Camel☆

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This is an update of G.A. Alhadrami, B. Faye, Animals that Produce Dairy Foods: Camel, In Reference Module in Food Science, Elsevier Inc., 2016, https://doi.org/10.1016/B978-0-08-100596-5.00620-X.

Introduction

The dromedary and the Bactrian camel are among the mammals domesticated by human to provide milk for human consumption. In Africa, dromedaries are still considered as an important livestock species for milk and meat production, while in the Arabian Peninsula more attention is directed toward camel racing although the demand for camel milk and meat is increasing. For hundreds of years, camels have been used as multipurpose animals to provide; transport goods and people, milk, meat, wool, leather, draught services, leisure and sport. Mainly used in the past for transport, the interest for its milk and meat production is increasing especially for the last 30 years. However, little selection for specific traits has taken place.

Milk production from camels is mainly practiced in pastoral migratory systems which is providing around 70% of the camel milk, especially for self-consumption even in Gulf countries (Faye et al., 2014). However, semi-intensive, peri-urban systems are increasing as well as intensive camel dairy farming, especially in the Arabian Peninsula and North Africa. Camel raising is conducted most of the time outside crop system, but in Sahelian countries, the roles of camels increased in crop-livestock systems as element of securitization of the production system face to climatic changes marked by the repetition of drought (Faye et al., 2012). Most camel herds are kept in natural pastures with little or no supplemental feeding except in intensified systems. Differences in the composition of camel milk reported from different countries may reflect differences in breeds, nutrition, and stage of lactation at sampling (Konuspayeva, 2020a). Despite its marginal place in world dairy economy, camel milk can play an important role in providing high-quality protein to the people living in the arid and semiarid areas of the world. Moreover, the true or expected "medicinal virtues" attributed to camel milk is boosting the demand not only in "camel countries" but also worldwide (Alhaj, 2020).

☆*Change History*: June 2015. G.A. Alhadrami, B. Faye updated text, references and figures. Update of G.A. Alhadrami. Animals that Produce Dairy Foods: Camel. Encyclopedia of Dairy Sciences, Second Edition, 2011, Pages 351–357. April 2021, Update of information and references by authors.

Geographical Distribution

Camels are pseudo-ruminant mammals and they first evolved in North America (Rybczynski et al., 2013). In time, the camels evolved into a number of species of the camel family Camelidae (camelids). The Camelidae belongs to the order Artiodactyla (even-toed ungulates) and the suborder Tylopoda (pad-footed animals). The Camelidae family consists of two genera: *Camelus* and *Lama*. The genus *Camelus* comprises two domestic species: *Camelus dromedarius* (also known as the one-hump camel or Arabian camel) and *Camelus bactrianus* (also known as the two-hump camel or Bactrian camel). The wild Bactrian camel from Tartarian desert (Mongolian-China border) is defined as genetically different as domesticated Bactrian and named *Camelus b. ferus* (Burger, 2016). The *Lama* genus comprises four species: *Lama glama* (llama), *Lama pacos* (alpaca), *Lama guanicoe* (guanaco), and *Lama vicugna* (vicuna).

The dromedary was first domesticated in southern Arabia at about 4000–3000 BC mainly for transport and milk (Monchot, 2015). Moving from Arabian Peninsula, dromedary camels occupied South-Asia and African continent through two ways of migration from 1000 BC, via the Horn of Africa and via Sinai, as was demonstrated by DNA monitoring (Almathen et al., 2016). Nowadays, dromedary camels are an important part of the domestic livestock population in most of the dry areas of the Africa, Middle East and South-Asia.

Bactrian camels are mainly distributed through the deserts and semi-deserts of the north and northwest of China, throughout Mongolia and some part of Central Asia (Kazakhstan, Russia). Some Bactrian camels are living also in India, Pakistan, Afghanistan and Iran. A residual population is present in Turkey and Crimea (Zarrin et al., 2020). While dromedary camel is living in hot-desert areas with ambient temperatures in the range 5–45 °C, the temperature in cold areas where Bactrian camels are raised ranges from −20 to 40 °C.

The camel population in the world is estimated to 35 million (source: www.faostat.org, 2020) of which 1 million are Bactrian camels (Faye and Konuspayeva, 2020). Of the 34 million dromedaries, approximately 86% (more than 30 million) are found in Africa, with the largest population in East and central Africa (Somalia, Chad, Sudan, Ethiopia and Kenya). The reminder of dromedaries is found mainly in Mauritania, the Arabian Peninsula and the Indian subcontinent.

Breeds and Genetic Groups

Because they are multipurpose animals (Hjort af Örnas and Hussein, 1993), camels have been selected for these different purposes during domestication. Thus, they may be roughly classified in relation to these function but also to their habitat as proposed by Blanc and Hennesser (1989) who suggested to differentiate eight types of camel according to their size (tall/medium/short), their global conformation (longilineal/brevilineal) and environment (flat/mountainous areas, sandy/rocky desert). For example, longilineal animals are used mainly for riding and racing, and brevilineal camels for packing and work activities. In traditional identification, variation in coat color can be used to differentiate camel sub-populations despite it is not consider as a genetic distinctive trait (Abdallah and Faye, 2012; Abdussamad et al., 2015).

However, the recent genetic studies reported little population structure in the world camel population as stated in the review of Burger et al. (2019). According to these authors, genetic studies failed to clearly differentiate distinct camel breeds. To define them, only "genome-wide analyses on well-classified populations using standardized phenotyping criteria across countries, might identify genetically distinct groups" (Burger et al., 2019).

Moreover, in regards to dairy production, camel milk sale for market was taboo for long time and use was mainly confined to self-consumption or as a gift.

The recent increased interest in camel milk for a more urbanized population has boosted the integration of camel milk into market and research activities on dairy camel selection (Faye, 2018). Thus, recent studies were initiated on udder morphology (Ayadi et al., 2016a,b), adaptation to milking machine (Atigui et al., 2015), management in intensive systems (Nagy and Juhasz, 2016) or assessment of genetic and non-genetic factors for milk composition (Nagy et al., 2017).

Despite the lack of official system of performance control in camel, the experiences and observations of scientists and camel breeders through the world made possible the distinction between three groups of dairy camels classified in high, medium, and low, based on their milk production. Only the high and medium milk-producing camels can be considered as true dairy camel types. Lactating camels with an annual milk production of more than 3000 L/lactation will be considered as high-producing dairy camel types, while camels with an annual milk yield of more than 1500 L/lactation but less than 3000 L/lactation will be considered as medium-producing dairy camel types.

