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Physico-chemical Properties and Processing Characteristics of Camel Milk as Compared with Other Dairy Species: A Review

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ABSTRACT

Camels are the most climate resilience dairy species which survives and produces more milk in dry lands. Camel milk has a significant role in livelihood improvement and become the most promising industrial products in the future. Additionally, it has medicinal values, rich source of bioactive, antimicrobial, and antioxidant substances. Camel milk differs markedly from other dairy species by its protein composition, milk fat structure and mineral and vitamin. These characteristics have an obvious impact on product processing characteristics and product quality. Systematic review method was used; in which published and unpublished scientific research literatures were reviewed. In camel milk the absence of β-lactoglobulin, β-casein content, the colloidal structure and amino acid composition are the main factors which affect camel milk product processing. During processing chymosin extracted from calf cow does not allow the optimal clotting of casein micelles in camel milk, but lead to a weak curd. The higher content of whey protein to casein ratio, broader casein micelles structure and lower κ-casein content are considered the main factors responsible for the differences in cheese coagulation between a camel and bovine milk. Moreover, the thicker and smaller fat globule results for the formation of a weak gel during fermentation processing. Therefore this review document provide the scientific evidence about the physicochemical property and processing characteristics of camel milk as well as point out where research is lacking.

Key words: Camel, Composition, Milk, Physico-chemical, Processing.

Camels are the most climate resilient dairy species, which plays a great role in livelihood improvement of the pastoral and agro-pastoral communities' (Faye *et al.,* 2010; Yirda *et al.,* 2020). The world's camel population is approximately 35 million with *Camelus dromedarius* (one-humped) representing around 95% and Bactrian camels (*Camelus bactrianus*) constituting the rest (Mbye *et al.,* 2022). Majority (86%) of the dromedary camels are found in Africa and Somalia, Sudan, Ethiopia and Kenya account the largest share (Eyassu, 2022). According to Central Statistical Agency (2021), Ethiopian has 8.1 million camels and 70.54% were females. Concerning the purpose of camel production 36.68% and 17.95% was mainly kept for milk and transportation respectively.

Camel milk is incredibly nutrient-dense food consumed in arid and semi-arid areas (Kaskous, 2019; Tesfemariam *et al.,* 2017). It has numerous unique characteristics such as functional proteins and a predominance of medium-chain fatty acids (Alhaj *et al.,* 2022; Konuspayeva and Faye, 2021). It has smaller fat globule size and higher bioactive property as compared to bovine milk (Dugassa, 2021; Mbye *et al.,* 2022). Due to these special qualities, camel milk is becoming one of the most promising industrial products in the future (Abdullahi, 2019; Sara *et al.,* 2022).

At world level camel milk production report it shows a considerable annual growth, exceeding 8% in the period 2009-2019 (Konuspayeva and Faye, 2021). Despite of this so far camel milk processing has not received much attention as compared to others (Alhaj *et al.,* 2022; Bakry *et al.,* 2021). Moreover, the scientific evidence shows that the detail information about camel milk chemistry, its physicochemical property and processing characteristics are scarce (Dugassa, 2021). Milk composition, particularly protein and fat contents and composition, will also significantly affect cheese yield and composition. Understanding the specific characteristics of milk like *i.e* its composition, physical properties before processing will helps to decide the correct method of product processing technology. On the other hand so far dairy processing centers coping similar technologies used as cow milk without considering the physicochemical property of milk, it can have a significant effect on product quality (Konuspayeva and Faye, 2021). Therefore the objective of this review is to highlight the scientific information regarding to physicochemical property and processing characteristics of camel milk as compared to other dairy species.

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Physicochemical properties of camel milk as compared to others

Camel milk is frothy and opaque-white in color due to the fine distribution of fat globules throughout the milk (Abbas *et al.*, 2013; Arab *et al.,* 2020; Oselu *et al.,* 2022). Its test changes with stage of lactation; it is sweet in the early lactation but salty in the latter stage of lactation (Dugassa, 2021). Also the type of feed and accessibility to drinking water affect how it tastes (Patel *et al.,* 2016). It is less viscous than bovine milk (Al haj and Al Kanhal, 2010), it has a pH of 6.2-6.7 (Khaliq *et al.,* 2019; Lunda *et al.,* 2013). The specific gravity at 20°C is 1.020°C to 1.022°C (Dugassa, 2021). Additionally, it has a freezing point of -0.576°C to 0.61°C, however for cows; it varies from -0.51 to 0.55°C (Vincenzetti *et al.,* 2022).

Characterizing the milk composition of dairy animal is absolutely necessary, because the nutritional composition of all dairy animal species vary considerably (Khaliq *et al.,* 2019). Specifically researchers have been noted that camel milk composition can vary depending on the feeding habitat; season of the year and genetic make-up (Alhaj *et al.,* 2022; Zeleke, 2007). Despite its proximity with cow milk in term of gross composition, camel milk shows much specificity (Konuspayeva and Faye, 2021). Concerning the milk protein composition, camel milk has a lower protein level than that of cows, ranging from 2.29 to 4.9 percent (Alhaj *et al.*, 2022).

