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Camel milk: Composition, properties and processing potential

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Camel milk serves a crucial role in arid regions, providing exceptional nutritional and health benefits. It is characterized by a lower cholesterol and sugar content compared to the milk of other ruminants, along with a high concentration of minerals such as sodium, potassium, phosphorus, and manganese, and elevated levels of vitamins C and B3. Furthermore, camel milk contains higher levels of protective proteins such as lactoferrin, lactoperoxidase, immunoglobulins, and lysozyme. This specific composition underpins the use of camel milk in the treatment of various diseases. Numerous studies have confirmed its diverse functional properties and health benefits, including antimicrobial, anticancer, antioxidant, anti-inflammatory, and antidiabetic effects. However, despite these significant advantages, its industrial transformation into dairy products remains a major technical challenge. This is due to its low κ-casein content, the large size of its casein micelles, and the absence of β-lactoglobulin, characteristics that complicate the production of cheeses, yogurts, and other dairy products. Finally, specialized technologies and future research are required to optimize transformation processes and fully harness the potential of this milk with exceptional properties.

Keywords : Camel milk, chemical composition, technological properties, processing potential

INTRODUCTION

For a long time, camelids have represented a significant value and importance as means of survival for pastoral populations. They have become symbols of wealth and prestige (Hartley, 1979). The camelid family is divided into three genera: Camelus, Lama and Vicugna. The Camelus genus is represented by two domesticated species: the dromedaries (Camelus dromedarius), or one-humped camels and the Bactrian camels (Camelus bactrianus), or two-humped camels (Khomeiri and Yam, 2015).

According to FAO statistics from 2022, the global camelid population stands at approximately 41,772,353 animals, of which 35,100,908 are located in Africa. In arid regions, camelids play an essential economic role. Part of the herd is destined for commercialization on national or international markets for the production of meat, milk, leather, wool and hides. Additionally, dromedaries are often used as transport and riding animals during local festivals and cultural events (Gwida et al., 2012; Ben Chehida et al., 2021). Furthermore, dromedaries have added value due to their milk production. According to FAO statistics in 2022, global camel milk production reached approximately 4.116 million tons, of which 2.876 million tons were produced in Africa. Moreover, the dromedary (Camelus dromedarius) represents an important cultural, economic and health icon in the lives of people in arid and semi-arid regions, due to its exceptional ability to survive in harsh climatic conditions. This significance highlights the value of the products derived from this animal.

Camel milk stands out from the milk of other ruminants due to its low cholesterol and sugar content, its high mineral content such as sodium, potassium, phosphorus and manganese, as well as its richness in vitamin C and vitamin B3 (Haddadin et al., 2008; Sboui et al., 2009). In addition, camel milk contains higher levels of protective proteins such as lactoferrin, lactoperoxidase, immunoglobulins and lysozyme (Elagamy et al., 1996; El-Hatmi et al., 2007). This specific composition is the basis for the use of camel milk to treat various diseases.

Numerous studies have confirmed its various functional and health benefits, including its antimicrobial, anticancer, antioxidant, anti-inflammatory and antidiabetic properties (Yassin et al., 2015; Ayyash et al., 2018; Sboui et al., 2022; Hamouda et al., 2022).

The transformation of camel milk into dairy products is a complex task that requires appropriate technologies, due to multiple factors such as the low concentration of κ-casein, the presence of a multi-component colloidal system, the large size of protein micelles, the small size of fat globules and the presence of antibacterial compounds (El-Zeini, 2006; Bornaz et al., 2009; Arain et al., 2023).

CAMEL MILK CHEMICAL COMPOSITION

Camel milk is a biological liquid produced by a female camel. It is characterized by its opaque white color, a normal milky odor and a sweet-salty taste (Khaskheli et al., 2005; Sakandar et al., 2018).Camel milk has a unique composition that distinguishes it from other types of milk. It has lower fat, protein and dry matter content compared to cow's milk, but it is richer in minerals, protective proteins and certain trace elements (Fe, Cu and Zn) (Nikkhah, 2011). Furthermore, notable differences have been detected in the distribution and molecular structure of the main components between camel milk and cow's milk (Berhe et al., 2017).

