DOI : 10.5958/2231-6736.2024.00020.5 *Vol 31 No 2, p 147-161*

SOME ASPECTS OF CAMEL MILK AND ITS SAFETY FOR HUMAN CONSUMPTION-AN OVERVIEW

Shehadeh Kaskous[1] and Michael W. Pfaffl[2]

[1]Department of Research and Development, Siliconform, Schelmengriesstrasse 1, 86842 Türkheim, Germany
[2]Department of Animal Physiology and Immunology, School of Life Sciences, Technical University of Munich, 85354 Freising, Liesel-Beckmann-Straße 1, Germany

ABSTRACT

Camel milk is in high demand in many countries around the world. There appears to be increasing awareness of the use of camel milk in human diet. Therefore, the aim of this study was to determine the importance of camel milk and its safety for human consumption. Camel milk contains numerous antimicrobial components and protective factors, making it a unique milk compared to the milk of other lactating animal species. Camel milk production varies between 1000 and 12000 kg during the lactation period of 8 to 18 months, with large differences between geographical regions, feeding and husbandry conditions. The composition of camel milk is 2.5-5.5% fat, 2.2-4.5% protein, 2.5-5.5% lactose, 0.7-1.0% ash and 8.0-15% dry matter. To increase milk production for each camel and improve the quality and safety of raw camel milk, the use of a suitable milking machine such as StimuLactor is necessary. In addition, correct husbandry, feeding and hygiene measures must be considered. In conclusion, regarding the importance of camel milk and the associated related health benefits of its bioactive ingredients, improvements in milking hygiene, milk storage and transport conditions are required to ensure the quality of camel milk meets consumer needs.

Key words: Camel, human milk, milking machine, milk yield

Camel milk is one of the most important nutritional sources for the population in many arid and semi-arid areas of the world, as it contains almost all the vital nutrients needed in dry climate. The camel population in the world is approximately 35 million, about 95% of which are dromedaries (FAO, 2022). Camel milk yield varies between 1000 and 12000 kg during the lactation period of 8 to 18 months (Boujenane, 2020; Swelum *et al,* 2020). However, the amount of milk per lactation depends on many factors such as breed (Type), animal health, lactation stage, lactation number, living conditions and season (Yamina *et al,* 2013; Chamekh *et al,* 2020; Swelum *et al,* 2021; Boudalia *et al,* 2023). Camel milk was named as the most valuable product (Davati *et al,* 2015) and it is known as "white gold of the desert" (Wernery, 2006). However, camel milk contains numerous minor components that have special bioactive properties (Kaskous and Pfaffl, 2017; Swelum *et al,* 2021; Oselu *et al,* 2022). These are present in significant concentrations and are extremely important and beneficial to human nutrition and health (Kaskous, 2016). Therefore, camel milk is usually consumed as a fresh or naturally fermented product and is therefore not pasteurised (Mehari *et al,* 2007; Matofari *et al,* 2013; Abera *et al,* 2016; Mwangi *et al,* 2016; Serda *et al,* 2018). But camel milk is an excellent food for the growth of microorganisms (Zangerl, 2007; Matofari *et al,* 2013) and non-heat-treated milk and raw milk products are the main cause of diseases caused by pathogens (De Buyser *et al,* 2001; Smits *et al,* 2023). It is noteworthy that the milk from a healthy udder is usually "sterile" (Johnson *et al,* 2015) because the camel udder is protected by a variety of defence mechanisms such as innate or specific immunity as well as physiological peculiarities and is only contaminated with germs when it passes through the teat canal (Zangerl, 2007). In addition, the germs that get into the milk come from the udder-and teat-surface, the stall, the air, the water, the feed, the milker, and the milking equipment. Contamination of raw camel milk can be very high if udder health is not checked, plastic containers are used during milking and storage, hygiene measures are not carried out during milking, and water is not available to clean the teat and udder before milking (Mulwa *et al,* 2011; Ismaili *et al,* 2019; Atigui *et al,* 2023). During milk transportation, especially when the route is long, and poor and the milk is not refrigerated, the microbial content of the milk multiplies rapidly (Mulwa *et al,* 2011; Ismaili *et al,* 2019). Due to the many contaminated factors, it has been shown that the poor hygiene status in the

SEND REPRINT REQUEST TO SHEHADEH KASKOUS email: skaskous@siliconform.com

production and handling of camel milk as well as the lack of low-cost post-harvest technologies mean that camel milk has lost its potential to improve the living conditions of the camel farmer (Matofari *et al,* 2007; Ismaili *et al,* 2019; Hassen *et al,* 2022) and this limitation leads to losses in quality and quantity after harvest, especially physical-chemical and microbiological deterioration of the milk (Odongo *et al,* 2016; Ismaili *et al,* 2019; Atigui *et al,* 2023). The production of hygienically perfect, ready-to-process milk places high demands on the camel farmer. This means optimal animal husbandry, animal care, good feeding, ideal milking machines and cooling of the milk during storage and transport to deliver consistently high-quality milk to the consumer. To achieve this goal, the transition from traditional production systems to intensive production systems must be accelerated. In the following some aspects of camel milk and its safety for human consumption are presented and discussed.

Composition of camel's milk

The composition of camel milk is different from those of other lactating animals' species particularly due to its protein composition, milk fat structure and mineral and vitamin content (El-Hatmi *et al,* 2015; Abduku and Eshetu, 2024), but it contains all the important nutrients (Farah, 2011; Kanca, 2017; Boujenane, 2020; Swelum, 2021; Lajnaf *et al,* 2023). Camel milk contains the following components: 2.2-4.5% protein, 2.5-5.5% fat, 2.5-5.5 lactose, 0.7-0.95% ash and 8.0-15% total dry matter (El-Hatmi *et al,* 2006; Konuspayeva *et al,* 2009; Kaskous *et al,* 2012; Ali *et al,* 2019; Ismaili *et al,* 2019; Roy *et al,* 2020; Seifu 2022; Kaskous, 2023). However, the composition varies greatly and depends on various factors, such as the breed (type), individual, husbandry and feeding condition, age, milking interval, stage of lactation, number of lactations, season, management, and udder health (Wernery, 2007; Shuiep *et al,* 2008; El-Hatmi *et al,* 2015; Jrad *et al,* 2015; Patel *et al,* 2016; Ismaili *et al,* 2019; Swelum *et al,* 2021; Behrouz *et al,* 2022; Kraimia *et al,* 2024). In general, camel milk has lower amounts of fat, protein, and lactose compared to bovine milk (Smits *et al,* 2011; Konuspayeva *et al,* 2011; Arab *et al,* 2014; Alhaj *et al,* 2022).

Camel milk Proteins

Camel's milk is a rich source of proteins with potential anti-microbial and protective activity (Kaskous and Pfaffl, 2017; Mohamed *et al,* 2020; Lajnaf *et al,* 2023). It was observed that camel milk has 21 different amino acids compared to 18 amino acids in bovines. Such amino acids are the synthesis basis of all proteins in camel milk (Fig 1). Practical results have shown that the average protein content of camel milk under European conditions was 3.34% in the Netherlands (Smits *et al,* 2011), 2.28% in Germany (Kaskous, 2019) and 2.39% in Switzerland (Kaskous, 2023), while the average protein content in camel milk outside Europe was 3.1% (Konuspayeva *et al,* 2009; Al haj and Al Kanhal, 2010). In general, the protein content of camel milk ranges between 2.2 and 4.5% (Konuspayeva *et al,* 2009; Yadav *et al,* 2015; Kula and Dechasa, 2016; Patel *et al,* 2016; Swelum *et al,* 2021; Seifu, 2022). This difference is due to environmental conditions and the availability of food and water for the lactating camels (Yamina *et al,* 2013; Ismaili *et al,* 2019). Camel milk proteins appear as: Casein, whey proteins, fat globule membrane proteins. However, the average casein content and whey protein content of camel milk vary between 1.9 and 2.3% and 0.7 and 1.0%, respectively (Farah, 2011). Caseins make up the highest proportion of the protein fraction in camel milk (Hamed *et al,* 2012; Swelum *et al,* 2021). This represents 65-70% of total proteins compared to an average of 83% in bovine milk (Khaskheli *et al,* 2005; Frister, 2007; Hamed *et al,* 2012). Like cow's milk, casein in camel milk consists of four fractions. These are αs1, αs2, β and k-casein (Al haj and Al kanhal, 2010; Abbas *et al,* 2013). However, camel milk contains more β-casein (75%) than α-casein (21%) of total casein, compared to cows' milk, which contains approximately the same content of β-casein and α-casein (36 and 38%) (Devendra *et al,* 2016; Kappeler *et al,* 2003; Yirda *et al,* 2020). Interestingly, camel milk contains very little k-casein (3.5%) of total casein, compared to the k-casein content (13%) in cow's milk (Devendra *et al,* 2016; Mbye *et al,* 2022). It was observed that whey proteins in camel milk constituted about 30-35% of total protein (Khaskheli *et al,* 2005; Jilo and Tegegne, 2016; Dugassa, 2021; Vincenzetti *et al,* 2022). Camel milk as human milk does not contain β-Lactoglobulins (El-Hatmi *et al,* 2007; Elagamy *et al,* 2009; Kaskous and Pfaffl, 2017; Rahmeh *et al,* 2019). Therefore, α-lactalbumin is the main whey protein in camel milk (Wernery, 2007; Redington *et al,* 2016; Lajnaf *et al,* 2023). Camel milk contains other important components of whey proteins such as serum albumin with a variation of 2.9 and 13.8 g/l (El-Hatmi *et al,* 2006) and lactoferrin with 227-229 mg/l (Konuspayeva *et al,* 2007; Kaskous *et al,* 2012). In addition, several reports have shown that camel milk has higher immunoglobulins (0.72 g/l) than cow's milk (0.47 g/l) (Kaskous and Pfaffl, 2017).