Casein (CN) is the major protein which constitutes about 50-85% of the total proteins (Khaskheli *et al.,* 2005). Camel milk casein has two forms "α_{S1}- casein" and "α_{S2} -casein" (El-Agamy, 2006). There are four type of casein in camel milk, *i.e.* α_{s1}- CN, α_{s2}- CN, α- casein (α-CN) and κ-casein (k-CN) (Abbas *et al.,* 2013; Al-haj and AlKanhal, 2010). The estimated molecular mass of camel β-CN and α-CN are 32 and 35 kDa respectively, which are considerably higher than those reported for bovine β-CN 24 and α-CN 22-27 kDa (Saliha *et al.,* 2013). The majority of camel caseins are β-CN (65%) followed by α_{s1}-CN (22%) from total casein, while, bovine caseins contains has high percentage of β-CN (39%) followed by α_{s1}-CN (38%) from the total caseins (Brezovecki *et al.,* 2015; Yirda *et al.,* 2020). Camel milk has lower concentrations of κ-CN which account 3.3% as compared to bovine milk which is 13% (Mbye *et al.,* 2022). The detail information about the relative distribution of camel milk casein and bovine milk is shown in Table 1.

Table 2 shows the protein profile (whey protein) distribution of camel and bovine milk. Amino acid profile of camel milk is similar to that of bovine milk; only few differences in the primary structure of casein were observed as compared to bovine caseins (El-Elagamy, 2009). The whey protein content in camel's milk varies between 20% and 25%, which is slightly more than in cow's milk (Dugassa, 2021; Vincenzetti *et al.,* 2022).

According to Rafiq *et al.* (2016) camel milk has a higher amount of whey proteins (0.80%) than buffalo (0.68%), sheep (0.66%), goat (0.53%) and bovine milk (0.47%). This is primarily due to the higher content of albumin and lactoferrin. Camel milk whey protein lacks β-lactoglobulin (β-lg) but it contains larger amount of α-lactalbumin (α-La) (27%) and Serum albumin (SA) (26%) as compared with bovine α-la (20.1%) and SA (6.2%). β-lg is the main protein in bovine whey protein which accounts 53.6% of total whey proteins (Mbye *et al.,* 2022). Whey protein includes: SA, α-La, lactoferrin (LF), Immunoglobulins and peptidoglycan

Table 1: Casein protein distribution of camel and bovine milk.

Casein	Milk caseins composition in %	
	Camel	Bovine
α_{s1}- casein (g/l)	5.3 (22%)	9.5 (38%)
α_{s2}- casein (g/l)	2.3 (9.6%)	2.5 (10%)
β- casein (g/l)	15.6 (65%)	9.8 (39%)
κ- casein (g/l)	0.8 (3.3%)	3.3 (13%)
Total casein content as % of the proteins	2.4/3.1 (77%)	2.51/3.4 (74%)

Sources: Hailu *et al.* 2016; Li *et al.*, 2019; Tesfemariam *et al.,* 2017.

Table 2: Whey protein distribution of camel and bovine milk.

Whey protein	Whey protein composition	
	Camel milk	Bovine milk
β -Lactoglobulin	*Absent	3.3 (53.6%)
α- Lactalbumin	2.3 (27%)	1.1 (20.1%)
Serum albumin	2.2 (26%)	0.35 (6.2%)
Whey acidic protein	0.16 (1.8%)	Not present
Immunoglobulins IgA, IgG, IgM (g/l)	1.5 (18%)	0.30 (5.3%)

*Absent indicates that corresponding coding sequence is absent in genome. Sources: Hailu *et al.*, 2016; Li *et al.*, 2019; Tesfemariam *et al.,* 2017.

recognition protein (Hinz *et al.,* 2012). Lactoferrin content of camel milk is significantly higher than sheep, goat, cow and buffalo milk (Abbas *et al.,* 2013).

Table 3 shows the number of amino acid residue, its molecular weight and isoelectric point of cow and camel milk casein. The number of amino acid residues of α_{s1}-CN of camel milk is 217 while its concentration in cow milk is 199. The κ-CN contains higher amount of arginine and lysine than cow milk (Salmen *et al.,* 2012). It has also 162 amino acids, 22.4 molecular weight (kDa) and its isoelectric point (IP) is 4.11, while its concentration in cow milk is 19.038 in molecular weight (kDa) with isoelectric point of 5.97 (Khaliq *et al.,* 2019). The number of amino acids residues of camel milk lactoferrin is slightly lower from bovine (El-Elagamy, 2009). Moreover the concentration of antioxidant amino acids residues (cysteine, tryptophan, and methionine) is higher than others (Salami *et al.,* 2009).

