy market, credit goes to the emergence of powder milk manufacture, Drying is the best method to store this perishable commodity for subsequent use. Furthermore, because camel milk is typically produced far from the consumption basin, the only way to transport a significant quantity of it is to remove the water that makes up 88–90% of its weight. This approach also preserves liquid milk's nutritional value, which is a bonus. Camel milk powder is currently produced using two basic drying techniques: freeze-drying and spray-drying (Chhasatiya and Tagalpallewar 2022). Deshwal et al. (2020) prepared spray-dried whole camel milk powder (SDW), spray-dried skimmed camel milk powder (SDS), and freeze-dried whole camel milk powder to study the impact of spray and freeze drying on the physico-chemical and functional qualities of camel milk. The authors' findings stated that the SDS showed higher moisture content, followed by the SDW, and then the FDW. Powders' calcium and iron contents significantly decreased as a result of spray drying. SDW exhibits strong flowability. The best wettability and solubility were found in FDW. SDS showed the best foaming ability and stability due to the lack of fat and absence of LG and higher LA in camel milk. Ibrahim and Khalifa (2015) evaluated the effect of lyophilization process on the nutritional value of camel milk. The result showed that the protein (casein and whey), amino-acids ash fat, and lactose content were enhanced after lyophilization. Vitamins and minerals content also increases except for vitamin c and calcium, potassium, and phosphorus.

### Camel milk cheese

The process of manufacturing camel cheese is novel. The difficulties in clotting observed in the preparation of camel milk cheese are due to the different casein proportions between cow and camel milk, particularly the lower amount of  $\kappa$ -casein (3–4% of casein, compared to 13–15% in cow milk). Furthermore, camel milk's casein micelles cannot coagulate well with the bovine chymosin used in the dairy industry, resulting in a weak curd. So, the first difficulty confronted by researchers and dairy technologists is obtaining a hard coagulum (Konuspayeva and Faye 2021). Numerous researchers have tried to make cheese from camel milk using a variety of processing techniques, including starter cultures, heat treatments, the addition of calcium chloride ( $\text{CaCl}_2$ ), rennet, and salting. Al-zoreky and Almuthen (2021) prepared soft cheese from camel milk using recombinant camel chymosin. Recombinant camel chymosin (50 IMCU/kg) was used to curdle pasteurized camel milk. The result showed that thermophilic starter cultures coagulate camel milk faster. Konuspayeva et al. (2017), in their study, compared camel cheese with bovine cheese and prepared both dry and brine-salted soft camel milk cheese. They concluded that camel milk with good starter cultures and raising the protein content of camel milk maximized cheese yield and utilized thermophilic cultures to hasten the acidification of camel milk. They also reported that the recombinant camel chymosin was able to coagulate camel milk faster. El Zubeir and Jabreel (2008) prepared fresh using camifloc (a product that comprises calcium phosphate and vegetable rennet to curdle camel milk cheese.) and calcium chloride + Camifloc. They concluded that the yield of calcium chloride + Camifloc cheese was found to be higher than the camifloc cheese.

### Camel milk ice-cream

Presently, the *United Arab Emirates* (UAE), Kazakhstan, and Morocco are countries where camel milk ice cream is manufactured commercially. 'Orom', a soured cream popular in Mongolia, is made from Bactrian camel milk. A good-quality, sensory-acceptable ice cream can also be produced by combining camel and cow milk. In the same way that bovine milk is processed, camel milk can also be processed to make ice cream, albeit the finish product may have distinct qualities and storage properties. However, camel milk ice-creams typically have a lower viscosity, a lower dry matter content, and a lower melting point than cow milk ice-creams when made using the same formulations. This is explained by the difference in total solids between camel milk (10.02%) and cow milk (12.30%) (Seifu 2023). Elkot et al. (2022) prepared a synbiotic ice cream using camel milk and black rice powder. They concluded that the incorporation of black rice powder improved the physicochemical and rheological characteristics of ice cream samples and had a substantial protective impact on the longevity of probiotic bacteria *Lactobacillus acidophilus* LA-5. Hajian et al. (2022) created low fat camel milk ice cream by incorporating chymotrypsin-generated camel milk casein antioxidant hydrolysates. The incorporation of antioxidant hydrolysates

improves free radical scavenging activity. The viscosity and consistency of the ice creams were also increased by the addition of casein hydrolysates because of their water-holding capacity.