Figure 1 illustrates the detailed chemical composition of camel milk.

The composition of camel milk varies depending on various factors, including breed, geographical origin, feeding conditions, lactation stage, season and the health status of the camels (Sakandar et al., 2018).

Additionally, this composition can vary based on other factors such as analytical measurement methods, the number of births and the age of the animal (Khaskheli et al., 2005).

Fat

The fat content of camel milk varies depending on nutrition, breed, season and lactation stage (Konuspayeva et al., 2009). Furthermore, a strong positive correlation has been found between fat content and protein content (Haddadin et al., 2008). Camel milk fat has a lower carotene content than cow's milk (Singh et al., 2017). This low carotene content may explain the white color of camel milk. According to Konuspayeva et al. (2008), camel milk is distinguished by its unique composition of unsaturated fatty acids and its low content of short-chain fatty acids. Additionally, the cholesterol content is higher in camel milk (34.5 mg/100 g) compared to cow's milk (25.6 mg/100 g) (Konuspayeva et al., 2008). Similarly, camel milk fat contains more long-chain fatty acids (84.5%) than short-chain fatty acids (14.6%) (Figure 1). The fat globules in camel milk are smaller but have higher digestibility compared to those in cow and goat milk (Meena et al., 2014).

Lactose

Lactose is the primary carbohydrate in milk of all mammals. In camel milk, lactose content remains unchanged throughout a season and under conditions of hydration or dehydration. Camel milk can be a good substitute for cow's milk for people suffering from lactose intolerance, as it contains lower lactose levels that the human body can easily digest and metabolize without causing undesirable symptoms (Nguyen et al., 2016).

Minerals

The mineral content of camel milk depends on several factors such as diet, breed and water consumption (Haddadin et al., 2008). The major minerals present in camel milk are Cl, K, Ca and the main trace elements are Zn, Fe and Cu (Figure 1) (Baig et al., 2022). The richness of this milk in chloride can be attributed to the ingestion of certain plants, such as Atriplex and Acacia, which are generally rich in salt (Volpato and Puri, 2014; Khaskheli et al., 2005).

Vitamins

Camel milk contains various vitamins, such as fat-soluble vitamins (A, D, E and K) and water-soluble vitamins (B and C) (Haddadin et al., 2008). It is distinguished by its richness in vitamin C, which is 3 to 5 times higher than that of cow's milk (Stahl et al., 2006; Sboui et al., 2009). Indeed, this high concentration of vitamin C makes camel milk a good source for populations living in the harsh climatic conditions of arid and semi-arid regions. Furthermore, camel milk contains more niacin (B3), pantothenic acid (B5), folic acid (B9) and cobalamin (B12) than cow's milk.

However, camel milk contains comparable levels of thiamine (B1), pyridoxine (B6) and vitamin E to cow's milk, although it has lower levels of vitamin A and riboflavin (B2) (Haddadin et al., 2008).

According to the United States Department of Agriculture (USDA), 250 mL of camel milk provides an adult with approximately 5.25% of the recommended daily intake of vitamin A, 8.25% of riboflavin (B2), 15.5% of cobalamin (B12) and 10.5% of the recommended daily intake of ascorbic acid (C), thiamine (B1) and pyridoxine (B6) (Al Kanhal, 2010).

Proteins

The proteins in camel milk are divided into two main groups: caseins and whey proteins (Berhe et al., 2017).

Caseins

The caseins in camel milk are present in the form of four main fractions, similar to cow's milk (Table 1): αs1-casein, αs2-casein, β-casein and κ-casein (El-Salam and El-Shibiny, 2013). Compared to cow's milk, camel milk β-casein is significantly more abundant (65% vs. 39%), while the levels of αs1-casein (22% vs. 38%) and κ-casein (3.5% vs. 13%) are lower in camel milk (Farrell et al., 2004; Berhe et al., 2017).

The casein micelles in camel milk are large, with an average diameter of 380 nm compared to 150, 260 and 180 nm for cow, goat and sheep milk, respectively (Farah and Ruegg, 1989; Bornaz et al., 2009). Indeed, the large size of the casein micelles in camel milk is a limiting factor for its coagulation ability. Smaller casein micelles tend to form a more compact gel network, leading to firmer coagulation compared to larger micelles (Glantz et al., 2010).