Camel milk fat

The fat content of camel milk varies between 2.5 and 5.5% depending on the nutritional status, stage of lactation, breed and the season of the year (Mal *et al,* 2006; Yamina *et al,* 2013; Devendra *et al,* 2016; Kaskous, 2019; 2023; Abduku and Eshetu, 2024). The fat globules in camel milk are the smallest among all ruminants ranging from 0.1 to 18 micrometers in diameter (El-Zeini, 2006), and these do not naturally aggregate due to the absence of agglutinin (Khalesi *et al,* 2017). 96% of the fat in camel milk is triacylglycerol (Nikkhah, 2011; Dugassa, 2021). Compared to cow's and buffalos' milk, camel milk fat contains lower concentrations of short-chain fatty acids and higher concentration of long-chain fatty acids (C_{14}-C_{18}) (Abu-Lehia, 1989; Konuspayeva *et al,* 2008; Abbas *et al,* 2013; Sara *et al,* 2022). The saturated fatty acid (SFA) in camel milk varied between 50% (Bactrian camel milk) and 60% (dromedary camel milk) of total fatty acids (Rahmeh *et al,* 2019) and about 65% of total fatty acids according to Wang *et al* (2011) and Oselu *et al* (2022). However, the monounsaturated fatty acids (MUFA) in dromedary camel milk were 56-80% of total fatty acids (Medhammar *et al,* 2012). In addition, the proportion of unsaturated fatty acids in camel milk was between 35 and 50% of the total fatty acids (Izadi *et al,* 2019). It is noteworthy that the proportion of unsaturated fatty acids in the fatty acid pattern of camel milk in the intensive production system was 43.1% (Stahl *et al,* 2006). In addition, the fat content in camel milk was found to be highly dependent on the stage of lactation, with the highest concentration occurring in the first three months of lactation (34.67±1.30 g/l), compared to the concentration in the middle (27.40±5.69 g/l) and the end of lactation (29.12±2.83 g/l) (Kraimia *et al,* 2024).

Camel milk lactose

The lactose content in camel milk is not stable, although it is involved in the osmotic pressure in the udder. It is noteworthy that a different mechanism exists in camels, as regular feeding and water are not available in many regions of the world. Therefore, different concentrations of lactose have been found in camel milk. Milk lactose content was observed to be 4.3 ±0.2% higher in camels deprived of water for four days compared to 4.1±0.2% for 16 days (Bekele *et al,* 2011). These results illustrate that the variation in lactose content in camel milk is mainly related to water intake and the type of feed consumed (Al haj and Al kanhal, 2010; Kula and Dechasa, 2016). In general, the lactose content in camel milk varied between 2.5% and 5.5% (Khan and Iqbal, 2001; Konuspayeva *et al,* 2009; Devendra *et al,* 2016; Faraz, 2020; Dugassa, 2021; Alhaj *et al,* 2022; Karaman *et al,* 2022). In addition, lactose content in camel milk was observed to be high in the first months of lactation (42.5 g/l), followed by a significant ($P<0.05$) decrease at the end of lactation (38.35 g/l) (Kraimia *et al,* 2024). At this point, it must be said that the significant change in lactose concentration in camel milk is due to the health of the udder. It is known that in clinical or subclinical mastitis, the lactose content of the milk decreases and new synthesis is reduced (Schulz, 2003). New research has shown that the average lactose content in the milk of a healthy camel udder was around 4.09±0.03% after using new "StimuLactor" milking machines on a practical farm in Switzerland (Kaskous, 2023).

Camel milk vitamins and minerals

Studies on the vitamin content of camel milk have been carried out for a long time (Sawaya *et al,* 1984; Farah *et al,* 1992). Stahl *et al* (2006) found that fresh dromedary milk contains less vitamin A, E, B_1 and β-carotene than cow's milk. An interesting aspect: The vitamin C content in camel milk (34.16 mg/l) was 2 to 3 times higher than in cows' milk (Farah *et al,* 1992) and 6 times higher than in human milk (Gizachew *et al,* 2014). However, the vitamin C content of camel milk was between 24 and 52 mg/kg and was therefore, 2-4 times higher than that of cow's milk (15±6.3 mg/l) (Mehaia, 1994; Stahl, 2005; Kamal and Karoui, 2017). The high vitamin C content in camel milk makes nutritional sense because fruits and vegetables are rarely part of the human diet in dry areas and intake of vitamin C *via* camel milk can help prevent vitamin deficiencies in humans. It has also been found that the lower carotene content makes the colour of camel milk whiter compared to cow's milk (Stahl *et al,* 2006; Devendra *et al,* 2016). In addition, studies using Bactrian camel milk showed that camel milk was rich in vitamin D and riboflavin and consumption of two cups daily provided 160% of the recommended dietary intake of vitamin D (5 µg/day) and riboflavin (0.5 mg/day) (Wijesinha-Bettoni and Burlingame, 2013).

Furthermore, research has shown that camel milk is rich in minerals such as calcium, phosphorus, sodium, potassium, chloride, iodine, and magnesium (Shamsia, 2009; Gizachew *et al,* 2014; Aljumaah *et al,* 2012; Alhadrami and Faye, 2016). The average contents of Ca, K, Mg and Na in camel milk were 1.47±0.38, 0.98±0.24, 0.07± 0.01, and 0.65±0.11 g/l,

respectively (Jrad *et al,* 2015). However, the average ash content in camel milk varied between 7.5 and 8.8 g/l (Jrad *et al,* 2015; Abdel Galil *et al,* 2016). It is noteworthy that the content of iron, zinc and copper in camel milk was higher than in cows' milk (Singh *et al,* 2006). It should be noted that many factors such as breed (type), diet, water consumption and analytical methods can affect the mineral content of camel milk (Mehaia *et al,* 1995; Haddadin *et al,* 2008). A new study has shown that the season can have an impact on the minerals in camel milk (Kraimia *et al,* 2024) (Table 1).

Safe raw camel milk for human consumption

In many countries, particularly in Africa and the Middle East, the consumption of raw camel milk has increased and is often considered as a "health food" with positive effects on digestion, the immune system and for treatment of various diseases (Gonfa *et al,* 2001; Seifu, 2007; Zaitlin *et al,* 2013). According to an online survey of 852 consumers conducted in the United Arab Emirates (UAE), about 58.4% consumed unpasteurised camel milk (Cheikh Ismail *et al,* 2022). The reason for consuming unpasteurised camel milk was that this milk strengthens the immune system and has higher nutritional content (Smits *et al,* 2023). Therefore, raw camel milk was used to treat, alleviate, or prevent health conditions such as diabetes, autism, cancer, dementia, allergies, and parasites (Kaskous, 2016). In Ethiopia, most of camel milk is consumed in the raw state without any heat treatments (Eyassu, 2007; Mehari *et al,* 2007; Roess *et al,* 2023). In the Arabian Peninsula, consumption of unpasteurised camel milk is also common (Omrani *et al,* 2015). Furthermore, fresh and fermented camel milk has been also used in India, Russia, and Sudan for human consumption as well as for treatment of a series of diseases (Kumar *et al,* 2016). Unpasteurised sour camel milk and fresh cow's milk form the core of the Somali diet (Seifu, 2007; Sadler and Catley, 2009; Carruth, 2014). On the other hand, some countries like UAE, Australia and USA warned that camel raw milk was not generally recognised as safe or effective for the therapeutic uses. However, consuming raw or unpasteurised dairy products poses several known risks, especially if refrigeration is not ensured (Zaitlin *et al,* 2013; Carruth *et al,* 2017). The Food and Drug Administration (FDA) in USA warned that if the camel farmer was going to market their product as a "drug", they needed to get federal approval, which would require the farm to provide scientific data demonstrating the safety and effectiveness of their product. Moreover, FDA warned that a consumption of raw camel milk is a health risk, because it is associated with foodborne illness caused by pathogens including *Campylobacter, Escherichia coli, Listeria, Brucella, Staphylococcus* and *Salmonella* (Yamina *et al,* 2013; Swinburne, 2017; Wernery *et al,* 2017; Dadar *et al,* 2019). Based on the observation of Spargue *et al* (2012) that brucellosis a bacterial disease caused by various infectious Brucella

Table 1. Some factors that affect the concentration of minerals in camel milk, according to Kraimia *et al* (2024), with some changes.