Group 1: High-Producing Dairy Camel Types (Dromedaries)

Dairy camels in this group are characterized by large body size but less beefy body conformation, a relatively big abdomen, well-developed humps, prominent milk veins, and well-developed udder. Camels belonging to this category are mainly black and light to dark brown in color. Average milk production is more than 3000 L/lactation although a wide individual variability is observed.

Known types in this group are as follows:

1. Marecha: This type originated in Pakistan and is named after Marecha tribe from the desert of Pakistan. This type has real production potential for milk (Faraz et al., 2018).
2. Al-Majahim Al-Arabia: This is also called Al-Njdeiah. It originated in Saudi Arabia especially in Najd and Dawaser Valley in the north and northeast of Saudi Arabia (Fig. 1).
3. Sirtawi: This is found mainly in the Sirt area in the middle coastal zone in Libya.
4. Fakhreya: This is found in the southern and western areas of Benghazi in Libya.
5. Arvana: This was developed in Turkmenistan in the Kara-Kum Desert, and can also be found in Uzbekistan, Kazakhstan, Afghanistan, and Iran (Fig. 2).
6. Bikaneri: Bikaneri camels (Fig. 3) are predominantly bred in Bikaner and nearby districts of Rajasthan and adjoining parts of Haryana and Punjab state (India).

Group 2: Medium-Producing Dairy Camel Types (Dual Purpose)

Camels in this group are characterized by medium body size and a medium-sized hump. Most of the pack and riding types are dual-purpose camels. These breeds are mainly white, gray, light brown, and brown to reddish in color. Average milk production ranges from more than 1500 L/lactation to less than 3000 L/lactation. Known types in this group are as follows:

Dromedaries

1. Hor (Godir): This can be found in central Somalia. It is the most common type of camel distributed in different parts of Somalia.
2. Rashaida: This is found in the Kasala area of eastern Sudan and is raised by the Rashaida tribe.
3. Ould Sidi Al-Sheikh: This is found in the northeast area of Mauritania and the southeast of Morocco (Fig. 4).
4. Al-Homor: This is found in many areas of the Arabian Peninsula and is especially popular in certain parts of Saudi Arabia (Fig. 5).
5. Seifdar: This is found in Somalia. Camels belonging to this type are good producers of milk and they have the characteristics of racing camels.
6. Al-Khawar (also called Atfateir): This type is found in the northern steppes of Syria and the western steppes of Iraq.
7. Al-Shameya: This is found in the Syria steppe, north of Jordan, west of Iraq, and north of Saudi Arabia (Fig. 6).
8. Pishin: This type is named after the Pishin district of Baluchistan in Pakistan. Camels belonging to this group have body structure of a typical mountain camel and can carry heavy weights.
9. Brela or Thalocha: This breed can be found in Punjab province, Pakistan. Camels of this breed are tall and have a big strong body and big head and neck with a broad chest and a wide girth.
10. Benadir: This Somali dairy camel belongs to the heavy baggage type.
11. Birabish: This can be found in Mauritania.
12. Al-Tilal: This can be found in Morocco.
13. Al-Tibawi: This can be found in Libya. Camels of this breed are small and have the ability to withstand a long period of water deprivation.
14. Waddha: white camel from Saudi Arabia (Fig. 7).
15. Dankali: the dairy camel of Afar people in Ehiopia, Djibouti and Erythrea (Fig. 8).

Fig. 1 Majaheem, Saudi Arabia.

Fig. 2 Arvana, Turkmenistan, Kazakhstan.

Fig. 3 Bikaneri camel, India.

Fig. 4 Ould Sidi Al-Sheikh, Mauritania.

Bactrian Camels

Bactrian camels are low-yield dairy camels compared to the dromedary camels. Three main Bactrian groups are described: Kalmouk (Russia), Kazakh (Kazakhstan) and Mongol (Mongolia and China).

1. Mongol: Several ecotypes are described but most of them are renowned for their wool production rather than for their milk. In China, five ecotypes are recorded while three are described in Mongolia. Among Mongol group, Alxa breed (Fig. 9) is the higher dairy producer (on average 650 L/lactation). Alxa camels can be found in the Alxa county in China, but also in northern Afghanistan, Tajikistan, and parts of Mongolia (Zhang et al., 2005).
2. Kalmouk: this is the biggest Bactrian camel of the world (Fig.10), but its dairy potential is low

Fig. 5 Al-Homor, Saudi Arabia.

Fig. 6 Al-Shameya, Syria.

Fig. 7 Waddha, Saudi Arabia.

3. Kazakh: three types of Kazakh Bactrian camel are described according to their location and their size, Oralbokeilik type (north of Caspian Sea), close to Kalmouk by their size and meat performance, with abundant fur, Kyzylorda type (central Kazakhstan) used for meat purpose (Figs. 11 and 12), and the Ongtüstik type (South Kazakhstan) used for meat, milk and good quality wool (Fig. 11).

In Kazakhstan, hybridization between dromedary and Bactrian (Fig. 13) is common (Faye and Konuspayeva, 2012) to get higher dairy productive animal. Different ways of hybridization are used (e.g., male Bactrian or dromedary).

Fig. 8 Dankali, Ethiopia.

Fig. 9 Alxa Bactrian, China.

Fig. 10 Kalmouk Bactrian, Russia.

Husbandry

Considering the harsh climate of the desert, with extremely low annual rainfall and very hot climate, the economic importance of the camel is based on its physiological and anatomical adaptation to such harsh conditions prevailing in the arid zones (Yagil, 1985). It can resist severe dehydration, high differences in temperatures, and a low energy and protein content diet. The camel can regain body water losses of up to 30% of its body weight within 10 min without producing intravascular hemolysis.

Fig. 11 Kazakh-Kyzylorda Bactrian, Kazakhstan.

Fig. 12 Kazakh-Ongustik Bactrian, Kazakhstan.

Fig. 13 Hybrid between Arvana dromedary and Kazakh Bactrian, Kazakhstan.