The lactose content of camel milk rages 3.12-4.5% (Alhaj *et al.,* 2022; Dugassa, 2021; Konuspayeva *et al.,* 2009). Buffalo milk also contains lower lactose compared to camel milk as well as cow milk (Jaydeep *et al.,* 2015). The variation in the concentration of lactose in camel milk is associated with water intake and type of feed consumed (Al-haj and AlKanhal, 2010; Kula and Dechasa, 2016). In cases of dehydration of the camel the lactose content will decreases, thus the taste of milk become less sweet (Al-Juboori *et al.,* 2013). According to Bekele *et al.* (2011) study milk lactose concentration was higher 4.3±0.2% for camel deprived of water for 4 days as compared with 4.1±0.2% for 16 day.

Fat is the other important component of camel milk, including a complex mixture of natural fats (*i.e*., triglycerides, phospholipids, cholesterol, and other elements), representing one of the main sources of energy (Bakry *et al.,* 2021). In dromedary camels, milk fat varies from 1.2% to 4.5% depending on the nutritional status, lactation stage, breed type and the season of the year. The fat contents decrease from 4.3 to 1.1% in thirsty camel (Konuspayeva *et al.,* 2009). Triacylglycerol accounted for 96% of the total lipids in camel milk (Dugassa, 2021; Nikkhah, 2011). Milk fat has a wide range of physical characteristics since it includes over 400 different fatty acids (FAs). Nevertheless, it is mostly composed of 16 major FAs that are responsible for its physical properties, *i.e*., melting and solidification temperatures, solid-phase content, firmness/hardness, and spread ability of the resulting butter (Bakry *et al.,* 2021).

Fatty acids are divided based on the linkage of the carbon atoms into saturated and unsaturated fatty acids. In saturated fatty acids, the carbon atoms are linked in a chain by single bonds, in unsaturated fatty acids by one or more double bonds. Camel milk fat contains lower amounts of short chain fatty acids and a higher proportion of long chain fatty acids (C_{14}-C_{18}) as compared to buffalo and bovine milk (Abbas *et al.,* 2013; Sara *et al.,* 2022) as shown in Table 4 below. Its fat globule membrane is thicker and smaller in size than cow milk (Sunita *et al.,* 2014). The milk fat globules size (MFGs) range from 1.1 to 2.1 µm, which is lower than those of buffalo (3.9-7.7 µm), cow (1.6-4.9 µm), and goat milk (1.1-3.9 µm) (Bakry *et al.,* 2021; Richard, 2017). Unsaturated FA in camel milk is 65.02 g/100 g FA which is highest proportion followed by the cow milk (40.76 g/100 g), goat milk (40.23 g/100 g) and 58.17 g/100 g for human milk (Wang *et al.,* 2011; Oselu *et al.,* 2022). The amount of saturated fatty acids found in camel milk is lower (67.7%) than cow milk (69.9 %) (Konuspayeva et *al.,* 2008); it exhibit 50-65% of saturated and 35-50% unsaturated fatty acids. Dominant fatty acids found in camel milk are Palmitic and oleic acid (Attila *et al.,* 2000).

Reviewed literature shown that water content of camel milk ranges 88.7-89.4%, while cow milk ranges 87.7-89.2% (Dahlborn *et al.,* 1997; Haddadin *et al.,* 2008; Sulieman *et al.,* 2014). Feed availability and water consumption frequency were found to be the main factors affecting the water content of camel milk (Brezovecki *et al.,* 2015).

Table 3: The number of AA residue, MW and isoelectric point of bovine and camel milk casein.

Protein composition	Milk property	Camel milk	Bovine milk
α_{s1}- CN	Number of amino acid residues	217	199
	Molecular weight (kDa)	24·668	22.98
	Isoelectric point	4.40	4.76
α_{s2}- CN	Number of amino acid residues	178	207
	Molecular weight (KDa)	21.993	24.35
	Isoelectric point	4.58	5.0
β- CN	Number of amino acid residues	217	209
	Molecular weight (KDa)	24.90	23.58
	Isoelectric point	4.66	4.80
κ- CN	Number of amino acid residues	162	169
	Molecular weight (KDa)	22.4	18.97
	Isoelectric point	4.11	5.97
α- Lactalbumin	Number of amino acid residues	123	123
Lactoferrin	Number of amino acid residues	689	700

Sources: Kappeler *et al.,* 1998; Salmen *et al.,* 2012; Tesfemariam *et al.,* 2017.

According to research finding, when the camel has free access to water the water content of the milk is decrease 86%, while when water is scarce; the water content of milk has increased up to 91% (Yadav *et al.,* 2015). Similarly Kanca (2017) reported that camels produce diluted milk when water is scarce.