Factors		Minerals in camel milk					
		Na (g/l)	K (g/l)	Ca (g/l)	Mg (g/l)	I (g/l)	P (g/l)
Day	Morning	0.39	2.44	1.90	0.07	0.13	0.70
	Evening	0.45	2.39	1.73	0.07	0.13	0.83
	P<0.05			*			**
Stage of lactation	Beginning	0.43	2.63	1.51	0.07	0.15	0.72
	Middle	0.44	2.35	1.67	0.07	0.14	0.65
	End	0.41	2.37	1.75	0.07	0.12	0.69
	P<0.05					*	
Lactation number	1	0.49	2.28	1.67	0.07	0.13	0.63
	2-6	0.46	2.19	1.48	0.07	0.12	0.78
	>6	0.44	2.40	1.66	0.08	0.11	0.66
	P<0.05						
Season	Winter	0.46	2.26	1.48	0.07	0.12	0.66
	Spring	0.39	2.44	1.90	0.07	0.13	0.70
	Summer	0.45	2.38	1.55	0.08	0.15	0.68
	Fall	0.52	2.28	1.61	0.08	0.13	0.77
	P<0.05	***		***	***	**	

*: P<0.05; **: P<0.01; ***: P<0.001

species and is transmitted through both close contact with camels and consumption of raw camel milk. However, camel brucellosis has been diagnosed in all camel-rearing countries except Australia and mainly depends on the management system (Wernery, 2014). Zimmermann (2016) reported that one of the primary risks of camel's milk is consumed in unpasteurised form. Reviewed by Roess *et al* (2023) found that consumption of days-old unrefrigerated raw camel milk was significantly associated with gastrointestinal symptoms. The Saint Louis Institute for conservation medicine studied the consumption of camel milk in northern Kenya, where around 10% of people drink unpasteurised camel milk, exposing themselves to a few animal-based pathogens. The study found a higher prevalence of pathogenic bacteria in raw camel milk than in sheep and cattle milk. Furthermore, Musinga *et al* (2008) found that contaminations of raw camel milk in Kenya can occur along the chain from producers to final consumers and the consumption of raw camel milk should be of major concern to public health. Research in Saudi Arabia and Morocco found that raw camel milk samples were contaminated due to poor handling practices and hygiene conditions (El-Ziney, 2007; Alaoui Ismaili *et al,* 2019). Matofari *et al* (2013) found in Kenya that salmonella enteric occurrence along the camel milk chain had an incidence of 13% with the highest being in the farm environment. The sources of this pathogen may constitute the risk factors that are associated with its prevalence in the environment. However, milk from individuals without clinical or subclinical mastitis may also contain mastitis-causing pathogens, and other factors, such as soil, water, and pastoralists (Elmoslemany *et al,* 2010). Farm management practices and seasonality have also been shown to have a significant impact on the contamination of raw camel milk (Shuiep *et al,* 2008; Smits *et al,* 2023). The control of raw camel milk is an important issue for human consumption (Alebie *et al,* 2021). In fact, pasteurisation is a good preservation method to produce high-quality milk.

Raw camel milk and udder inflammation

Camel udder can get clinical or subclinical mastitis, like other dairy animals (Alebie *et al,* 2021; Rahmeh *et al,* 2022). A high percentage of subclinical mastitis in camels is reported by several authors (Obeid *et al,* 1996; Almaw and Molla, 2000; Wanjohi *et al,* 2013; Niasari-Naslaji *et al,* 2016) and the values varied between 15 and 70% (Bhatt *et al,* 2004; Abera *et al,* 2010; Seifu and Tafesse, 2010; Alamin *et al,* 2013). In general, 46% of the global camel population suffers from mastitis (Aqib *et al,* 2022). It was shown that mastitis pathogens of the dromedary are the same as cultured from the mammary gland of bovines and these are *Streptococcus agalatiae, Staphylococcus aureus, Coagulse- negative Staphylococcus, Streptococcus bovis, Streptococcus uberis, Streptococcus dysagalactia*e (Wernery *et al,* 2008). In the traditional husbandry systems, poor management, and unhygienic milking lead to mastitis in camels (Obeid *et al,* 1996; Almaw and Molla, 2000). The results from Golestan province in Iran have shown that out of 243 camel milk samples from individual quarters (95 milking camels), 18.1% were subclinical mastitis and somatic cell count values beyond 306 x 10^3 cells/ml could be considered as subclinical mastitis in camel (Niasari-Naslaji *et al,* 2016). Bekele and Molla (2001) reported that, out of 152 camels in Afar Region, north-eastern Ethiopia examined, 19 (12.5%) were diagnosed as clinical mastitis cases based on clinical signs and bacteriological examinations. The main mastitis pathogens isolated were *Staphylococcus aurous, coagulate negative staphylococci, Streptococcus agalactiae, S. dysgalactiae,* and other species of *streptococci, Pasteurella haemolytica* and *E. coli*. Similar results have been shown by Wanjohi *et al* (2013) that subclinical mastitis was prevalent in dromedary camels of two districts of north-eastern province of Kenya, and that Gram-positive cocci (*Staphylococcus* and *Streptococcus*) were the dominant mastitis pathogens isolated. Other isolated bacteria were found as *Klebsiella/Enterobacter, Escherichia coli* and *Bacillus*. In addition, *Staphylococcus aureus, Streptococcus agalactiae, Escherichia coli* and *Corynebacterium bovis* were the main pathogens of camel mastitis (Aqib *et al,* 2022). Rahmeh *et al* (2022) found that the genera *Staphylococcus, Streptococcus, Schlegelella,* unclassified *Enterobacteriaceae, Lactococcus, Jeotgalicoccus* and *Klebsiella* were abundant in mastitis milk compared to healthy samples. Abdel Gadir Atif *et al* (2006) have performed comparison of California mastitis test (CMT), somatic cell counts (SCC) and bacteriological examinations for detection of camel mastitis in Ethiopia. A total of 956 quarter milk samples from 253 camels were detected. 59.7% quarter milk samples had microorganisms. A positive correlation was found between CMT scores and bacteriological classes ($P<0.001$) and SCC ($p<0.001$). Detection of subclinical mastitis in dromedary camels using somatic cell counts, California mastitis test and udder pathogen was also done in Saudi Arabia (Saleh and Faye, 2011). A total of 120 quarter milk samples from 30 clinically healthy dromedary camels were cultured. SCC varied from 9000 to 2 000.000

cells/ml with an average of 125000. Intramammary infections were present in most of examined quarter milk samples. The current review by Aqib *et al* (2022) showed the forms of camel mastitis. Clinical mastitis is characterised by hardening and swelling of the udder, pain on palpation, and visible changes in the colour and texture of the milk. Subclinical mastitis is inflammation without obvious signs (El Tigani-Asil *et al,* 2020) that can be detected by CMT, SCC and microbiological examination. It is noteworthy that an increase in SCC above the physiological value not only indicates a problem with udder health, but also leads to reduced milk yield, a change in milk composition, an impairment of milk processing and a change in the bioactive ingredients of camel milk (Kaskous *et al,* 2021)

Based on that, the disease has been reported in numerous camel-producing countries in Africa and Asi (Aqib *et al,* 2022). The following table presents the results of some works on contaminated udder quarters with microorganisms (Table 2).

In Sudan, raw camel milk samples were collected and the isolated aerobic bacteria (115 isolates) were identified as Gram-negative (85.26%), while 14.73% of samples were Gram-positive. The authors emphasised that raw camel milk is a source of many bacteria which may lead to health hazards for men (Elhaj *et al,* 2014). In the southern province of Jordan, raw camel milk samples were collected from 90 dromedary camels. About 21% of the camels revealed clinical signs of mastitis. The most predominant bacteria isolates were *Staphylococcus aureus*, *Streptococcus* spp. *Micrococcus* spp. and *Corynebacterium* spp. (Hawari and Hassawi, 2008). The microbial quality of raw camel milk in United Arab Emirates was investigated, 50 samples were analysed for: Aerobic plates count, total coliform, total *Staphylococcus aureus*, total yeast, and Mold. The results indicated that the mean value of aerobic plate count was 1.8×10^5 cfu/ml, the mean value of total coliform was 6.8×10^{-1}, the mean value of *Staphylococcus aureus* was 1.2×10^3, and the yeast mean value was 4.1×10^{-1} cfu/ml (Omer and Eltinay, 2008). Furthermore, it should also be noted that the calf may be a source of prevalence of microbes in camel milk. So, in many countries, the calf will have their mother suckle to induce the milk ejection reflex. But the calf may compromise the udder hygiene since

Table 2. Raw camel milk with subclinical and clinical mastitis in some countries.

Country	Number of milk samples (quarter or udder)	Positive samples of subclinical or clinical mastitis (%)	References
Egypt	90 (udder)	87.78	Asfour and Anwer (2015)
Ethiopia	956 (quarter)	59.7%	Abdel Gadir Atif *et al* (2006)
Ethiopia	205 (quarter)	37.6%	Abdurahman (2006)
Ethiopia	145 (udder)	29%	Abera *et al* (2010)
Ethiopia	47 (udder)	76.60%	Abera *et al* (2016)
Ethiopia	543 (quarter)	63%	Bekele and Molla (2001)
Ethiopia	34 (udder)	5.88 %	Hadush *et al* (2008)
Ethiopia	374 (quarter)	8.9%	Alebie *et al* (2021)
Iran	243 (95)	18.1%	Niasari-Naslaji *et al* (2016)
Jordan	90 (udder)	21%	Hawari and Hassawi (2008)
Kenya	86 (quarter)	81.4%	Guliye *et al* (2002)
Kenya	107 (udder)	66%	Matofari *et al* (2013)
Kenya	66 (udder)	Most of examined quarter milk samples	Odongo *et al* (2016)
Kenya	380 (quarter)	44.5%	Toroitich *et al* (2017)
Kenya	207 (udder)	23%	Younan *et al* (2001)
Kenya	384 (udder)	61.2%	Wanjohi *et al* (2013)
Kuwait	25 (udder)	36%	Rahmeh *et al* 2022
Saudi Arabia	120 (quarter)	Most of examined quarter milk samples	Saleh and Faye (2011)
Saudi Arabia	740 (quarter)	33 % of tested quarters had subclinical mastitis based on CMT	Al Jumaah *et al* (2012)
Sudan	160 (udder)	71.9%	Elhaj *et al* (2014)
Sudan	391 (quarter)	43.5%	Abdurahman *et al* (1995)

after suckling no cleaning of the udder before milking is done (Noor *et al,* 2013). Several lines of evidence suggest that the risk factors for camel mastitis were severe tick infestation, teat injuries, poor milking hygiene and physiological disorders (Ahmad *et al,* 2012; Aqib *et al,* 2022). Finally, the negative effects of mastitis on camel owners include a reduction in milk production, deterioration in milk quality, a decrease in milk price due to high SCC, loss of milk due to antibiotic treatment, and increased animal care costs (Hertl *et al,* 2010; Tuteja *et al,* 2013).