Reproduction

Puberty of the female camel usually occurs at 4 years of age. The dromedary is a seasonal polyestrous animal. The mean duration of the estrous cycle is 17.2–23.4 days (Tibary and Anouassi, 1997). Ovulation occurs at coitus, as in the rabbit. The placenta is the diffuse and noninvasive epitheliochorial type, as in the mare. Pregnancy duration is 12–13 months. Lactation length in the dromedary and Bactrian camel varies from 6 to 18 months. Russian investigators have reported that on rare occasions when Bactrian camels calve every year, a lactation period of 7 months is normal. In the case of dromedaries, there is no report in the literature indicating that dromedary camel can calve once every year without cessation of milk production. However, if camels do not become

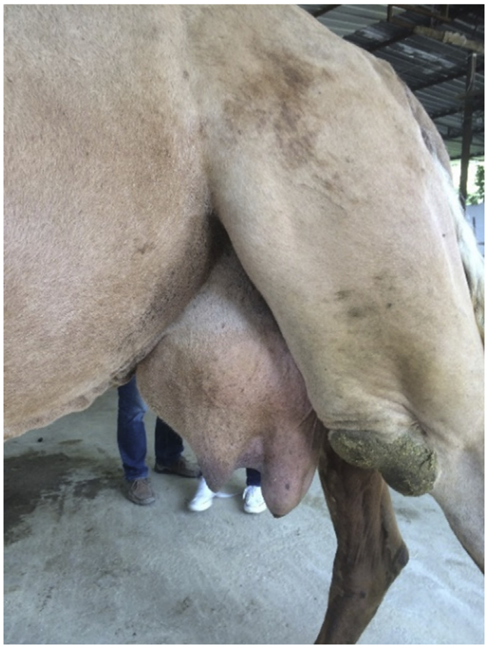

Fig. 14 Well-developed udder of lactating dromedary.

pregnant, the lactation may continue for up to 24 months. The udder (mammary glands) of the camel consists of four glandular quarters (Fig. 14), each with its own teat. The left and right halves are separated from each other by a double sheet of fibroelastic tissue taking origin from the linea alba and prepubic tendon. Arterial blood supply is mainly by the external pudendal artery and the venous drain is mainly by the superficial thoracic vein, the external pudendal vein, and the femoral vein.

Mastitis is one of the main problems in lactating camels. Major factors that contribute to the occurrence of mastitis infection in lactating camels are poor milking hygiene, bad management, and teat injuries. Infection by bacterial or mycotic pathogens is the main cause of mastitis in camels. These include *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Corynebacterium pyogenes*, *Streptococcus agalactiae*, *Pasteurella haemolytica*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Candida albicans*. Different types of mastitis in camels have been reported from different countries (Jilo et al., 2017). These include per acute, acute, chronic, and subclinical forms. *Staphylococcus* mastitis appears to be the more prevalent form. *Staphylococcus aureus* is found in both peracute (gangrenous) and chronic mastitis cases. In acute forms, the udder is swollen, hot, and painful and changes in milk composition are obvious. The milk is often watery with flakes. If the udder is not treated, the affected gland becomes hard and less productive. Multiple abscesses with complete fibrosis of the affected gland can be noticed. In subclinical mastitis, no obvious changes in the mammary gland can be seen. However, milk secretion is not normal.

Diagnosis of mastitis can be based upon clinical examination of the udder, bacteriological isolation of the causative agent, and physical examination of the milk. The California mastitis test (CMT) and milk cell counts are of value in the diagnosis of mastitis in camels (Saleh and Faye, 2011). A cell count of less than 400,000 cells mL^{-1} is normal (Nagy et al., 2013). However, in mastitic milk, cell counts of between 800,000 and 1,600,000 cells mL^{-1} have been reported (Woubit et al., 2001). Locally and parenteral administered antibiotics have been used to treat mastitis infection in camels. The antibiotic is infused into the affected quarter every 12–24 h for three to five treatments. The affected gland is infused after emptying the gland of milk. Administration of oxytocin (10 IU) intravenously will help in emptying the milk from the affected gland.

Udder edema is another problem that affects milk production in lactating camels (Al-Ani and Vestweber, 1986). It is characterized by an excessive accumulation of fluid in the interstitial spaces of the udder that occurs at the time of parturition. High-producing camels are more susceptible. Udder edema at parturition results from a decreased mammary blood flow associated with an increase in the venous blood pressure in the cranial superficial epigastric veins (milk vein). Clinically, a typical case of udder edema usually involves all four-quarters of the udder (Muhammad et al., 2005). The condition has two distinct stages. During the first stage, there is a gradual congestion of the skin of the udder. The udder becomes greatly distended, swollen, and filled with colostrum. During the second stage, digital pressure produces pitting of the edematous areas. The udder skin also becomes thick and hard on digital palpation. The base of the teats is also edematous. This makes milking difficult. In most cases, udder edema does not need any treatment. The swelling gradually decreases after calving. However, physical massage of the udder during milking together with the alternate application of hot and cold water will help to remove the fluid. Diuretics, especially furosemide, may have some beneficial effects by reducing the edema. A dose of 5 mL of a 5% solution twice daily for up to 3 days can be used to treat udder edema. Other minor diseases that affect the udder of the camels are teat stenosis and udder wounds.

Milk Harvesting

In the extremely hot arid areas of Arabia and all the drought-stricken areas of the world, where continuous drought decimates the cattle, sheep, and goat populations, only the camels survive and continue producing milk and calves. Progress in improving camel milk production faces several constraints. One major constraint to milk production is that camels stop lactating within 4 weeks' gestation (Nagy et al., 2014). This means a longer calving interval, which means higher costs of production. Another constraint is hand milking. Unlike dairy cows, lactating camels are almost always hand milked. Hand milking of camels is still practiced because it is believed that the presence of the calf is essential in ensuring satisfactory milk letdown before the camels are milked. However, recent developments have adapted milking machines to the lactational physiology of the camel without the presence of a calf (**Fig. 15**). A higher vacuum level, different pulsation ratio to dairy cows were tested showing a significant increase in the amount of milk produced (Nagy and Juhasz, 2016; Ayadi et al., 2018). With appropriate machine parameters, the harvested milk can increase by 30%. In intensive dairy farms, appropriate stimulation of the udder can replace the presence of the calf. The ratio cisternal milk/alveolar milk is low in camels (5%–15%) compared to cows (30%–50%) or to goats (70%–80%), underlining the importance of udder stimulation before milking (Ayadi et al., 2016a,b).

Intensive Systems

Camel milk production from intensive systems has started to become a reality and has shown promising results. The settlement of Bedouin in the oil-producing countries in the Arabian Peninsula and the distribution of wealth there have made it possible for the Bedouin to keep their camels in confinement for the purpose of milk production and racing. The intensification of the camel farming is also observed in West and North Africa when dairy plant processing of camel milk is implemented.

Milk Yield

Nowadays, many data on camel milk yield and composition are available, but the lack of systematic milk control and socioeconomic constraints hinder the efforts of scientists to improve camel milk production. The potential for high milk production from camels has prompted scientists to attempt to improve local husbandry methods. Unfortunately, camels have seldom been selected for high milk production as cattle are in developed countries (Al-Abri and Faye, 2019). Some nomadic tribes in Pakistan and East Africa have selected camels for milk production, but the methods of selection used are primitive compared to those

Fig. 15 Milking camels with a milking machine in Saudi Arabia.

employed in the developed countries. The establishment of an udder scoring and of a performance control system, the identification and selection of the gene of interest for milk production are some of the way being explored by scientists in the world, but not yet applied systematically.