On the other hand the other research finding indicates that the milk osmolality increased in parallel with plasma osmolality during dehydration. This finding is not consistent with previous study result which indicates milk becoming diluted during dehydration. According to Bekele *et al.* (2011) study do so far to investigate the effect of water provision or deprivation for (1, 4, 8, 12 and 16 week) on camel milk composition. Accordingly milk volume was decreased when the number of deprivation day increases but milk osmolality was increased from 315±3 on 1st day to 333±3 mosm/kg in 4th day of 4th week. Moreover during 16 week it increased from 318±3 to 336 ±3 mosm/kg during the first 4 day of water deprivation. The result of this study indicates that, camels did not dilute their milk when they are dehydrated. Instead milk osmolality will increase in parallel to blood osmolality.

Table 5 shows the mineral content of different dairy species. The total ash content of camel milk range from 0.6-0.9% (Konuspayeva *et al.,* 2009), which is relatively higher than buffalo and cow (Dugassa, 2021; Yoganandi *et al.,* 2014). It is rich in iron, zinc and copper content than cow milk (Oselu *et al.,* 2022; Raghvendar *et al.,* 2017). Calcium and Phosphorus content as well as its proportion found in the milk are the most important determining factor that affects the final dairy product quality. The proportion of Calcium to Phosphorus ratio in camel milk is 1:5 as compared to 2:1 and 1:29 for human and cow milk, respectively. The fat soluble vitamin (A, D and E) and water

Table 4: Fatty acid profile of camel milk compared to bovine and human milk.

Carbon number	Fatty acid	Camel milk[ab]	Bovine milk[abc]	Human milk[c]
4:0	Butyric (%)	0.8	1.4	0.1
6:0	Caproic (%)	0.4	2.1	0.2
8:0	Caprylic (%)	0.3	1.7	0.3
10:0	Capric (%)	0.4	3.5	2.0
12:0	Lauric (%)	0.7	3.9	6.8
14:0	Myristic (%)	11.0	12.6	10.4
16:0	Palmitic (%)	29.1	29.5	28.1
18:0	Stearic (%)	12.4	13.3	6.9
Monounsaturated				
14:1		0.5	-	-
16:1	Palmitoleic (%)	10.1	1.7	3.5
18:1	Oleic (%)	24.5	26.3	33.6
Polyunsaturated				
18:2	Linoleic (%)	3.1	2.9	6.4
18:3	Linolenic (%)	1.4	1.1	1.7
Unsaturated/saturated		0.7	0.47	0.82
Short chain (C4-C14)		14.6	25.2	19.8
Long chain (C16-C20)		84.5	72.18	80.2

Source: [a]El-Alagamy (2009), [b]El-Agamy (2008) and [c]Malacarne *et al.* (2002).

Table 5: Mineral concentrations of milk from different mammalian species.

Minerals	Species type					
(mg/100 g)	Camel	Cow	Sheep	Goat	Mare	Human
Calcium	114-116	112-120	195-200	132-134	132.7	33.0
Phosphorus	63-90	59-92	124-158	97.7-121	88.4	43.0
Potassium	156-173	106-150	136-140	152-181	66.5	55.0
Magnesium	12-14	7-11	18-21	15.8-16.0	10.2	4.0
Sodium	69-73	45-58	44-58	41-59.4	19.8	15.0
Zinc	530-590	530.0	520-747	56-370	270.0	380.0
Iron	230-290	80.0	72-122	7.0-60	37.0	200.0
Copper	140.0	60.0	40-68	5.0-80.0	64.0	60.0
Manganese	80.0	20.0	5.3-9.0	3.2-6.53	n.d.	70.0

Adopted from Vincenzetti *et al.,* 2022.

soluble vitamins (C and B) are found in higher quantities in camel milk (Haddadin *et al.,* 2008; Konuspayeva *et al.,* 2011; Stahl *et al.,* 2006). The content of vitamin C is of specific interest as its levels are three times higher than cow milk and one-and-a-half that of human milk (Oselu *et al.,* 2022; Stahl *et al.,* 2006).

Processing character of camel milk

The physical characteristics of the milk have its own effect on the final product quality during processing. Camel milk has a high alcohol stability number which is 32.3 versus 20.8, 10.3, 12.5, and 14.1 for cow, buffalo, goat and sheep milk respectively (Eyassu, 2022). Camel milk has a higher melting point than cow milk due to high content of unsaturated long chain FA and very high levels of higher molecular weight of triacylglycerols (TAGs) C48-C52 (Eyassu, 2022). The shelf life of camel milk is higher than others milk due to its higher concentration of lactoferrin which have anti-microbial qualities (Dukwal *et al.,* 2007; Khaliq *et al.,* 2019; Sara *et al.,* 2022).