Using a milking machine to obtain safe raw camel milk for consumption.

Usually, camels are milked by hand in most countries of the world in traditional farming systems (Bekele *et al,* 2002; Alhadrami and Faye, 2016; Atigui *et al,* 2023). The introduction of machine milking makes only slow progress and is limited to intensive dairy camel farms in a few countries (Kaskous and Fadlelmoula, 2014). To improve the quality and the safety of raw camel milk, machine milking must be used instead of hand milking (Hammadi *et al,* 2010; Nagy and Juhasz, 2016; Kaskous, 2018a, 2019). Saleh *et al* (2013) showed a clear difference between two milking methods in terms of udder health and milk quality. Therefore, microbiological contamination was higher in farms with hand milking than in farms with machine milking (Table 3).

Table 3. Bacteriological finding of camel milk samples in two farms with different milking methods (Saleh *et al,* 2013).

Parameters	Farm with machine Milking	Farm with hand milking
Number of Camels	14	14
Duration of the investigation	6 months after calving	6 months after calving
Total samples	84 (100%)	84 (100%)
Uninfected samples	65 (77.4%)	53 (63.1)
Coagulase-negative Staphylococci	15 (17.8%)	22 (26.2%)
Staphylococcus aureus	-	3 (3.6%)
Micrococcus	4 (4.8%)	6 (7.1%)

However, it must be noted that many milking machines used do not succeed in completely emptying the udder. The amount of residual milk after machine milking was high (up to 30% or even more) (Kaskous, 2018b). Review by Ayadi *et al* (2013) clearly showed that low fat levels were observed in milk during mechanical milking, indicating incomplete milk letdown. In addition, it has also been found that improper use of the milking machine, especially improper use of liners, can damage the camel's udder, lead to oedema, and promote the colonisation of *Staphylococcus aureus* during the time of machine milking (Juhasz and Nagy, 2008). Results from Tunisia have shown, that the use of machine milking in the field was associated with higher milk yields, but also resulted in increased microbial contamination compared to hand milking (Atigui *et al,* 2023). Kaskous (2023) has shown reverse results that no pathogenic bacteria were detected in the milk produced after using the milking machine (StimuLactor). Improper use of the milking machine is known to have negative effects on udder health as the udder cannot be completely emptied (Kaskous and Pfaffl, 2023). As a result, the remaining milk after milking can serve as a substrate for pathogens and increase the risk of mastitis (Bruckmaier and Wellnitz, 2008). Therefore, completely emptying the udder during milking promotes milk synthesis and secretion and ensures that the udder remains healthy.

As the market is looking for a suitable milking machine for camels, a special modern milking machine called "StimuLactor" was developed by Siliconform, Germany in 2018, which has been used in practice since then (Fig 2). This milking machine for camels was necessary to enable rapid and complete milk extraction during milking and to maintain udder health. A field study showed that the udder remained healthy and completely emptied after using the "StimuLactor" milking machine (Kaskous, 2019), since this milking machine has been adapted to the anatomical, morphological, and physiological characteristics of the camel's udder.

Training on the milking machine is an important point because by getting the camels used to machine milking, their stress behaviour is reduced, their milk production is increased and the milking time is normalised (Brahmi *et al,* 2024).

Finally, maintaining healthy udders and teats during milking is a key component of an effective milking machine to achieve good and higher quality milk production by preventing mastitis and maintaining animal welfare. In this way, we can help provide consumers with good and safe camel milk.

Factors affecting safe raw camel milk after harvest

Raw camel milk is a natural food that can be contaminated with microbiota in the chain from the milking to the consumer as the milk is very good

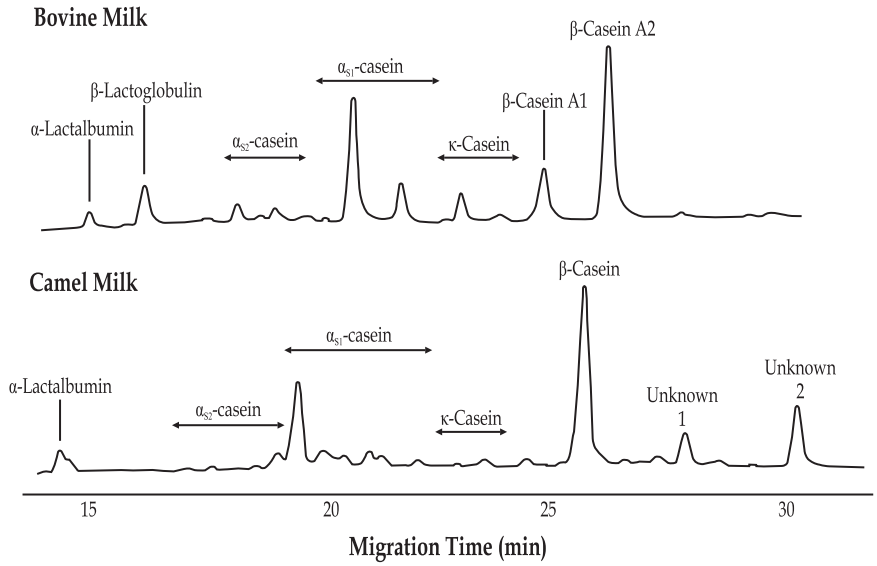

Fig 1. Representative electropherogram of bovine and dromedary camel milk samples determined by capillary electrophoresis according to Mohamed *et al* (2020).

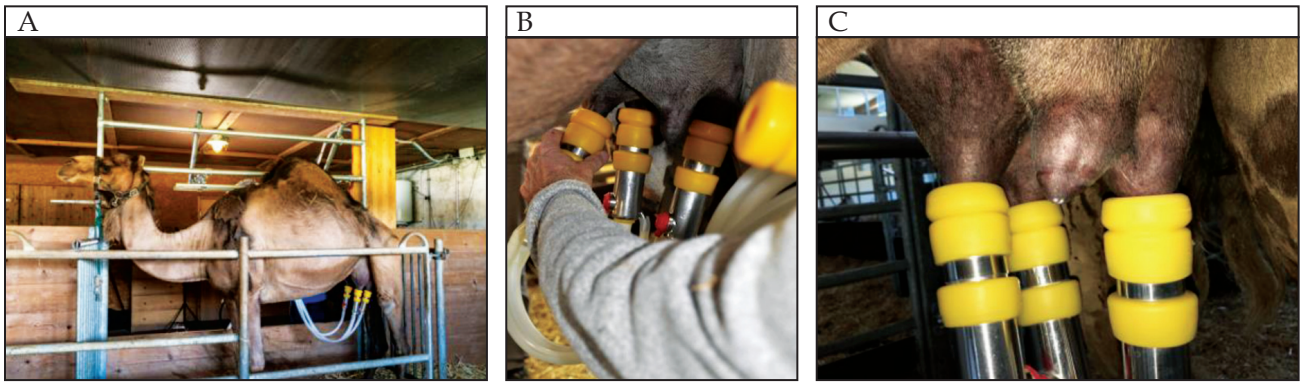

Fig 2. A: A StimuLactor milking machine during milking in camel farm, B+C: Attach milk teat cups.

suitable liquid for these microbiotas (Mohammed *et al,* 2016; Kaskous, 2018a). Therefore, a great deal of research has been done to determine the prevalence of microbial content in the raw camel milk after harvesting from the healthy udder (Wanjohi *et al,* 2013; Matofari *et al,* 2013; Odongo *et al,* 2016; Serda *et al,* 2018; Ismaili *et al,* 2019). Autochthonous microbiota from the exterior of the camel's udder and teats can contribute to the contamination as well as microbiota that are derived from the environment in which the camel is housed and milked (Bachmann,1992; Bekele and Molla, 2001; Hawari and Hassawi, 2008; Omer and Eltinay, 2008; Wanjohi *et al,* 2013; Atigui *et al,* 2023). However, most important it appears to be the contribution of microbiota from teats soiled with manure, mud, and feed. Teats and udders of camels inevitably become contaminated while they are lying or when allowed in dirty lots. The influence of dirty camels on total bacteria counts depends on the extent of soiling of the teat surface and the udder prep procedures employed. Such microbiota could be reduced if hygiene measures were implemented during milking. However, many milkers or camel owners did not adhere to the hygiene measures during milking (Hassen *et al,* 2022). This means that the milk can become contaminated after it leaves the streak canal. Therefore, due to the traditional nature of camel milk production and the lack of appropriate hygiene measures, there is a high risk of milk contamination with microbiota in the milk production sector in many developing countries (Getachew, 2003). The factors that increase microbiota contamination are mainly due to the high ambient temperatures coupled with a lack of on-farm refrigeration, long distances to markets and a lack of transportation options (Husein *et al,* 2016). Matofari *et al* (2013) reported that camel milk is less contaminated at farm because it has not undergone

many handlers. The only contamination at this stage may come from the infected udder mostly caused by the cocci group. Abera *et al* (2016) reported that the two dominant factors of the quality of camel raw milk after harvesting are the condition of keeping the product and the time before delivery to the consumer. In any case, a high number of microbiotas in the collected milk samples is an indication of unhygienic milk production conditions (Abdurahman, 2006; Kamal *et al,* 2010). It is noteworthy that many farmers store their raw camel milk in plastic canisters after harvest (Hassen *et al,* 2022). An interesting aspect was that 66% of raw camel milk samples at the farm (Production area) had a microbial load less than 10^5 cfu/ml, compared to 54% at the collection point (bulk tank) and marketing where the microbial load was above 10^6 cfu/ml (Matofari *et al,* 2013). In addition, bicycles, donkeys, and existing vehicles were used to transport raw camel milk from production areas in Kenya to collection or market centres 10 to 20 km away. The ambient temperature in the production areas and on the transport, route was around 39 °C. The raw camel milk reaches the collection points in 2 to 3 hours and the large markets in the cities in 6 to 8 hours (Matofari *et al,* 2013). Through these transportation processes, the raw camel milk could maintain millions of microbiotas, and when this raw camel milk is consumed, the health situation will be severely affected. In this context, Husein *et al* (2016) reported that consuming raw camel milk from production areas was less dangerous than consuming raw camel milk from the market. Furthermore, Abera *et al* (2016) found that about 85.7% of raw camel milk samples in Somali Regional State of Ethiopia were bacterially contaminated and the total bacterial count (TBC) of the contaminated raw camel milk samples was on average 4.75±0.17 log cfu/ml. These bacteria multiply rapidly from the udder to the market. These results indicate that there was a lack of hygiene in the production and milking areas, during transport, and during sale of raw camel milk. A new study in Nigeria has shown that milk samples were taken from five healthy dromedaries and the microbiota *Escherichia coli, Salmonella* in the first camel and *Staphylococcus aureus* in the remaining camels were found (Dogondaji *et al,* 2023). The authors emphasise that the consumption of raw camel milk should therefore, be done with caution. Kaskous (2019) found that by adhering to hygienic measures, good, safe raw camel milk with normal composition was obtained. Therefore, hygiene measures must also be observed after the harvest in order to maintain the quality standard of raw camel milk.