Generally, apart from genetics, there are some factors influencing the milk yield and composition, including nutrition, water availability, reproduction, health status, stage of lactation, milking frequency, and presence of the calf. Thus, frequency of suckling or milking is likely to have a considerable effect on milk production. The frequency of milking lactating camels depends on the customs of the people. Some people milk their camels once a day, others up to six times. Even though frequency of milking tends to increase milk yield in camels, it is not a consistent practice. The Afar people in Ethiopia sometimes milk their camels six times a day, while at other times they may leave their animals for a whole day without milking them. This practice may hinder improving milk production in camels.

Data on camel milk yield in different regions vary greatly (Faye, 2004). This may be due to differences in breeds and camel management systems. The dromedary, like most mammalian species, gives most milk during the early stage of lactation. However, the peak of lactation in camels occurs as a plateau for several weeks or even months and the persistence rate is higher than in cows (Musaad et al., 2013; Aziz et al., 2016). It has been reported that some camels in the Punjab district of Pakistan immediately after calving can produce up to 30 kg day^{-1} of milk with an average of 17.4 kg day^{-1} over a 10-month period. This means a total yield of 5300 kg per 305 days. A report from Saudi Arabia indicates that Al-Majahim camels can produce up to 18 L day^{-1} of milk under intensive systems. Also, the milk production of Somali camels on pasture during the rainy season has been estimated at an average of 10 L day^{-1} during the lactation period. It appears that the milk yield of camels is low, especially if compared with the yield of Holstein cows. Nevertheless, camels are much better providers of milk than cows, sheep, and goats in the arid areas of the world.

Milk Composition

The compilation of 121 references published between 1905 and 2019 gives a mean and standard deviation of 3.68 ± 1.00 for percentage of fat matter, 3.28 ± 0.59 for total protein, 4.47 ± 0.66 for lactose and 0.81 ± 0.19 for ash with dry matter varying between 8.25% and 16.70% (mean=12.2 ± 1.62%) (Konuspayeva, 2020a). The gross composition of camel milk is comparable to cattle and goat milk (Fig. 16). Camel milk is generally opaque white due to its low carotene content. It has a sweet and sharp taste, but sometimes can also be salty. The type of fodder and the availability of drinking water affect the taste of camel milk. The pH of camel milk ranges from 6.5 to 6.7, titratable acidity is 0.03 after 2 h and 0.149 after 6 h, and the specific gravity ranges from 1.025 to 1.032.

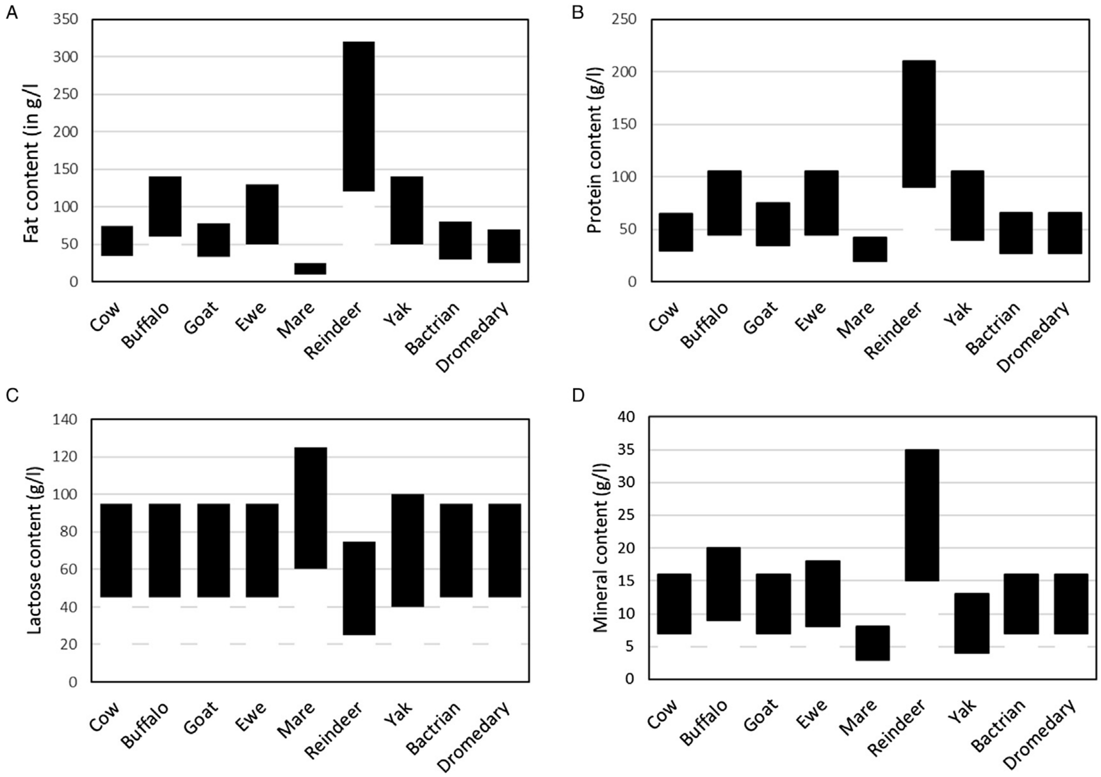

Fig. 16 Normal ranges of fat (A), protein (B), lactose (C) and minerals (D) in different dairy animals (in g/L). From after Konuspayeva (2020a).

The milk composition of Bactrian camel is little bit different of that of dromedary. Bactrian milk appeared richer in fat and protein but with a lower part of poly-unsaturated fatty acids (Faye et al., 2008).

As for other species, this composition varied widely according to many factors linked to the animal (genetic, lactation stage, parity) and to its environment (climatic conditions, feeding and watering). Moreover, the fine composition differs from that of cow milk (Konuspayeva et al., 2009).

Water

Water content of camel milk fluctuates from 84% to 90%. Some published results on the effect of lack of drinking water on camel milk indicated that when water was freely accessible to the lactating camels, the water content of the milk was 84%–86%. But when water was restricted, the water content of milk rose to 90% (Yagil, 1982). The lactating camel loses water to the milk in times of drought. This could be a natural adaptation to provide necessary fluid to the calf. The antidiuretic hormone (ADH) secretion is elevated in the dehydrated camels and thus the loss of water into the milk is due to the action of this hormone.