Pasteurization, fermentation, cream separation, butter and cheese making were the processing techniques applied (Konuspayeva and Faye, 2021). The processing techniques applied for camel milk was copied from technologies used for cow milk (Konuspayeva and Faye, 2021). Manufacturing milk by using the same technology as other dairy species milk can lead to processing difficulties or result to poor quality products. Pasteurization of milk is a commonly applied technique in dairy product processing industry. However the pasteurization procedure and indicators method used for camel milk vary from cow milk (Konuspayeva and Faye, 2021). The presence or absence of Gamma glutamyl transferase (GGT) is an indicator used to assess the effectiveness of pasteurization in camel milk, while lactoperoxidase is used for cow milk.

In cheese making, milk coagulation properties are considered as a good indicator of processing effectiveness as it is correlates with cheese yield (Mbye *et al.,* 2020). Camel milk cheese is characterized by a weak crusting and a continuous loss of moisture, due to serum release, leading often to a very dry curd which hinders correct ripening. Furthermore, milk coagulation process done by using calf chymosin in cheese making from camel milk was not effective, the site for hydrolysis of k-casein is different in camel milk it is Phe^{97}-Ile^{98} as compared with bovine (Phe^{105}-Met^{106}) (Hailu *et al.,* 2016; Kappeler *et al.,* 1998). The other difficulty in camel milk product processing features is associated with the low amount of k-casein content and the large casein micelle structure (Vincenzetti *et al.,* 2022). An average diameter of camel casein is 380 nm as compared to bovine (150 nm), caprine (260 nm) and ovine (180 nm) milk (Dugassa, 2021; Khaliq *et al.,* 2019; Oselu *et al.,* 2022). The scholars reported that when the surface area of casein micelles is enhanced it will result in strengthening of gel and firming the texture of curd as compared to poor aggregated gel in case of large size micelle. Additionally casein-to-whey protein ratio affects the texture and protein network formed during the cheese-making (Roy, 2021). In contrary to cow milk processed cheese where ripening is started after curdling with the rapid appearance of crust formation.

The process of fermentation, including camel milk, is a traditional ancestral method used all over the world (Konuspayeva and Faye, 2021). It is the transformation of lactose into lactic acid by the action of natural microflora or in some cases produced by yeasts. Fermented camel milk has higher lactic acid bacteria, which have been shown to be effective against pathogens including *Bacillus, Staphylococcus salmonella* and *Escherichia* (Marwa *et al.,* 2013). Mesophilic, thermophilic, or their mixture types of starters are used for fermentation of camel milk; it's led to an acidification rate at 37°C between 33% and 79% which is lower than for cow milk (Konuspayeva and Faye, 2021). The proteolysis rate in fermented camel milk has been reported to be greater compared with cow's milk (Marwa *et al.,* 2013). Fermented camel milk products have different name at different areas of the country, *i.e. shubat* in Kazakhstan and China, *khoormog* in Mongolia, *Garris* in Sudan, *Suusac* in Kenya, *Ititu* and *dhanaan* in Ethiopia (Berhe *et al.,* 2019). The difference was mainly based the processing method and the starter culture type used during processing.

Butter processing is heavily depends on the size of fat globule and its outside component or the fat globule interface. Camel milk fat contains less than 0.5% butyric acid as compared to cow milk 5% (Konuspayeva and Faye, 2021). It has characterized by a small fat globule size and a thicker fat globular membrane (Eyassu, 2022). These properties make it difficult to produce butter. Moreover the melting range of camel milk butter ranges from 41-42°C and is on average 8°C higher than the corresponding value for cow milk butter. Moreover it has a lower content of carotene as compared to bovine milk. Hence the color of processed camel's milk butter becomes white (Swelum *et al.,* 2021).

SUMMARY AND CONCLUSSION

Camel milk product processing technologies was not getting enough attention. Camel milk is markedly differing from other dairy species by its physicochemical and functional property. Despite these technological constraints, the global camel milk market is demand is increasing. Compositional difference can plays an important role in determining the product processing characteristics; absence of β-lactoglobulin, lower α-casein content, lower k-casein concentration and smaller fat globule membrane as well as higher whey protein ratio make camel milk difficult for processing. Continuous removal of serum from curd, and the slow acidification of the curd are the other technological difficulties of cheese processing from camel milk. Nutritionally camel milk has more nutritious it contain higher concentration of long chain fatty acids, vitamins C, minerals like iron, copper, zinc and magnesium. Therefore, it is essential to understand the fundamental processing features of camel milk which helps to fully explore and utilize the available resources effectively.

Conflict of Interest

Authors have no conflict of interest to declare.

REFERENCES

Abbas, S., Ashraf, H., Nazir, D.A. and Sarfraz, D.L. (2013). Physicochemical analysis and composition of camel milk. International Research Journal. 2: 83-98.

Abdullahi, A. (2019). Camel milk. A review. Journal of Animal Sciences and Livestock Production. 3(1): 13. ISSN 2577-0594.