Conclusion

- Regarding the importance of camel milk and the associated related health benefits of its bioactive ingredients, improvements in milking hygiene, milk storage and transport conditions are required to ensure the quality of camel milk meets consumer needs.
- Camels must be kept healthy and raw milk must be refrigerated immediately after milking and during storage and transport.
- The used milking system should adapt to the morphological, anatomical, and physiological characteristics of the udder and teat of the lactating camels and it should achieve a physiologically ideal milking process that meets high animal welfare standards and increases milk production with a high-quality standard.
- To obtain safe camel milk for human consumption, it is recommended to consume pasteurised camel milk.

References

Abbas S, Ashraf H, Nazir DA and Sarfraz DL. Physiochemical analysis, and composition of camel milk. International Research Journal. 2013; 2:83-98.

Abdel Gader AGM and Alhaider AA. The unique medicinal properties of camel products: A review of the scientific evidence. Journal of Taibah University Medical Sciences. 2016; 11(2):98-103.

Abdel Gadir Atif E, Hildebrandt G, Kleer JN, Molla B, Kyule MN and Baumann MP. Comparison of California Mastitis Test (CMT), somatic cell counts (SCC) and bacteriological examinations for detection of camel (*Camelus dromedarius*) mastitis in Ethiopia. Berliner und Münchener Tierärztliche Wochenschrift. 2006; 119(1-2):45-49.

Abduku H and Eshetu M. Physico-chemical properties and processing characteristics of camel milk as compared with other dairy species: A review. Asian Journal of Dairy and Food Research. 2024; 43(1):1-7.

Abdurahman OA, Agab H, Abbas B and Aström G. Relations between udder infection and somatic cells in camel (*Camelus dromedarius*) milk. Acta Veterinaria Scandinavica. 1995; 36(4):423-431.

Abdurahman OA. Udder health and milk quality among camels in the Errer Valley of eastern Ethiopia. Livestock Research for Rural Development. 2006; 18: Article 110.

Abera M, Abdi O, Abunna F and Megersa B. Udder health problems and major bacterial causes of camel mastitis in Jijiga, eastern Ethiopia: implication for impacting food security. Tropical Animal Health and Production. 2010; 42:341-347.

Abera T, Legesse Y, Mummed B and Urga B. Bacteriological quality of raw camel milk along the market value chain in Fafen zone, Ethiopian Somali regional state. BMC Research Notes. 2016; 9:285-290.

Abu-Lehia IH. Physical and chemical characteristics of camel milk fat and its fraction. Food Chemistry. 1989; 34(4):261-267.

Ahmad S, Yaqoob M, Bilal MQ, Khan MK, Muhammad G, Yang LG and Tariq M. Factors affecting yield and composition of camel milk kept under desert conditions of central Punjab, Pakistan. Tropical Animal Health and Production. 2012; 44:1403-1410.

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

Alamin MA, Alqurashi AM, Elsheikh AS and Yasin TE. Mastitis incidence and bacterial causative agents isolated from lactating she-camel (*Camelus dromedarius*). IOSR Journal of Agriculture Veterinary Science. 2013; 2:7-10.

Alaoui Ismaili M, Saidi B, Zahar M, Hamama A and Ezzaier R. Composition and microbial quality of raw camel milk produced in Morocco. Journal of the Saudi Society of Agricultural Sciences. 2019; 18:17-21.

Alebie A, Molla A, Adugna W, Tesfaye A and Ejo M. Prevalence, isolation, identification, and risk factors of major bacterial cause of camel subclinical mastitis. BioMed Research International. 2021; 5522331.

Alhadrami GA and Faye B. Animals that produce dairy foods: Camel. Reference Module in Food Science. Elsevier, 1st Ed. 2016; pp 1-12.

Alhaj OA, Lajnaf R, Jrad Z, Alshuniaber MA, Jahrami HA and Serag El-Din MF. Comparison of ethanol stability and chemical composition of camel milk from five samples. Animals. 2022; 12(5):1-11.

Ali W, Akyol E, Ceyhan A, Dilawar S, Firdous A, Qasim MZ and Ahmad MM. Milk production and composition in camel and its beneficial uses: A review. Turkish Journal of Agriculture - Food Science and Technology. 2019; 7(12):2142-2147.

Aljumaah RS, Almutairi FF, Ismail E, Alshaikh MA, Sami A and Ayadi M. Effects of production system, breed, parity, and stage of lactation on milk composition of dromedary camels in Saudi Arabia. Journal of Animal and Veterinary Advances. 2012; 11:141-147.

Almaw G and Molla B. Prevalence and aetiology of mastitis in camels (*Camelus dromedarius*) in Iraq. Journal of Camel Practice and Research. 2000; 7:97-100.

Aqib AI, Muzammil I, Naseer MA, Shoaib M, Bakht P, Zaheer T, Khan YR, Khan RL, Usman M, Shafeeq M, Tanveer Q, Hussain HI, Saleem A and Prince K. Pathological insights into camel mastitis. Acta Tropica. 2022; 231: 106415.

Arab HH, Salama SA, Eid AH, Omar HA, Arafa E-SA and Maghrabi IA. Camel's milk ameliorates TNBS-induced colitis in rats via downregulation of inflammatory cytokines and oxidative stress. Food and Chemical Toxicology. 2014; 69:294-302.

Asfour HAE and Anwer AM. Some bacteriological and immunological studies on camel's milk. Alexandria Journal of Veterinary Sciences. 2015; 47:38-46.

Atigui M, Fguiri I, Arroum S, Brahmi M, Ghzaiel B and Hammadi M. Effect of milking routines and hygiene practices and evolution along the market value chain on raw camel milk quality in Tunisia. Italian Journal of Animal Science. 2023; 22:337-346.

Ayadi M, Aljumaah RS, Musaad A, Samara EM, Abdelrahman MM, Alshaikh MA, Saleh SK and Faye B. Relationship between udder morphology traits, alveolar and cisternal milk compartments and machine milking performance of dairy camels (*Camelus dromedarius*). Spanish Journal of Agriculture Research. 2013; 11(3):790-797.

Bachmann T. Quality control at reception. In: Handbook on Milk Collection in Warm Developing Countries. IDF, Brussels. 1992; pp 1-12.

Behrouz S, Saadat S, Memarzia A, Sarir H, Folkerts G and Boskabady MH. The antioxidant, anti-inflammatory and immunomodulatory effects of camel milk. Front. Immunology. 2022; 13:855342.

Bekele T and Molla B. Mastitis in lactating camels (*Camelus dromedarius*) in Afar Region, north-eastern Ethiopia. Berliner und Münchener Tierärztliche Wochenschrift. 2001; 114(5-6):169-172.

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

Bekele T, Zeleke M and Baars RMT. Milk production performance of the one humped camel (*Camelus dromedarius*) under pastoral management in semi-arid eastern Ethiopia. Livestock Production Science. 2002; 76:37-44.

Bhatt L, Chahar A, Tuteja FC and Verma D. Prevalence aetiology and antibiogram of subclinical mastitis isolates from camel. Veterinary Practitioner. 2004; 5:61-65.

Boudalia S, Gueroui Y, Zebsa R, Arbia T, Chiheb AE, Benada M, Hadri Z, Youcefi A and Bousbia A. Camel livestock in the Algerian Sahara under the context of climate change: Milk properties and livestock production practices. Journal of Agriculture and Food Research. 2023; 11:100528.

Boujenane I. Review of milk let-down in camels and proposition of a milk recording method. Tropical Animal Health and Production. 2020; 52(6):2845-2853.

Brahmi M, Atigui M, Hammadi I, Seddik M-M, Ben Salem W, Marnet P-G and Hammadi M. Effect of camel's previous experience on behavioural response and milk production during training to machine milking. Applied Animal Behaviour Science. 2024; 270:106118.

Bruckmaier R and Wellnitz O. Induction of milk ejection and milk removal in different production systems. Journal of Animal Science. 2008; 86:15-20.

Carruth L, Roess AA, Mekonnen YT, Hosh FM and Salman MD. Antimicrobial resistance and food safety in Africa. The Lancet Infectious Diseases. 2017; 7(6):575-576.

Carruth L. Camel milk, amoxicillin, and a prayer: medical pluralism and medical humanitarian aid in the Somali region of Ethiopia. Social Science and Medicine. 2014; 120:405-412.