Lactose

Camel lactose provokes less intolerance than cow lactose (Cardoso et al., 2010) due to a different stereo-structure of the lactate molecule, the product of lactose fermentation in intestinal gut (Konuspayeva et al., 2019). Thus, if the content of total lactate in camel milk was comparable to cow milk (1.82–2.49 g/L), the quantity of L-Lactate, more digestible, was 100 times more in camel milk (2.21% of the total lactate) than in cow milk (0.02%).

Proteins

Camel milk has no β-lactoglobulin (strong allergenic protein), more lactoferrin and immunoglobin (Konuspayeva et al., 2007) and lysozyme, less caseins and presence of specific peptides as WAP or PGRP (Kappeler et al., 2006a; Ryskaliyeva et al., 2019).

Fat

The bulk of the fat in milk exists in the form of very small spherical globules (1.2–4.2 μm in diameter). The surface of these fat globules is coated with a thin layer known as the fat globule membrane, which acts as an emulsifying agent for the fat suspended in milk. Compared with cows' milk, camel milk shows a very slow creaming rate. Creaming layers vary from 0.5 to 2 mL at 4 °C. The ratio of fat to total solids averages 31.6%.

Compared to the fat in cows', buffaloes', and ewes' milk, the fat in camel milk contains fewer short-chain fatty acids, but similar long-chain fatty acids. In general, short-chain fatty acids (C_4—C_{12}) are present in very small amounts in camel milk compared to cows' milk. But the concentrations of $C_{14:0}$, $C_{16:0}$, and $C_{18:0}$ are relatively high (**Table 1**). Also, camel milk has high concentrations of linoleic acid and polyunsaturated fatty acids (Konuspayeva et al., 2008). Phospholipids are a small, but important, fraction of the lipids of milk and are found mainly in the milk fat globule membrane. Camel milk contains more phospholipids than cow and goat milk (Garcia et al., 2012). Also, it has been noticed that phospholipid fatty acids of camel milk are not entirely characteristic of the

Table 1 Proportion of major fatty acids in camel milk fat

Fatty acid	*g per 100 g total fat*
C4:0	0.85
C6:0	0.37
C8:0	0.28
C10:0	0.37
C12:0	0.69
C14:0	10.90
C14:1	1.50
C15:0	1.14
C16:0	29.87
C16:1	9.60
C17:0	0.88
C17:1	0.55
C18:0	12.90
C18:1	23.50
C18:2	3.10
C18:3	1.40
C20:0	0.70

Table 2 Content of minerals and vitamins in camel milk

	mg L⁻¹
Minerals	
Calcium	1060.0–1570.0
Inorganic phosphate	580.0–1040.0
Copper	13.0–1.8
Iron	1.3–2.5
Magnesium	75.0–160.0
Manganese	0.1–0.2
Sodium	360.0–620.0
Zinc	4.0–5.0
Vitamins	
Retinol (A)	0.10–0.15
Thiamin (B1)	0.33–0.60
Riboflavin (B2)	0.42–0.80
Pyridoxine (B6)	0.52
Cobalamin (B12)	0.002
Niacin	4.6
Folic acid	0.004
Pantothenic acid	0.88
Tocopherol (E)	0.53
Ascorbic acid (C)	24–36

ruminant herbivores. Camel milk phospholipid fatty acids have high amounts of linoleic acid ($C_{18:3n\text{-}3}$) and long-chain polyunsaturated fatty acids. The fatty acid composition can be modified by the type of diet. The use of olive cake for example has increased the part of unsaturated fatty acids in the milk (Faye et al., 2013). The cholesterol content is controversial, some authors considering camel milk with lower quantity than in cow and other authors the reverse. In fact, this content is linked to the fat content in milk, the ratio cholesterol/fat being comparable in both species (Faye et al., 2015).

Minerals and Vitamins

Mineral content in milk includes mainly chlorides, phosphates, and citrates of sodium, calcium, and magnesium (**Table 2**). It includes also trace elements as copper, zinc and selenium (Seboussi et al., 2009). Camel milk contains more iron than cow milk. Vitamin A, vitamin E, thiamin, riboflavin, folic acid, and pantothenic acid contents in camel milk are lower than that found in cows' milk, while the contents of pyridoxine and vitamin B_{12} are about the same (**Table 2**). The contents of niacin and vitamin C are substantially higher than that found in cows' milk (Konuspayeva et al., 2011; Faye et al., 2019). In particular, the high level of vitamin C in camel milk (25–60 mg L^{-1}) is of significant nutritional relevance in the arid areas where fruits and vegetables containing vitamin C are scarce (Farah, 1993). The Bactrian milk contains generally a higher quantity of vitamin C than dromedary milk (Faye et al., 2008).

Milk Products: Fermented Milk

Camel milk is one of the most valuable food resources for the people living in arid and semiarid zones. Most of the camel milk is consumed as fresh milk. One of the oldest ways of consumption of surplus of camel milk is its fermented form. The diversity of fermented camel milk products in the world is extraordinarily rich. Each camel milk producer region had his own varieties of fermented camel milk with their specific taste, texture and flavor. Nowadays each camel country describes their traditional fermented milk by microbiological, physico-chemical, chemical properties. Most known fermented beverages issued from camel milk are *shubat* in Kazakhstan (Akhmetsadykova et al., 2014), *garris* in Sudan (Ahmed et al., 2014), *suusac* in Kenya (Jans et al., 2012), *laben* (lben) in Arabic countries Algruin and Konuspayeva, 2015), *ititu* in Ethiopia (Seifu et al., 2012), *chal* in Iran (Soleymanzadeh et al., 2016) and Turkmenistan, etc.

Some researchers claimed that fermented camel milk as *shubat* can be used to cure tuberculosis and some gastric and intestinal diseases (Chuvakova et al., 2000).

Milk Product: Butter

The method of making butter from cows' milk cannot be applied to camel milk. Production of butter from camel milk cannot be achieved easily because camel milk shows little tendency to cream. It takes a large quantity of camel milk to produce a small amount of butter. To obtain a reasonable amount of butter, cream from camel milk must be churned at a higher temperature (22–25 °C) than the temperature (8–14 °C) used with cream from cows' milk. The reason for this may be due to the high melting point (40 °C) of camel milk fat. The average moisture content of butter from camel milk is lower (12%–13%) than the moisture content of butter from cows' milk (15%–16%), which may explain the sticky texture of butter from camel milk (Berhe et al., 2013). Butter made from camel milk is white and waxy.