Al-haj, A. and Al Kanhal, H.A. (2010). Compositional, technological and nutritional aspects of dromedary camel milk. International Dairy Journal. 20(12): 811-821.

Alhaj, O.A., Lajnaf, R., Jrad, Z., Alshuniaber, M.A., Jahrami, H.A., Serag El-Din, M.F. (2022). Comparison of ethanol stability and chemical composition of camel milk from five samples. Animals. 12(5): 1-11.

Al-Juboori, A., Mohammed, M., Rashid, J., Kurian, J. and El Refaey, S. (2013). Nutritional and medicinal value of camel (*Camelus dromedarius*) milk. WIT Transactions on Ecology and the Environment. 170: 221-232.

Arab, K.L., Shah, A.H., Jatoi, A.S., Khaskheli, G.B., Malhi, M.C., Khaskheli, A.A., Khanzada, M.A. and Kalwar, Q. (2020). Effect of heating on shelf life and sensory characteristics of camel milk. Pure and Applied Biology. 9(1): 74-79.

Attila, H., Kherouatou, N., Fakhfakh, N., Khorchani, T., Trigui, N. (2000). Dromedary milk fat: Biochemical. Microscopic and rheological characteristics. Journal of Food Lipids. 7: 95-112.

Bakry, I.A., Yang, L., Farag, M.A., Korma, S.A., Khalifa, I., Cacciotti, I., Ziedan, N.I., Jin, J., Jin, Q., Wei, W. (2021). A comprehensive review of the composition, nutritional value and functional properties of camel milk fat. Foods. 10: 2158. https://doi.org/10.3390/foods10092158.

Bekele, T., Lundeheim, N. and Dahlborn, K. (2011). Milk production and feeding behavior in the camel (*Camelus dromedarius*) during 4 watering regimens. Journal of Dairy Science. 94(3): 1310-1317.

Berhe, T., Ipsen, R., Seifu, E., Kurtu, M.Y., Fugl, A., Hansen, E.B. (2019). Metagenomic analysis of bacterial community composition in Dhanaan, Ethiopian traditional fermented camel milk. FEMS Microbiol. Lett. 366(11): fnz128. doi: 10.1093/femsle/fnz128.

Brezovecki, A., Cagalj, M., Dermit, Z. F., Mikulec, N., Ljoljic, D.B. and Antunac, N. (2015). Camel milk and milk products. Camel Milk, Mljekarstvo. 65: 81-90.

Central Statistical Agency, (2021). Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey, Volume II Report on Livestock and Livestock Characteristics, Addis Ababa, Ethiopia, pp. 20-21.

Dahlborn, K., Hossaini-Halali, J. and Benlamlih, S. (1997). Changes in fluid balance, milk osmolality and water content during dehydration and rehydration in two lactating camels (*Camelus dromedarius*). J. Camel Pract. Res. l4: 207-211.

Dugassa, D. (2021). Quality and therapeutic aspect of camel milk: A review. J. Food Process Technology. 12(8): 902.

Dukwal, V., Modi, S., Singh, M.A. (2007). Comparative study of nutritional composition of camel and cow's milk. Int Camel Conf. 7: 91-92.

El-Agamy, (2006). "Camel Milk," in Handbook of Milk of Non Bovine Mammals, Parkand, Y.W. Haenlein, G.F.W. 1st Edition, 297.

El-Agamy, (2008). The challenge of cow milk protein allergy. Small Ruminant Research. 68: (1-2): pp. 64-72.

El-Alagamy, I. (2009). Bioactive Components in Camel Milk. In: Bioactive Components in Milk and Dairy Products, [Park, Y.W. (Ed.)], Wiley-Blackwell. 159-185.

Eyassu, S. (2022). Recent advances on camel milk: Nutritional and health benefits and processing implications: A review. AIMS Agriculture and Food. 7(4): 777-804.

Faye, B., Konuspayeva, G., Loisean, G. (2010). Variability of urea concentration in camel milk in Kazakhstan. Dairy Science and Technology. 90: 707-71.

Haddadin, M., Gammoh, S. and Robinson, R. (2008). Seasonal variations in the chemical composition of camel milk in Jordan. Journal of Dairy Research. 75(1): 8-12. doi: 10.1017/S0022029907002750.

Hailu, Y., Hansen, E.B., Seifu, E., Eshetu, M., Ipsen, R. and Kappeler, S. (2016). Functional and technological properties of camel milk proteins: A review. Journal of Dairy Research. 83: 422-429. doi: 10.1017/S0022029916000686.

Hinz, K., O'Connor, P.M., Huppertz, T., Ross, R.P. and Kelly, A.L. (2012). Comparison of the principal proteins in bovine, caprine, buffalo, equine and camel milk. Journal of Dairy Research. 79(2): 185-191. doi: 10.1017/S0022029912000015.