Whey protein

Whey protein account for about 20 to 30% of the total protein and approximately 0.63 to 0.80% of the milk (Khaskheli et al., 2005). The main fractions of whey protein in camel milk include α-lactalbumin, lactoferrin, serum albumin, immune proteins and peptidoglycan recognition protein (Gizachew et al., 2014; Sakandar et al., 2018; Oussaief et al., 2020).

Furthermore, camel milk contains other whey protein such as whey acidic protein (Yang et al., 2013). The whey protein levels in camel milk show significant differences compared to those in cow's milk (Table 2).

In camel milk, α-lactalbumin is the major whey protein, whereas β-lactoglobulin is notably absent (Laleye et al., 2008). In this regard, camel milk proteins are of growing interest due to their bioactive properties (Mati et al., 2017).

Camel milk has a higher whey protein/casein ratio than cow's milk, resulting in a soft curd that is easy to digest in the gastrointestinal system (Shamsia, 2009).

PHYSICOCHEMICAL AND TECHNOLOGICAL PROPERTIES

The pH of fresh camel milk ranges between 6.4 and 6.7, which is slightly lower than that of cow's milk (Sboui et al., 2009; Singh et al., 2017). The slightly acidic pH of camel milk can influence its stability and shelf life. In fact, it has a longer shelf life compared to cow's milk (Sboui et al., 2009). The acidity of camel milk ranges from 0.12 to 0.20% (Khaskheli et al., 2005). Moreover, the viscosity of camel milk is 1.72 mPa.s, whereas that of cow's milk is 2.04 mPa.s (Khaskheli et al., 2005). The viscosity of milk is primarily influenced by temperature, fat and protein concentration (Christiansen et al., 2021; Hamouda et al., 2022). At high temperatures (100-130°C), the thermal stability of camel milk is lower than that of cow's milk (Farah and Atkins, 1992).

Camel milk exhibits technological properties, including solubility, water-holding capacity, physical behavior and chemical structure, which are essential parameters in milk processing (Konuspayeva and Faye, 2021). Similarly, camel whey exhibits foaming and emulsifying properties, which can serve as a basis for the formulation and development of functional food products (Laleye et al., 2008).

CAMEL MILK PROCESSING POTENTIAL

The processing of camel milk into dairy products is a delicate process that requires the application of specific technologies. This challenge is attributed to several factors, including the complexity of the multi-component colloidal system and the unique chemical composition of camel milk (Zhang et al., 2005; Bornaz et al., 2009; Seifu, 2023). Camel milk is characterized by a low κ-casein content, a high proportion of β-casein and the absence of β-lactoglobulin, which are key factors limiting its ability to be processed into dairy products (Zhang et al., 2005). These characteristics make camel milk thermally less stable than cow's milk, leading to coagulation difficulties (Ipsen, 2017). Additionally, camel milk has larger casein micelles and smaller fat globules compared to cow's milk. Consequently, these differences in composition, structure and functional properties of camel milk proteins are the main factors responsible for the challenges in its processing (Zhang et al., 2005; Seifu, 2023; Omrani et al., 2023). Moreover, camel milk does not achieve satisfactory coagulation with bovine rennet, unlike milk from other dairy species (Hailu et al., 2016). Camel milk also possesses antimicrobial properties, which can contribute to slowing down the acidification rate during fermentation compared to cow's milk (Berhe, 2018).

CONCLUSION

Camel milk is a valuable resource for populations in arid and semi-arid regions, offering not only nutritional benefits but also unique health benefits and technological properties. Its distinctive composition, rich in bioactive proteins, minerals and vitamins, makes it a food with multiple health benefits, ranging from the management of chronic diseases to improved nutrition. However, the challenges associated with its processing, particularly coagulation and dairy product manufacturing, require suitable technological solutions. A better understanding of the chemical and physicochemical mechanisms of camel milk could pave the way for increased utilization of its potential, promoting its integration into the food and pharmaceutical industries. Finally, future research is needed to optimize processing methods and fully harness the exceptional characteristics of camel milk.

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