Milk Product: Cheese

Traditionally, camel milk was not processed into cheese due to difficulties achieving coagulation with the most common bovine rennet. The difficulty in obtaining a coagulum with camel milk is due to its low concentration in k-casein which is responsible for clotting and for curd quality. The concentration is around 3% in camel vs 13% in cow milk. Thus, the first trials appearing in the 1980s regarding the possibility of making cheese from camel milk were focused on improving the coagulation process (Ramet, 1989). Different coagulation agents were proposed: bovine rennet enriched with minerals marketed under the name of Camifloc® (El-Zubeir and Jabreel, 2008), plant extracts such as Zingiber officinale, and crude gastric enzymes extracted from the camel's abomasum (Konuspayeva, 2020b). Later, recombinant specific camel rennet (Kappeler et al., 2006a,b) was elaborated and marketed under the name of Chymax-M1000®, Ch. Hansen© (Jensen et al., 2013). Camel milk coagulation being no longer a constraint, nowadays, the challenge for cheese makers is to adapt the different known types of cheese technology to camel milk on a semi-industrial or industrial scale. Different technological parameters for camel cheese making have been tested, and mozzarella, white cheese (**Fig. 17**) or gruyere was produced (Konuspayeva et al., 2014, 2017). Recently, haloumi and feta cheese are available in the Saudi market.

Pasteurized Milk

Pasteurization of camel milk is routinely achieved in many countries, including Western countries (**Fig. 18**), but the conditions of pasteurization by each holder were decided without taking in consideration the specificity of camel milk, the rules being mainly based on the standard issued from pasteurization of cow milk. So, data regarding the conditions of pasteurization of camel milk could be quite variables (Alhaj et al., 2013).

There is a strong belief among camel owners in many parts of the world that pasteurizing camel milk will change its taste. There are very legitimate concerns regarding human health risks due to the consumption of camel milk. Because camel milk cannot be sterilized by ultra-high temperature technology, researchers at the United Arab Emirates University are testing a sterilization system based on a new concept in raw milk germicidal control using an electromagnetic orthogonal ripple field.

Milk Product: Powder

The development of camel milk powder processing is an important challenge for the international market, especially for the transport on long distance as one ton of fresh milk is corresponding to 120 kg of powder on average. Several technologies were applied on camel milk: spray-drying (Zouari et al., 2018) or lyophilization (Ibrahim and Khalifa, 2015). The first method appears more convenient to restore liquid milk but requires higher investment. However, lyophilized powder can be used in agro-food industry. Camel milk powder is available on e-market platform as Alibaba© or desertfarm©.

Fig. 17 White cheese from camel milk.

Fig. 18 Pasteurized camel milk produced in Europe, Australia and US.

Other Milk Products

There is ample literature on the possibility of making yoghurt with camel milk (Khalifa and Ibrahim, 2015). However, the manufacture of camel milk yoghurt poses a texture problem, the product appearing sticky and ultimately unpleasant to the palate. To obtain a better texture, trials with the addition of gelatin, alginate or calcium were attempted (Hashim et al., 2015) or using ferments producing exo-polysaccharides (Ibrahim, 2015).

Making ice creams with different flavors is easy. Several examples of marketing exist, for example, in the United Arab Emirates, Morocco or Kazakhstan (Fig. 19).

There are also traditional sweet products. For example, in Kazakhstan, a caramel called *Balkailmak* is obtained after a long thermal treatment of about 10 h at boiling temperature. We can also recall here the introduction of milk powder in chocolate as proposed in the Emirates.

In addition, camel milk is used for non-food productions, especially for cosmetic products (Metha and Agrawal, 2020) as soap, body cream, shampoo, lip sticks, etc (Fig. 20).

Future Developments

Specialized camel dairy farming is developing strongly for the last decades. Moreover, in certain countries, such as Saudi Arabia, Morocco, Kenya, Niger, Mauritania, China, Kazakhstan and the United Arab Emirates, large-scale camel dairy plants have been established. For a long time use has been limited to the consumption of raw or fermented milk. The diversification of the camel milk products and the introduction of those products into local, regional and even international market at higher prices than for cow milk products, are contributing to a promising development of the camel milk sector in the world.

Fig. 19 Camel milk cone ice cream in Kazakhstan.

Fig. 20 Box of cosmetic products based on camel milk made in China.

See Also: Mammals; Mammary Gland: Anatomy; Middle Eastern Fermented Milks

References

Abdallah, H.R., Faye, B., 2012. Phenotypic classification of Saudi Arabian camel (*Camelus dromedarius*) by their body measurements. Emir. J. Food Agric. 24, 272–280.

Abdussamad, A.M., Charruau, P., U Kalla, D.J., Burger, P., 2015. Validating local knowledge on camels: color phenotypes and genetic variation of dromedaries in the Nigeria-Niger corridor. Livest. Sci. 181, 131–136.

Ahmed, A.I., Blanchard, L., Abdelhadi, O.M.A., Bakheit, S.A., Faye, B., 2014. Statistical analysis of traditional practices of fermented camel milk in North Kordofan State, Sudan. Malaysian J. Anim. Sci. 17 (1), 117–128.

Akhmetsadykova, S., Baubekova, A., Konuspayeva, G., Akhmetsadykov, N., Loiseau, G., 2014. Microflora identification of fresh and fermented camel milk from Kazakhstan. Emir. J. Food Agric. 26 (4), 327–332.

Al-Abri, M., Faye, B., 2019. Genetic improvement in dromedary camels: challenges and opportunities. Front. Genet. 10 (167), 1–5.

Al-Ani, F.K., Vestweber, G.E., 1986. Udder oedema: an updated review. Vet. Bull. 56, 763–769.

Algruin, K., Konuspayeva, G., 2015. Making laben with camel milk. In: Kazakhstan, K.G. (Ed.), Proc. of 4th Conference of ISOCARD, "Silk Road Camel: The Camelids, Main Stakes for Sustainable Development", June 8–12, 2015 Almaty, p. 2393. Special Issue of Scientific and Practical Journal Veterinariya #2 (42).

Alhaj, O.A., Taufik, E., Handa, Y., Fukuda, K., Saito, T., Urashima, T., 2013. Chemical characterization of oligosaccharides in commercially pasteurized dromedary camel (*Camelus dromedaries*) milk. Int. Dairy J. 28 (2), 70–75.

Alhaj, O., 2020. Exploring potential therapeutic properties of camel milk. In: AlHaj, O., Faye, B., Agrawal, R.D. (Eds.), Handbook of Research on Health and Environmental Benefits of Camel Products. IGI Global, Hershey, US, pp. 123–154.