Chamekh L, Khorchani T, Dbara M, Hammadi M and Yahyaoui MH. Factors affecting milk yield and composition of Tunisian camels (*Camelus dromedarius*) over complete lactation. Tropical Animal Health and Production. 2020; 52:3187-3194.

Chekh Ismail L, Osaili TM, Mohamad MN, Zakaria H, Ali A, Tarek A, Ashfaq A, Al Abdouli MA, Saleh ST, Daour RA, Alrajaby R, Stojanovska L and Al Dhaheri AS. Camel milk consumption patterns and perceptions in the UAE: A cross-sectional study. Journal of Nutritional Science. 2022; 21(11):e59

Dadar M, Shahali Y and Whatmore AM. Human brucellosis caused by raw dairy products: a review on the occurrence, major risk factors and prevention. International Journal of Food Microbiology. 2019; 292:39-47.

Davati N, Yazdi FT, Zibaee S, Shahidi F and Edalatian MR. Study of lactic acid bacteria community from raw milk of Iranian one humped camel and evaluation of their probiotic properties. Jundishapur Journal of Microbiology. 2015; 8(5):1-6.

De Buyser ML, Dufour B, Maire M and Lafarge V. Implication of milk and milk products in food-borne disease in France and different industrialised countries. International Journal of Food Microbiology. 2001; 67:1-17.

Devendra K, Verma KA, Chatli MK, Singh R, Kumar P, Mehta N and Malav OP. Camels milk: Alternative milk for human consumption and its health benefits. Nutrition and Food Science. 2016; 46:217-227.

Dogondaji RA, Lawal M, Wasagu RSU, Yakubu A and Umar S. Microbial assessment of raw milk of some female camels (*Camelus dromedarius*) in Sokoto, Nigeria. PSM Microbiology. 2023; 8(1):1-8.

Dugassa D. Quality and therapeutic aspect of camel milk: A review. Journal of Food Processing and Technology. 2021; 12(8):Nr. 902.

El Tigani-Asil ETA, Abdelwahab GE, Veedu JTVP, Khalafalla AI, Mohamed ZSA, Ishag HZA, Shah AAM, Alhosani MAA and Muhairi SSM. Gangrenous mastitis in dromedary camels in UAE caused by *Streptococcus agalactiae*. BMC Veterinary Research. 2020; 16:174-178.

Elagamy EI, Nawar M, Shamsia SM, Awad S and Haenlein GF. Are camel milk proteins convenient to the nutrition of cow milk allergic children? Small Ruminant Research. 2009; 82:1-6.

Elhaj AE, Freigoun, Somaya AB and Mohamed TT. Aerobic bacteria and fungi associated with raw camel's milk. Online Journal of Animal and Feed Research. 2014; 4(1):15-17.

El-Hatmi H, Girardet J-M, Gaillard J-L, Yahyaoui MH and Attia H. Characterisation of whey proteins of camel (*Camelus dromedarius*) milk and colostrum. Small Ruminant Research. 2007; 70:267-271.

El-Hatmi H, Jrad Z, Salhi I, Aguibi A, Nadri A and Khorchani T. Comparison of composition and whey protein fractions of human, camel, donkey, goat, and cow's milk. Mljekarstvo/Dairy. 2015; 65:159-167.

El-Hatmi H, Levieux A and Levieux D. Camel (*Camelus dromedarus*) immunoglobulin G, α-lactalbumin, serum albumin and lactoferrin in colostrum and milk during the early post-partum period. Journal of Dairy Research. 2006; 73(3):288-293.

Elmoslemany AM, Keefe GP, Dohoo IR, Wichtel JJ, Stryhn H and Dingwell RT. The association between bulk tank milk analysis for raw milk quality and on-farm management practices. Preventive Veterinary Medicine. 2010; 95:32-40.

El-Zeini HM. Microstructure, rheological and geometrical properties of fat globules of milk from different animal species. Polish Journal of Food and Nutrition Sciences. 2006; 56(2):147-154.

El-Ziney MG. Microbiological quality and safety assessment of camel milk (*Camelus dromedarius*) in Saudi Arabia (Qassim region). Applied Ecology and Environmental Research. 2007; 5:115-122.

Eyassu S. Handling, preservation and utilization of camel milk and camel milk products in Shinile and Jigiiga Zones, Eastern Ethiopia. Livestock Research for Rural Development. 2007; 19(6): Article 86.

FAO stat. World Food and Agriculture-Statistical Yearbook. Rome, Italy, 2022; pp 184-188.

Farah Z, Rettenmaier R and Atkins D. Vitamin content of camel milk. International Journal for Vitamin and Nutrition Research. 1992; 62(1): 30-33.

Farah Z. Camel milk. In: Fuquay JW, Fox PF, McSweeney PLH, Encyclopaedia of Dairy Sciences. 2nd Ed., London, UK: Academic Press, 2011; pp 512-517.

Faraz A. Composition of camel milk: A Blessing for Health. Annals of Public Health and Epidemiology. 2020; 1(2): APHE.MS.ID.000509.

Frister H. Zusammensetzung der Milch, In: Krömker, V. Kurzes Lehrbuch Milchkunde und Milchhygiene. Parey, MVS Medizinverlag Stuttgart GmbH. 2007; pp 80-101.

Getachew F. Milk and dairy products, post-harvest losses and food safety in sub–Saharan Africa and the near east. Assessments Reports in the dairy sub sector in Ethiopia. Action programme for the prevention of food losses. FAO, Rom. 2003; pp 1-60.

Gizachew A, Teha J, Birhanu T and Nekemete E. Review on medicinal and nutritional values of camel milk. Natural Science. 2014; 12(12):35-41.

Gonfa A, Foster HA and Holzapfel WH. Field survey and literature review on traditional fermented milk products of Ethiopia. International Journal of Food Microbiology. 2001; 68:173-186.

Guliye AY, Van Creveld C and Yagil R. Detection of subclinical mastitis in dromedary camels (*Camelus dromedarius*) using somatic cell counts and the N-acety-beta-D-glucosaminidase test. Tropical Animal Health and Production. 2002; 34(2):95-104.

Haddadin MS, Gammoh SI and Robinson RK. Seasonal variation in the chemical composition of camel milk in Jordan. Journal of Dairy Research. 2008; 75(1):8-12.

Hadush B, Kebede E and Kidanu H. Assessment of bacteriological quality of raw camels' milk in Ab-Ala,

north eastern Ethiopia. Livestock Research for Rural Development. 2008; 20(9):Article 151.

Hamed H, Trujillo A-J, Juan B, Guamis B, Elfeki A and Gargouri A. Interrelationships between somatic cell count, lactation stage and lactation number and their influence on plasmin activity and protein fraction distribution in dromedary (*Camelus dromedarius*) and cow milk. Small Ruminant Research. 2012; 105:300-307.

Hammadi M, Atigue M, Ayadi M, Barmat A, Belgacem A, Khaldi G and Khorchani T. Training and short time effects of machine milking on milk yield and milk composition in Tunisian Maghrebi camels (*Camelus dromedarius*). Journal of Camel Practice and Research. 2010; 17(1):1-7.

Hassen M, Amentie T, Abdimahad K, Maalin A and Mahamed A. Hygienic production, and post-harvest handling practices of raw camel milk in Degahbour District of Jarar Zone, Somali Regional State, Ethiopia. Open Journal of Animal Sciences. 2022; 12:303-316.

Hawari AD and Hassawi DS. Mastitis in one humped she-camels (*Camelus dromedarius*) in Jordan. Journal of Biological Science. 2008; 8:958-961.

Hertl JA, Grohn Yrjo, Leach JdG, Bar D, Bennett GJ, Gonzalez RN, Rauch BJ, Welcome FL, Tauer LW and Schukken YH. Effects of clinical mastitis caused by gram-positive and gram-negative bacteria and other organisms on the probability of conception in New York State Holstein dairy cows. Journal of Dairy Science. 2010; 93:1551-1560.

Husein M, Selamawit H, Ashenafi G, Fikre Z and Ashenafi F. Assessment on safety status of camel raw milk marketed in samara-logia town of afar National regional state, northeast Ethiopia. Food Science and Quality Management. 2016; 49:80-88.

Ismaili MA, Saidi B, Zahar M, Hamama A and Ezzaier R. Composition, and microbial quality of raw camel milk produced in Morocco. Journal of the Saudi Society of Agricultural Science. 2019; 18:17-21.

Izadi A, Khedmat L and Mojtahedi SY. Nutritional and therapeutic perspectives of camel's milk and its protein hydrolysates: a review on versatile bio functional properties. Journal of Functional Foods. 2019; 60(2):103441.

Jilo K and Tegegne D. Chemical composition and medicinal values of camel milk. International Journal of Research in BioSciences. 2016; 4(4):13-25.

Johnson B, Joseph M, Jose Sh, Jose S, Kinne J and Wernery U. The microflora of teat canals and udder cisterns in nonlactating dromedaries. Journal of Camel Practice and Research. 2015; 22(1):55-59.

Jrad Z, Oulahal N, Adt I, Khorchani T, Degraeve P and El-Hatmi H. Camel colostrum: Nutritional composition and improvement of the antimicrobial activity after enzymatic hydrolysis. Emirates Journal of Food and Agriculture. 2015; 27(4):384-389.

Juhasz J and Nagy P. Challenges in the development of a large-scale milking system for dromedary camels. In: Nagy P, Huszenicza G, and Juhasz J (Eds.) WBC/ ICAR Satellite Meeting on Camelid Reproduction, Budapest, Hungary. 2008; pp 1-4

Kamal M and Karoui R. Monitoring of mild heat treatment of camel milk by front-face fluorescence spectroscopy. LWT-Food Science and Technology. 2017; 79:586-593.