Jaydeep, Y., Bhavbhuti, M., Wadhwani, K.N.M., Darji, V.B., Aparnathi, K.D. (2015). Evaluation and comparison of camel milk with cow milk and buffalo milk for gross composition. J. Camel Pract Res. 21(2): 259-265.

Kanca, H. (2017). Milk Production and Composition in Ruminants under Heat Stress. In: Nutrients in Dairy and their Implications for Health and Disease, [Watson, R.R., Collier, R.J., Preedy, V.R.], London, UK: Elsevier. 97-109.

Kappeler, S., Farah, Z., Puhan, Z. (1998). Sequence analysis of camelus dromedaries milk caseins. Journal of Dairy Research. 65: 209-222. doi: 10.1017/s0022029997002847.

Kaskous, S. (2019). Camel milk composition, udder health and effect of different storage times and temperatures on raw milk quality using camel milking machine "stimulactor". Agriculture and Food Sciences Research. 6(2): 172-181. DOI: 10.20448/journal.512.2019.62.172.181.

Khaliq, A., Farhan, M., Chughtai, J., Nadeem, M., Liaqat, A., Mehmmod, T., Ahsan, S. (2019). Camel milk: Massive paragon of nutritional and therapeutic potentials: A review. International Journal of Research Studies in Biosciences. 7(9): 12-26.

Khaskheli, M., Arain, M.A., Chaudhry, S., Soomro, A.H. and Qureshi, T.A. (2005). Physico-chemical quality of camel milk. Journal of Agriculture and Social Sciences. 1: 164-166.

Konuspayeva, G. Faye, B. (2021). Recent advances in camel milk, processing. Animals. 11: 1045. https://doi.org/10.3390/ani11041045.

Konuspayeva, G., Faye, B. and Loiseau, G. (2009). The composition of camel milk: A met analysis of the literature data. Journal of Food Composition and Analysis. 22(2): 95-101.

Konuspayeva, G., Faye, B., Loiseau, G. and others, (2011). Variability of vitamin C content in camel milk from Kazakhstan. J. Camelid Sci. 4: 63-69.

Konuspayeva, G., Lemarie, E., Faye, B., Loiseau, G., Montet, D. (2008). Fatty acid and cholesterol composition of camel's (Camelus bactrianus, *Camelus dromedarius* and hybrids) milk in Kazakhstan. Dairy Science and Technology. 88: 327-340.

Kula, J. and Dechasa, T. (2016). Chemical composition and medicinal values of camel milk. International Journal of Research in Bio Sciences. 4: 13-25.

Li, R.R., Yue, H.T., Shi, Z.Y., Shen, T., Yao, H.B., Zhang, J.W., Gao, Y., Yang, J. (2019). Protein profile of whole camel milk resulting from commercial thermal treatment. LWT. 134: 110256. DOI: 10.1016/j.lwt.2020.110256.

Lund, A.K., Shah, A.H., Jatoi, A.S., Khaskheli, G.B., Khaskheli, M.C., Malhi, A.A., Kalwar, M.A., Khanzada, Q. (2013). Effect of heating on shelf life and sensory characteristics of camel milk. Pure Appl. Biol. 9: 74-79.

Malacarne, M., Martuzzi, F., Summer, A. and Mariani, P. (2002). Protein and fat composition of mare's milk: Some nutritional remarks with reference to human and cow's milk. International Dairy Journal. 12(11): 869-877.

Marwa, M., Shalaby, D.S.M. and Soryal, K.A. (2013). Compositional, rheological and organoleptic qualities of camel milk *Labneh* as affected by some milk heat treatments. World Journal of Dairy and Food Sciences. 8(2): 118-13.

Mbye, M., Mohamed, H., Ramachandran, T., Hamed, F., AlHammadi, A., Kamleh, R., and Kamal-Eldin, A. (2020). Effects of pasteurization and high-pressure processing of camel and bovine cheese quality and proteolysis contribution to camel cheese softness. Frontiers in Nutrition. 8: 1-14.

Mbye, M., Ayyash, M., Abu-Jdayil, B. and Kamal-Eldin, A. (2022). The texture of camel milk cheese: Effects of milk composition, coagulants and processing conditions. Front. Nutr. 9: 868320. doi: 10.3389/fnut.2022.868320.

Nikkhah, A. (2011). Equidae, camel and yak milks as functional foods: A review. Journal of Nutrition and Food Sciences. 1: 116. DOI: 10.4172/2155-9600.1000116.

Oselu, S., Ebere, R. and Arimi, J.M. (2022). Review article camels, camel milk and camel milk product situation in kenya in relation to the world. Int J. Food Sci. 8: 1237423. doi: 10.1155/2022/1237423.

Patel, A.S., Patel, S.J., Patel, N.R. and Chaudhary, G.V. (2016). Importance of camel milk, An alternative dairy food. Journal of Livestock Science. 7: 19-25.