Almathen, F., Charruau, P., Mohandesan, E., Mwaharo, J.M., Orozco-Terwengel, P., Pitt, D., Abdussamad, A., Uerpmann, M., Uerpman, H.P., Decupere, B., Magee, P., Alnaqeeb, M., Salim, B., Raziq, B., Dessie, T., Abdelhadi, O., Banabazi, M., El-Eknah, M., Walzer, C., Faye, B., Hofreiter, M., Peters, J., Hanotte, O., Burger, P., 2016. Ancient and modern DNA reveal dynamics of domestication and cross-continental dispersal of the dromedary. Proc. Natl. Acad. Sci. U. S. A. 113 (24), 6707–6712.

Atigui, M., Marnet, P.G., Barmat, A., Khorchani, T., 2015. Effects of vacuum level and pulsation rate on milk ejection and milk flow traits in Tunisian dairy camels (*Camelus dromedarius*). Trop. Anim. Health Prod. 47 (1), 201–206.

Ayadi, M., Musaad, A., Aljumaah, R., Matar, A., Faye, B., 2016a. Effects of manual udder stimulation on milk partitioning and flow traits during the machine milking in dairy camels. J. Camel Pract. Res. 23 (1), 1–5.

Ayadi, M., Aljumaah, R.S., Samara, E.M., Faye, B., Caja, G., 2016b. A proposal of linear assessment scheme for the udder of dairy camels (*Camelus dromedarius L.*). Trop. Anim. Health Prod. 48, 927–933.

Ayadi, M., Musaad, A., Aljumaah, R., Matar, A., Konuspayeva, G., Abdelrahman, M., Abid, I., Bengoumi, M., Faye, B., 2018. Machine milking parameters for an efficient and healthy milking in dairy camels (*Camelus dromedarius*). J. Camel Pract. Res. 25 (1), 81–88.

Aziz, M.A., Faye, B., Al-Eknah, M., Musaad, A., 2016. Modeling lactation curve of Saudi (camels using a linear and non-linear forms of the incomplete Gamma function. Small Rumin. Res. 137, 40–46.

Berhe, T., Seifu, E., Kurtu, M.Y., 2013. Physicochemical properties of butter made from camel milk. Int. Dairy J. 31 (2), 51–54.

Blanc, C.P., Hennesser, Y., 1989. Approche zoo-géographique de la différenciation infraspécifique chez le dromadaire *Camelus dromedarius* Linnee, 1766 (Mammalia: Camelidae). Rev. Elev. Med. Vet. Pays Trop. 42, 573–587.

Burger, P., Ciani, E., Faye, B., 2019. Old world camels in a modern world—a balancing act between conservation and genetic improvement. Anim. Genet. 50, 598–612.

Burger, P., 2016. The history of old-world camelids in the light of molecular genetics. Trop. Anim. Prod. 48 (5), 905–913.

Cardoso, R.R.A., Santos, R., Cardoso, C., Carvalho, M., 2010. Consumption of camel's milk by patients intolerant to lactose: a preliminary study. Rev. Alerg. Mex. 57, 3–26.

Chuvakova, Z.K., Beisemayeva, R.U., Puzyevskaya, O.M., et al., 2000. Chemical Composition, Microbial Control and Antiviral Properties of Freshly Made and Conserved Shubat "Bota". Proceedings of the 2nd International Camelid Conference. Agroeconomics of Camelid Farming Kazakhstan, Almaty.

El-Zubeir, I.E.M., Jabreel, S.O., 2008. Fresh cheese from camel milk coagulated with Camifloc. Int. J. Dairy Technol. 61, 90–95.

FAOstat, 2020. Food and Agriculture Organization. http://www.fao.org/english/newsroom/highlights/2001/010701-e.htm.

Farah, Z., 1993. Composition and characteristics of camel milk. J. Dairy Res. 60, 603–626.

Faraz, A., Waheed, A., Nazir, M.M., Mirza, R.H., 2018. Milk production potential of Marecha dromedary camel in desert thal Punjab, Pakistan. J. Fisheries Livest. Prod. 6 (3), 280.