### Camel milk yogurt

Several strains of traditional lactic acid bacteria, including *Lactobacillus bulgaricus*, *Streptococcus thermophilus*, *Lactobacillus acidophilus*, *Lactobacillus casei*, and *Bifidobacteria*, have been tested. Unfortunately, the production of camel milk yoghurt has a textural issue, with the final product tasting sticky and unappealing (Konuspayeva and Faye 2021). The lack of  $\beta$ -LG and lower level of  $\epsilon$ -CN, as well as the high whey to casein ratio, are compositional factors that contribute to the weak texture and thin consistency of camel milk yoghurt (Seifu 2023). Trials with the addition of gelatine, alginate, or calcium were made to achieve a better texture. Ferments that produce exopolysaccharides were also utilized. Additionally, the introduction of a high-pressure treatment could improve the texture. Some authors have made sporadic attempts to enhance the production of camel milk yoghurt by combining it with milk from other species and by adding 0.75% biosynthesized xanthan, but it has given mixed results in terms of organoleptic qualities. Even with the addition of artificial or natural flavors, the finished product resembles 'drinking yogurt' without the expected taste. Shahein et al. (2022) reported that the addition of date syrup at the rate of 8% to fermented camel milk improve the taste. Frozen yoghurt has been seen as an alternative by several researchers as a product that falls between yoghurt and ice cream (Konuspayeva and Faye 2021). Galeboe et al. (2018) prepared yoghurt by the incorporation of 1.2% gelatine, 1.5 ml/L of CaCl<sub>2</sub>, 40 ml/L of maple strawberry syrup, 5% bovine skim milk powder and 6% culture in camel milk and incubate for 18 hours at 42°C. The findings demonstrated that the physical, chemical, and microbiological qualities of cow milk and camel milk yogurt were equivalent. However, the sensorial properties of camel milk yoghurt were not as well liked as those of cow milk yoghurt. Ibrahim et al. (2016) prepared yogurt by mixing camel milk with sheep milk in order to improve the processing aspects of camel milk and compared two different starter cultures used for fermentation. In comparison to yoghurt made from pure camel milk, yoghurt made from camel-sheep milk mixtures had higher fat, total solids, and protein contents. The quality and acceptability of camel milk yoghurt were enhanced by the addition of sheep milk.

### Camel milk butter, ghee and sweet

Butter manufacturing from camel milk is exceedingly challenging, and the procedure for making butter from cow milk cannot be used to camel milk due to variations in the physical and chemical nature of their fats and proteins, even though their fat contents are quite comparable to those of bovine milk. Thus, several authors asserted that camel milk cannot be used to make butter.

Camels' milk has little creaming ability due to the presence of tiny fat globules, the strong bonds between fat and proteins, and the absence of agglutinin, a protein that encourages the clustering of fat globules. Moreover, churning camel milk cream requires higher temperatures than those typically employed for bovine milk due to the high melting point of camel milk fat. Camel milk fat melts at a high temperature because of the large proportion of long-chain fatty acids in the fatty acid profile and the thicker globular membrane. Due to the probiotic properties of the microflora employed in traditional camel milk butter manufacturing, it is used for therapeutic purposes (Ho et al. 2022). Ghee (clarified butter), a well-known product in India, has also been made using camel milk; however, the yield of ghee was low when compared to buffalo or cow milk. Also, the finished product was more susceptible to rancidity. There is no information on making sweets from camel milk. Yet, conventional goods are accessible. For instance, a caramel known as 'Balkailmak' from Kazakhstan is produced following a lengthy heating process lasting almost 10 hours at boiling temperature. (Konuspayeva and Faye 2021).

### Foaming agent

The quality of many dairy products' top foam layer, such as cappuccino coffee, impacts the overall product quality and market acceptance. Foam is typically made from cow's milk in coffee shops, which may not be safe for people with dairy allergies due to the proteins in cow's milk that cause allergies. Since, camel milk does not contain the allergen  $\beta$ -lactoglobulin, it becomes a viable substitute for making foam. Under certain temperature and pH circumstances, the proteins in camel milk have foaming capabilities similar to those of cow milk. At pH 7 the foaming ability of camel milk sweet whey protein is slightly lower than cow milk sweet whey proteins. Camel acid whey proteins showed significantly higher foaming ability and stability after thermal treatment at 70 and 90 °C than their bovine counterparts. As  $\alpha$ -lactalbumin makes up a larger fraction (>70%) of acid whey proteins therefore these proteins have good foaming properties. In purest form,  $\beta$ -casein has greater foaming capabilities than  $\alpha$ -lactalbumin. Because camel milk proteins denature and aggregate when heated at 70-100°C for 30 minutes, surface hydrophobicity increases, electronegative charge decreases, and interfacial tension decreases, significantly improving camel milk's foaming capabilities (Ho et al. 2022). In a recent study, Lajnaf et al. (2022) examined the characteristics of camel and bovine milk's derived proteins, such as sodium caseinates, sweet whey,  $\beta$ -casein,  $\alpha$ -lactalbumin, and  $\beta$ -lactoglobulin. The result of this study showed that camel milk proteins, particularly sodium caseinates and  $\beta$ -casein, had the highest foaming ability, whereas bovine proteins had the highest foam stability, with greater foaming stability values for bovine  $\beta$ -casein.