Kamal ZL, Kamal ZA and Heydar NA. Total bacteria, coliforms and the *Staphylococcus aureus* bacteria count of raw milk (from farms to the processing factory), and pasteurised milk in Khuzestan province. The 4th Congress on Animal Science, Tehran, Iran. 2010; pp 21-18.

Kanca H. Milk production and composition in ruminants under heat stress. In: Watson RR, Collier RJ, Preedy VR, Nutrients in dairy and their implications for health and disease. London, UK, Elsevier, 2017; pp 97-109.

Kappeler S, Farah Z and Puhan Z. 5-Flanking regions of camel milk genes are highly similar to homologue regions of other species and can be divided into two distinct groups. Journal of Dairy Science. 2003; 86:498-508.

Karaman A, Akgül FY, Ogut S, Canbay HS and Alvarez V. Gross composition of raw camel's milk produced in Turkey. Food Sci. Technol. Campinas. 2022; 42:e59820.

Kaskous S and Fadlelmoula AA. The challenge of machine milking in dromedary camel. Scientific Journal of Review. 2014; 3(2):1004-1017.

Kaskous S and Pfaffl M. Bioactive properties of minor camel milk ingredients- an Overview. Journal of Camel Practice and Research. 2017; 24(1):15-26

Kaskous S and Pfaffl MW. Milking machine settings and liner design are important to improve milking efficiency and lactating animal welfare-Technical note. Agri Engineering. 2023; 5:1314-1326.

Kaskous S, Alasaad A, Nouh A, Mohamed U, Sauerwein H and Bruckmaier RM. The concentration of lactoferrin and other milk constituents in Syrian Shami camel during different lactation seasons. Journal of Agriculture Sciences, Damascus University. 2012; 28(2):273-287.

Kaskous S, Al-Momani AQ, Al-Yacoub AN and Al-Najjar KA. Physiological perspective of milk somatic cell counts in lactating camels. Journal of Camel Practice and Research. 2021; 28(3):319-325.

Kaskous S. A quarter individual milking machine "Stimu Lactor" in a camel farm in Switzerland: According to field Study. Journal of Camel Practice and Research. 2023; 30(3):267-271.

Kaskous S. 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. 2019; 6(2):172-181.

Kaskous S. Importance of camel milk for human health. Emirates Journal of Food and Agriculture. 2016; 28(3):158-163.

Kaskous S. Physiology of lactation and machine milking in dromedary she-camel. Emirates Journal of Food and Agriculture. 2018b; 30(4):295-303.

Kaskous S. Sources of contamination of raw camel milk with microorganisms. Conference "Tropentag" Global food security and food safety: The Role of Universities. Ghent, Belgium, September 17-19, 2018a, pp 251.

Khalesi M, Salami M, Moslehishad M, Winterburn J and Moosave-Movahedi AA. Biomolecular content of camel milk: A traditional superfood towards future healthcare industry. Trends in Food Science and Technology. 2017; 62:49-58.

Khan BB and Iqbal A. Production and composition of camel milk-review. Pakistan Journal of Agricultural Sciences. 2001; 38(3-4):64-68.

Khaskheli M, Arain MA, Chaudhry S, Soomro AH and Qureshi TA. Physioco- chemical quality of camel milk. Journal of Agriculture and Social Science. 2005; 2:164-166.

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

Konuspayeva G, Faye B, Loiseau G and Levieux D. Lactoferrin and Immunoglobulin contents in camels' milk (*Camelus bactrianus*, *Camelus dromedarius*, and hybrids) from Kazakhstan. Journal of Dairy Science. 2007; 90:38-46.

Konuspayeva G, Faye B, Pauw ED and Focant J-F. Level and trends of PCDD/Fs and PCBs in camel milk (*Camelus bactrianus* and *Camelus dromedarius*) from Kazakhstan. Chemosphere. 2011; 85:351-360.

Konuspayeva G, Lemarie E, Faye B, Loiseau G and Montet D. Fatty acid and cholesterol composition of camels (*Camelus bactrianus*, *Camelus dromedarius* and hybrids) milk in Kazakhstan. Dairy Science and Technology. 2008; 88(3):327.340.

Kraimia M, Adamou A, Boudjenah-Haroun S and Benaissa MH. Factors influencing the physicochemical and mineral composition of camel milk in eastern Algeria. Journal of Camel Practice and Research. 2024; 31(1):17-24.

Kula JT and Dechasa T. Chemical composition and medicinal values of camel milk. International Journal of Research in Biosciences. 2016; 4:13-25.

Kumar D, Verma AK, Chatli MK, Singh R, Kumar P, Mehta N and Malav OP. Camel milk: alternative milk for human consumption and its health benefits. Nutrition and Food Science. 2016; 46(2):217-227.

Lajnaf R, Attia H and Ayadi MA. Technological properties, and biological activities of camel α-lactalbumin-A review. International Dairy Journal. 2023; 139:105563.

Mal G, Dande S and Sahani MS. Milk production potential and keeping quality of camel milk. Journal of Camel Practice and Research. 2006; 13(2):175-178.

Matofari JW, Shalo PL, Younan M, Nanua JN, Adonogo A and Qabale Misiko BN Analysis of microbial quality and safety of camel (*Camelus dromedarius*) milk chain and implications in Kenya. Journal of Agricultural Extension and Rural Development. 2013; 5(3):50-54.

Matofari JW, Shitandi A, Shalo PL, Nanua NJ and Younan M. A Survey of *Salmonella* enteric contamination of camel milk in Kenya. African Journal of Microbiological Resources. 2007; 1(4):46-50.

Mbye M, Ayyash M, Abu-Jdayil B and Kamal-Eldin A. The texture of camel milk cheese: effect of milk composition, coagulants, and processing conditions. Front. Nutr. 2022; 9:868320.

Medhammar E, Wijesinha-Bettoni R, Stadlmayr B, Nilsson E, Charrondiere UR and Burlingame B. Composition of milk from minor dairy animals and buffalo breeds: A biodiversity perspective. Journal of the Science of Food and Agriculture. 2012; 92:445-474.

Mehaia MA, Hablas MA, Abdel-Rahman KM and El-Mougy SA. Milk composition of Majaheim Wadah and Hamra camels in Saudi Arabia. Food Chemistry. 1995; 52(2):115-122.

Mehaia MA. Vitamin C and riboflavin content in camel's milk: effects of heat treatments. Food Chemistry. 1994; 50(2):153-155.

Mehari Y, Mekuriaw Z and Gebru G. Potentials of camel production in Babilie and Kebribeyah woredas of the Jijiga Zone, Somali Region, Ethiopia. Livestock Research for Rural Development. 2007; 19(4):Article 58.

Mohamed H, Johansson M, Lundh A, Nagy P and Kamal-Eldin A. Short communication: Caseins and α-lactalbumin content of camel milk (*Camelus dromedarius*) determined by capillary electrophoresis. Journal of Dairy Science 2020; 103:11094-11099.

Mohammed H, Hailu S, Geberegiorgis A, Zeru F and Feyisa A. Assessment of safety status of camel raw milk marketed in Samara-Logia Town of Afar national regional state, Northeast Ethiopia. Food Science and Quality Management. 2016; 49:80-88.

Mulwa WD, Schelling E, Wangoh J, Imungi KJ, Farah Z and Meile L. Microbiological quality of raw camel milk across the Kenyan market chain. Global Science Book. 2011; 5(1):79-83.

Musinga M, Kimenye D and Kivolonzi P. The camel milk industry in Kenya: Results of a study commissioned by SNV to explore the potential of camel milk from Isiolo District to access formal markets. Netherlands Development Organization/Resource Mobilisation Centre, Kenya. 2008; 100:43-48.

Mwangi LW, Matofari JW, Muliro PS and Bebe BO. Hygienic assessment of spontaneously fermented raw camel milk (suusa) along the informal value chain in Kenya. International Journal of Food Contamination. 2016; 3:18-26.

Nagy P and Juhasz J. Review of present knowledge on machine milking and intensive milk production in dromedary camels and future challenges. Tropical Animal Health and Production. 2016; 48(5):915-926.

Niasari-Naslaji A, Pezeshk H, Atakpour AB, Ghaffari S, Nickchi P, Safi S, Shirazi-Beheshtiha SH, Arabha H, Samiei R, Amjadi M, Haji Moradlou AA, Narimani I and Moosavi-Movahedi AA Estimation of somatic cell count, as gold standard to detect subclinical mastitis, in dromedary camel. Journal of Camel Practice and Research. 2016; 23(1):175-178.

Nikkhah A. Equidae, camel and yak milks as functional foods: A review. Journal of Nutrition and Food Sciences. 2011; 1:116.

Noor IM, Guliye AY, Tariq M and Bebe BO. Assessment of camel and camel milk marketing practices in an emerging periurban production system in Isiolo county,

Kenya. Pastoralism Research Policy and Practice. 2013; 3:28-35.

Obeid AI, Bagadi HO and Mukhtar MM. Mastitis in *Camelus dromedarius* and the somatic cell content of camel's milk. Research in Veterinary Science. 1996; 61(1):55-58.

Odongo NO, Lamuka PO, Matofari JW and Abong GO. Risk factors associated with the post-harvest loss of milk along camel milk value chain in Isiolo County, Kenya. African Journal of Agricultural Research 2016; 11(8):674-682.

Omer RH and Eltinay AH. Microbial quality of camel's raw milk in central and southern regions of United Arab Emirates. Emirates Journal of Food and Agriculture. 2008; 20(1):76-83.

Omrani AS, Al-Tawfiq JA and Memish ZA. Middle east respiratory syndrome coronavirus (MERS-CoV): animal to human interaction. Pathogens and Global Health. 2015; 109(8):354-362.