Rafiq, S., Huma, N., Pasha, I., Sameen, A., Mukhtar, O. and Khan, M.I. (2016). Chemical composition, nitrogen fractions and amino acids profile of milk from different animal species. Asian-Australasian Journal of Animal Sciences. 29: 1022-1028.

Raghvendar, S., Mal, G., Kumar, D., Patil, N.V., Pathak, K.M.L. (2017). Camel milk: An important natural adjuvant, national research centre on camel, Bikaner, Rajasthan, India. Agricultural Research. 6(4): DOI: 10.1007/s40003-017-0284-4.

Richard, I. (2017). Opportunities for producing dairy products from camel milk: A comparison with bovine milk. East African Journal of Sciences. 11(2): 93-98.

Roy, D. (2021). Structural Changes in Milk of Different Species during Digestion. Massey University, Manawatû, New Zealand.

Salami, M., Yousef, R., Ehsani, M.R., Razavi, S.H., Chobert, J.M., Saboury, A.A., Moosavi-Movahedi, A.A. (2009). Enzymatic digestion and antioxidant activity of the native and molten globule states of camel α-lactalbumin: Possible significance for use in infant formula. International Dairy Journal. 19: 518-523.

Saliha, S.A.Z., Dalila, A., Chahra, S., Saliha, B.H. and Abderrahmane, M. (2013). Separation and characterization of major milk proteins from algerian dromedary (*Camelus dromedarius*). Emirates Journal of Food and Agriculture. 4: 283-290.

Salmen, S.H., Abu-Tarboush, H.M., Al-Saleh, A.A. and Metwalli, A.A. (2012). Amino acids content and electrophoretic profile of camel milk casein from different camel breeds in Saudi Arabia. Saudi Journal of Biological Sciences. 19: 177-183.

Sara, B., Elhassan, M.B.M. and Zubeir, I.E.M.E. (2022). Evaluation of pasteurization and sterilization process on camel milk quality. Global Journal of Science Frontier Research. 22(2): 1-11.

Stahl, T., Sallmann, H.P., Duehlmeier, R. and Wernery, U. (2006). Selected vitamins and fatty acid patterns in dromedary milk and colostrums. Journal of Camel Practice and Research. 13: 53-57.

Sulieman, A.M.E., Elamin, O. Elkhalifa, E.A., Laleye, L. (2014). Comparison of physicochemical properties of spray-dried camel's milk and cow's milk powder. Int. J. Food Sci. Nutr. Eng. 4: 15-19.

Sunita, S., Rajput, Y.S., Sharma, R. (2014). Comparative fat digestibility of goat, camel, cow and buffalo milk. International Dairy J. 35: 153-156.

Swelum, A.A., El-saadony, M.T., Abdo, M., Ombarak, R.A., Hussein, E.O.S., Suliman, G., Alhimaidi, A.R., Ammari, A.A., Ba-awadh, H., Taha, A.E., El-Tarabily, K.A. and El-Hack, M.E. A. (2021). Nutritional, antimicrobial and medicinal properties of camel's milk. Saudi Journal of Biological Sciences. 28(5): 3126-3136. https://doi.org/10.1016/j.sjbs.2021.02.057.

Tesfemariam, B., Seifu, E., Ipsen, R., Kurtu, M.Y. and Hansen, E.B. (2017). Processing challenges and opportunities of camel dairy products. International Journal of Food Science. 2017(2): 1-8.

Vincenzetti, S., Cammertoni, N., Rapaccetti, R., Santini, G., Klimanova, Y., Zhang, J., Polidori, P. (2022). Nutraceutical and functional properties of camelids' milk. Beverages. 8(12): 1-12. https://doi.org/10.3390/beverages8010012.

Wang, S.Y., Liang, J.P., Shao, W.J., Wen, H. (2011). Mineral, vitamin and fatty acid contents in the camel milk of dromedaries in the anxigansu china. J. Camel Pract Res. 18(2): 273-276.

Yadav, A. K., Kumar, R., Priyadarshini, L. and Singh, J. (2015). Composition and medicinal properties of camel milk. Asian Journal of Dairy and Food Research. 34: 83-91.

Yirda, A., Eshetu, M. and Babege, K. (2020). Current status of camel dairy processing and technologies: A review. Open Journal of Animal Sciences. 10: 362-377.

Yoganandi, J., Mehta, B.M., Wadhwani, K.N., Darji, V.B. and Aparnathi, D.K.D. (2014). Comarison of physico-chemical properties of camel milk with cow milk and buffalo milk. Journal of Camel Practice and Research. 21: 253-258.

Zeleke, M. (2007). Non-genetic factors affecting milk yield and milk composition of traditionally managed camels (*Camelus dromedarius*) in Eastern Ethiopia. Livestock Research for Rural Development. 19(6).