### Packaging of camel milk dessert

Food packaging is one of the stages of food production that enables foods to reach consumers safely. By selecting the appropriate packaging material and technologies for different food products shelf life of food is increased and food quality and freshness can be preserved (Khalil et al. 2021). Packaging of dairy products develops continuously along with advances in material technologies, which are in turn a response to demands of consumers. Novel dairy packaging systems include new packaging technologies such as the modified atmosphere packaging (MAP) that is widely used nowadays. Forms of active packaging relevant to dairy foods include oxygen scavenging, carbon dioxide absorbers, moisture and/or flavour/odour taints absorbers; releasing compounds (carbon dioxide, ethanol, antioxidants and/or other preservatives); maintaining temperature control and/or compensating temperature changes and antimicrobial packaging (Ščetar et al. 2019). When choosing packaging material for dairy products, various important factors need to be considered such as toxicity, compatibility with the product, impact resistance, maintenance of sanitation, odour, and light protection, chemically inactivity, shape and weight requirements, marketing appeal, printability, and cost (Karaman et al. 2015). The nature and the characteristics of the dairy product to be packaged define the selection of the appropriate packaging material and method. For example, if the product is susceptible to oxidation (such as butter) a selected material needs to have high barrier properties toward oxygen in order to enable the declared shelf life. Similarly, if the dairy product needs to be thermally treated after it has been packaged, the chosen material must be heat tolerant (Ščetar et al. 2019).

### Shelf-life of camel milk

Raw camel milk has shelf life of (8–9) h at 37 °C and more than a week at (4–6) °C. Whereas shelf life of pasteurized milk is 22 days, when heated at 65°C for 20 minutes and kept at 7°C. The fresh milk can also be stored for one year in frozen condition. Camel milk is produced in areas where there is lack of milk cooling facilities coupled with high ambient temperature that exacerbates milk spoilage before it reaches the ultimate market and consumers. To overcome this problem lactoperoxidase system (LPS) is one of the methods to preserve freshness of milk until it is marketed or reaches where there are milk cooling facilities (Amenu et al. 2017). In a study, lactoperoxidase system in fresh camel milk was activated within half an hour of the milking using various levels of thiocyanate and hydrogen peroxide (10–70:10–70 ppm ratios) and efficacy was evaluated. The best lowest activation level 20:20 is found to be effective in preserving raw camel milk up to 18–20 h at 37 °C. The enzyme activity in raw camel milk is high and the respective value in pasteurized milk is below the detection limit. In another study, acidity and pH of the pure fresh camel milk and milk diluted with water (1:1) stored at room temperature were  $0.12 \pm 0.03$ ,  $6.42 \pm 0.18$  and  $0.09 \pm 0.02$ ,  $6.65 \pm 0.22$ ,

respectively. Other parameters, which include clot on boiling, alcohol, and alizarin alcohol tests, were observed negative in fresh camel milk. The study indicated that pure and milk diluted with water (1:1) can be stored for 8 and 10 h, respectively, at room temperature (Singh et al. 2017)

### Camel milk- a need of future

The demand for milk and other dairy products is rising more quickly due to the increasing population, which is expected to reach 7.60 to 8.60 billion by 2030, 9.80 billion by 2050 and 11.20 billion by the year 2100 (Rehman et al. 2023). In addition, more than 6 billion people consume milk and milk products globally (Muthukumaran et al. 2022), with the majority of these consumers living in developing countries. Global milk production may also be constrained by unforeseen environmental factors, such as climate change and an increase in the likelihood of droughts, floods, and disease threats, all of which have a negative influence on the dairy business in various ways. Finding alternatives that are sustainable and climate-resilient is therefore urgently needed. Camel milk and its derived products have the potential to offer a more sustainable source of high-quality alternative of bovine milk (AL-Moosawi et al. 2023).

### Conclusion

Camel milk is rich in nutrition and a nutraceutical dietary source. In addition, it lacks allergic  $\beta$ -lactoglobulin and contains high levels of  $\alpha$ -casein, making camel milk suitable to be used as a daily drink for humans who are allergic to bovine milk. Camel milk has a high vitamin C content, a high iron content, and a lower fat content than cow's milk. Camel milk and its products have potential antimicrobial activities that can be attributed to the chemical composition of milk and the wide variety of valuable microorganisms present in them. Camel milk also has antidiabetic properties that are mostly due to the presence of bioactive peptides and insulin-like proteins. Overall, the medicinal benefits of camel milk are generating a lot of interest, and more thorough research is required to establish definite evidence of these benefits. However, the technologies used to transform camel milk into value-added products like pasteurized and sterilized milk, cheese, yoghurt, butter, powder, sweets, fermented products, etc. face challenges due to its unique chemical composition, which hinders its organoleptic acceptance. Even though there are lots of difficulties in processing camel milk, developing food products using camel milk remains an interesting topic. Several camel milk food products are being investigated, and some are commercially available, such as pasteurized and sterilized camel milk, camel milk powder, cheese, butter, yoghurt, various sweets, etc. However, these products need to be improved in terms of quality and sensory appeal so that they are at least comparable to those of bovine milk. Therefore, further extensive research and studies are required to improve the technological aspects of camel milk and its products.

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