Oselu S, Ebere R and Arimi JM. Camels, camel milk, and camel milk product situation in Kenya in relation to the world. Journal of Food Science. 2022; 8:1237423.

Park YW and Haenlein GFW. Milk from other minor species (Reindeer, Caribou, Musk Ox, Liama, Alpaca, Moose, Elk and others), chapter 30. In: Milk and Dairy Products in Human Nutrition. Wiley-Blackwell Publishers, Oxford, UK. 2013; pp 644-658.

Patel AS, Patel SJ, Patel NR and Chaudhary GV. Importance of camel milk-An alternative dairy food. Journal of Livestock Science. 2016; 7:19-25.

Rahmeh R, Akbar A, Alomirah H, Kishk M, Al-Ateeqi A, Shajan A, Alonaizi T and Esposito A. Assessment of mastitis in camel milk using high-throughput sequencing. PLOS One. 2022; 717(12):e0278456.

Rahmeh R, Alomirah H, Akbar A and Sidhu J. Composition and properties of camel milk, In: Javed K. Milk production, processing and marketing. IntechOpen. 2019; 82592, pp 1-17.

Redington JM, Breydo L, Almehdar HA, Redwan EM and Uversky VN. α-Lactalbumin: of camels and cows. Protein and Peptide Letters. 2016; 23(12):1072-1080.

Roess AA, Hosh FM, Morton LC, Bestul N, Davis J and Carruth L. Associations between unpasteurised camel and other milk consumption, livestock ownership, and self-reported febrile and gastrointestinal symptoms among semi-pastoralists and pastoralists in the Somali region of Ethiopia. Epidemiology and Infection 2023; 151:e44, 1-7.

Roy D, Ye A, Moughan PJ and Singh H. Composition, structure, and digestive dynamics of milk from different species-A review. Frontiers in Nutrition. 2020; 7:577759.

Sadler K and Catley A. Milk matters: The role and value of milk in the diets of somali pastoralist children in Liben and Shinile, Ethiopia. Feinstein International Centre, Tufts University and Save the Children, Addis Ababa. Report. 2009; pp 1-28

Saleh SK and Faye B. Detection of subclinical mastitis in dromedary camels (*Camelus dromedarius*) using somatic cell counts, California mastitis test and udder pathogen. Emirates Journal of Food and Agriculture. 2011; 23(1):48-58.

Saleh SK, Al-Ramadhan G and Faye B. Monitoring of monthly SCC in she-camel in relation to milking practice, udder status and microbiological contamination of milk. Emirates Journal of Food and Agriculture. 2013; 25 (5):403-408.

Sara B, Elhassan MBM and Zubeir IEME. Evaluation of pasteurisation and sterilisation process on camel milk quality. Global Journal of Science Frontier Research 2022; 22(2):1-11.

Sawaya WN, Khalil JK, Al-Shalhat A and Al-Mohammad H. Chemical composition and nutritional quality of camel milk. Journal of Food Science. 1984; 49:744-747.

Schulz J. Bau der Milchdrüse und Physiologie der Laktation. In: Fahr R-D and von Lengergen G. Milcherzeugung. Deutscher Fachverlag. 2003; pp 45-79.

Seifu E and Tafesse B. Prevalence and aetiology of mastitis in traditionally managed camels (*Camelus dromedarius*) in selected pastoral areas in eastern Ethiopia. Ethiopian Veterinary Journal. 2010; 14:103-113.

Seifu E. Handling, preservation and utilisation of camel milk and camel milk products in Shinile and Jijiga zones, eastern Ethiopia. Livestock Research for Rural Development 2007; 19(6):Article 86.

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

Serda B, Bekele A and Abebe D. Prevalence and contamination level of *Staphylococcus aureus* in raw camel milk and associated risk factors in Jigjiga District, eastern Ethiopia. Journal of Veterinary Science and Technology. 2018; 9(1):501-505.

Shamsia S. Nutritional and therapeutic properties of camel and human milks. International Journal of Genetics and Molecular Biology. 2009; 1(4):52-58.

Shuiep ES, El Zubeir IEM, El Owani OAO and Musa HH. Influence of season and management on composition of raw camel milk (*Camelus dromedarius*) milk in Khartoum state, Sudan. Tropical and Subtropical Agroecosystems. 2008; 8(1):101-106.

Singh R, Ghorui S and Sahani M. Camel milk: properties and processing potential. In: Sahani MS, The Indian camel. NRCC, Bikaner. 2006; pp 59-73.

Smits M, Huppertz T, Alting A and Kiers J. Composition, constituents, and properties of Dutch camel milk. Journal of Camel Practice and Research. 2011; 18(1):1-6.

Smits M, Joosten H, Faye B and Burger PA. The flourishing camel milk market and concerns about animal welfare and legislation. Animals (Basel). 2023; 13(47):1-16.

Spargue LD, Al-Dahouk S and Neubauer H. A review on camel brucellosis: a zoonosis sustained by ignorance and indifference. Pathogens and Global Health. 2012; 106:144-149.

Stahl T, Sallmann H-P, Duehlmeier R and Wernery U. Selected vitamins and fatty acid patterns in dromedary milk and colostrum. Journal of Camel Practice and Research. 2006; 13(1):53-57.

Stahl T. Vitamingehalte und Fettsäuremuster in Kamelmilch. phD thesis, Tierärzliche Hochschule Hannover, Hannover 2005; pp 1-130.

Swelum AA, El-Saadony MT, Abdelnour SA, Ba-Awadh H, Abd El-Halck ME and Sheiha AM. Relationship between concentration of macro and trace elements in serum and follicular, oviductal, and uterine fluids of the dromedary camel (*Camelus dromedarius*). Tropical Animal Health and Production. 2020; 52:1315-1324.

Swelum AA, El-Saadony MT, Abdo M, Ombarak RA, Hussein EOS, Suliman G, Alhimaidi AR, Ammari AA, Ba-Awadh H, Taha AE, El-Tarabily KA and Abd El-Halck ME. Nutritional, antimicrobial and medicinal properties of camel's milk: A review. Saudi Journal of Biological Sciences. 2021; 28(5):3126-3136.

Swinburne M. Raw milk: Camels, the FDA, and State deregulation. In: The Network for Public Health Law-Eastern Region. Report. 2017; February 13 (www.networkforphl.org).

Toroitich KC, Gitau GK, Kitala PM and Gitao GC. The prevalence and causes of mastitis in lactating traditionally managed one-humped camels (*Camelus dromedarius*) in West Pokot County, Kenya. Livestock Research for Rural Development. 2017; 29(4):Article 62.

Tuteja F, Patil N, Narnaware S, Nagarajan G and Dahiya S. Primarily human pathogenic fungi causing dermatophytosis in camel. Journal of Camel Practice and Research. 2013; 20(2):151-155.

Vincenzetti S, Cammertoni N, Rapaccetti R, Santini G, Klimanova Y, Zhang J and Polidori P. Nutraceutical and functional properties of camelid's milk. Beverages. 2022; 8(1):1-12.

Wang SY, Liang JP, Shao WJ and Wen H. Mineral, vitamin, and fatty acid contents in the camel milk of dromedaries in the Anxigansu China. Journal of Camel Practice and Research. 2011; 18(2):273-276.

Wanjohi M, Gitao CG and Bebora L. Subclinical mastitis affecting hygienic quality of marketed camel milk from Northeastern Province, Kenya. Microbiology Research International. 2013; 1(1):6-15.

Wernery U, Johnson B and Jose SH. The most important dromedary mastitis organisms. Journal of Camel Practice and Research. 2008; 15(2):159-161.

Wernery U, Soellner NK, Joseph S, Varghese P, Johnson B and Kinne J. Passive immunisation against brucella melitensis in dromedaries. Journal of Camel Practice and Research. 2017; 24(3):235-237.

Wernery U. Camel milk, the white gold of the desert. Journal of Camel Practice and Research. 2006; 13:15-26

Wernery U. Camelid brucellosis: a review. Rev. Science. Tech. 2014; 33(3):839-857.

Wernery U. Camel milk-new observations. Proceedings of the International Camel Conference, "Recent trends in camelids research and future strategies for saving camels". Rajasthan, India, 16-17 February 2007; 200-204.

Wijesinha-Bettoni R and Burlingame B. Milk and dairy product composition. In: Milk and Dairy Products in Human Nutrition. FAO Rome, Wiley-Blackwell. 2013; pp 41-102.

Yadav AK, Kumar R, Priyadarshini L and Singh J. Composition and medicinal properties of camel milk: a review. Asian Journal of Dairy and Food Research 2015; 34(2): 83-91.

Yamina M, Wassila C, Kenza Z, Amina Z, Noureddine S, Eddine HJ and Mebrouk K. Physico-chemical and microbiological analysis of Algerian raw camels' milk and identification of predominating thermophilic lactic acid bacteria. Journal of Food Science and Engineering. 2013; 3:55-63.

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

Younan M, Ali Z, Bornstein S and Müller W. Application of the California Mastitis Test in intramammary *Streptococcus agalactiae* and *Staphylococcus aureus* infections of camels (*Camelus dromedarius*) in Kenya. Preventive Veterinary Medicine. 2001; 51:307-316.

Zaitlin P, Dwyer J and Gleason GR. Mistaken beliefs and the facts about milk and dairy foods. Nutrition Today. 2013; 48:135-143.

Zangerl P. Mikrobiologie der Produkte. In: Krömker V. Kurzes Lehrbuch Milchkunde und Milchhygiene, Parey. 2007; pp 156-179.

Zimmermann KA. Camel milk: Nutrition Facts, Risks and Benefits. Published February 3, 2016 (www.livescience.com/53579-camel-milk).