Faye, B., Konuspayeva, G., 2012. The Encounter between Bactrian and dromedary camels in Central Asia. In: Knoll, E.-M., Burger, P. (Eds.), Camels in Asia and North-Africa-Interdisciplinary Perspectives on Their Past and Present Significance. Austrian Academy of Sciences Press, Wien, Austria, 27–33 (Photos Pp. 248–250).
Faye, B., Konuspayeva, G., 2020. Le chameau de Bactriane dans les vicissitudes de l'Histoire depuis 1917. In: Les vaisseaux du désert et des steppes: les camélidés dans l'Antiquité (Camelus dromedarius et Camelus bactrianus), Archéologies 2, MOM Editions, Lyon, France, pp. 265–272.
Faye, B., Konuspayeva, G., Messad, S., Loiseau, G., 2008. Discriminant milk components of Bactrian camel (*Camelus bactrianus*), dromedary (*Camelus dromedarius*) and hybrids. Dairy Sci. Technol. 88, 607–617.
Faye, B., Chaibou, M., Vias, G., 2012. Integrated impact of climate change and socioeconomic development on the evolution of camel farming systems. Br. J. Environ. Clim. Change 2 (3), 227–244.
Faye, B., Konuspayeva, G., Narmuratova, M., Serikbaeva, A., Musaad, A.M., Mehri, H., 2013. Effect of crude olive cake supplementation on camel milk production and fatty acid composition. Dairy Sci. Technol. 93, 225–239.
Faye, B., Madani, H., El-Rouili, A.H., 2014. Camel milk value chain in northern Saudi Arabia. Emir. J. Food. Agric. 26 (4), 359–365.
Faye, B., Bengoumi, M., Al-Masaud, A., Konuspayeva, G., 2015. Comparative milk and serum cholesterol content in dairy cow and camel. J. King Saud Univ. Sci. 27, 168–175.
Faye, B., Konuspayeva, G., Bengoumi, M., 2019. Vitamins of camel milk: a comprehensive review. J. Camelid Sci. 12, 17–32.
Faye, B., 2004. Dairy Productivity Potential of Camels. Proc. of the 34th Meeting FAO/ICAR (International Committee for Animal Recording). Session on Camelids. 28 Mai-3 Juin 2004, Sousse (Tunisie), pp. 93–105.
Faye, B., 2018. The enthusiasm for camel production. Emir. J. Food Agric. 30, 249–250.
Garcia, C., Lutz, N.W., Confort-Gouny, S., Cozzone, P., Armand, M., Bernard, M., 2012. Phospholipid fingerprints of milk from different mammalians determined by 31P NMR: towards specific interest in human health. Food Chem. 135 (3), 1777–1783.
Hashim, I.B., Khalil, A.H., Habib, H., 2015. Quality and acceptability of a set-type yogurt made from camel milk. J. Dairy Sci. 92 (3), 857–862.
Hjort af Ornas, A., Hussein, M.A., 1993. Camel herd dynamics in southern Somalia: long term development and milk production implications. In: Hjort af Orn€as, A. (Ed.), The Multi-purpose Camel: Interdisciplinary Studies on Pastoral Production in Somalia. EPOS, Uppsala University, Sweden, pp. 31–42.
Ibrahim, A.H., Khalifa, S.A., 2015. Effect of freeze drying on camel's milk nutritional properties. Int. Food Res. J. 22 (4), 1438–1445.
Ibrahim, A.H., 2015. Effects of exopolysaccharide-producing starter cultures on physicochemical, rheological and sensory properties of fermented camel's milk. Emir. J. Food Agric. 27 (4), 374–383.
Jans, C., Bugnard, J., Njage, P.M.K., Lacroix, C., Miele, L., 2012. Lactic acid bacteria diversity of African raw and fermented camel milk products reveals a highly competitive, potentially health-threatening predominant microflora. LWT - Food Sci. Technol. 47 (2), 371–379.
Jensen, J.L., Molgaard, A., Poulsen, J.N., Harboe, M.K., Simonsen, J.B., Lorentzen, A.M., Hjerno, K., van den Brink, J.M., Qvist, K.B., Larsen, S., 2013. Camel and bovine chymosin: the relationship between their structures and cheese-making properties. Biol. Crystallogr. D69, 901–913.
Jilo, K., Galgalo, W., Mata, W., 2017. Camel mastitis: a review. MOJ Eco. Environ. Sci. 2 (5), 00034.
Kappeler, S., Heuberger, C., Farah, Z., Puhan, Z., 2006a. Expression of the peptidoglycan recognition protein, PGRP, in the lactating mammary gland. J. Dairy Sci 87, 2660–2668.
Kappeler, S.R., van den Brink, H.J., Rahbek-Nielsen, H., Farah, Z., Puhan, Z., Hansen, E.B., Johansen, E., 2006b. Characterizations of recombinant camel chymosin reveals superior properties for the coagulation of bovine and camel milk. Biochem. Biophys. Res. Commun. 342, 647–654.
Khalifa, S.A., Ibrahim, A.H., 2015. Influence of addition modified starches as stabilizer on physicochemical and textural properties of camel's milk yoghurt. Zagazig J. Agric. Res. 42 (2), 1-201513.
Konuspayeva, G., Faye, B., Loiseau, G., Levieux, D., 2007. Lactoferrin and Immunoglobin content in camel milk from Kazakhstan. J. Dairy Sci. 90, 38–46.
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 Sci. Technol. 88, 327–340.
Konuspayeva, G., Faye, B., Loiseau, G., 2009. The composition of camel milk: a meta-analysis of the literature data. J. Food Compos. Anal. 22, 95–101.
Konuspayeva, G., Faye, B., Loiseau, G., 2011. Variability of vitamin C content in camel milk from Kazakhstan. J. Camelid Sci. 4, 63–69.
Konuspayeva, G., Camier, B., Gaucheron, F., Faye, B., 2014. Some parameters to process camel milk into cheese. Emir. J. Food Agric. 26, 354–358.
Konuspayeva, G., Camier, B., Aleilawi, N., Al-Shumeimyri, M., Al-Hammad, K., Algruin, K., Alshammari, F., Beaucher, E., Faye, B., 2017. Manufacture of dry- and brine-salted soft camel cheeses for the camel dairy industry. Int. J. Dairy Technol. 70 (1), 92-2017101.
Konuspayeva, G., Baubekova, A., Akhmetsadykova, S., Akhmetsadykov, N., Faye, B., 2019. Concentrations in D- and L-lactate in rawx cow and camel milk. J. Camel Pract. Res. 26 (1), 111–113.
Konuspayeva, G., 2020a. Camel milk composition and nutritional value. In: AlHaj, O., Faye, B., Agrawal, R.D. (Eds.), Handbook of Research on Health and Environmental Benefits of Camel Products. IGI Global, Hershey, US, pp. 15–40.
Konuspayeva, G., 2020b. Manufacture and challenges of camel milk cheese. In: AlHaj, O., Faye, B., Agrawal, R.D. (Eds.), Handbook of Research on Health and Environmental Benefits of Camel Products. IGI Global, Hershey, US, pp. 110–122.
Metha, R.D., Agrawal, R., 2020. Camel milk disguised cosmeceutical. In: AlHaj, O., Faye, B., Agrawal, R.D. (Eds.), Handbook of Research on Health and Environmental Benefits of Camel Products. IGI Global, Hershey, US, pp. 348–362.
Monchot, H., 2015. From paleontology to zooarchaeology, importance of camels through time and history. In: Kazakhstan, K.G. (Ed.), Proc. of 4th Conference of ISOCARD, "Silk Road Camel: The Camelids, Main Stakes for Sustainable Development", June 8–12, 2015 Almaty, pp. 43–47. Special Issue of Scientific and Practical Journal Veterinariya #2 (42).
Muhammad, S.A., Farooq, A.A., Akhtar, M.S., Hayat, C.S., 2005. Parturient udder oedema in a dromedary camel (*Camelus dromedarius*). Pakistan Vet. J. 25 (2), 100.
Musaad, A., Faye, B., Abu-Nikhela, A., 2013. Lactation curves of dairy camels in an intensive system. Trop. Anim. Health Prod. 4, 1039–1046.
Nagy, P., Juhasz, J., 2016. Review of present knowledge on machine milking and intensive milk production in dromedary camels and future challenges. Trop. Anim. Health Prod. 48, 915–926.
Nagy, P., Faye, B., Marko, O., Thomas, S., Wernery, U., Juhasz, J., 2013. Microbiological quality and somatic cell count in bulk milk of dromedary camels (*Camelus dromedarius*): descriptive statistics, correlations, and factors of variation. J. Dairy Sci. 96, 5625–5640.
Nagy, P., Faigl, V., Reiczigel, J., Juhasz, J., 2014. Effect of pregnancy and embryonic mortality on milk production in dromedary camels (*Camelus dromedarius*). J. Dairy Sci. 98, 975–986.
Nagy, P., Fabri, Z.N., Varga, L., Reiczigel, J., Juhasz, J., 2017. Effect of genetic and nongenetic factors on chemical composition of individual milk samples from dromedary camels (*Camelus dromedarius*) under intensive management. J. Dairy Sci. 100, 8680–8693.
Ramet, J.P., 1989. L'aptitude fromagère du lait de dromadaire. Rev. Elev. Med. Vet. Pays Trop. 42 (1), 105–111.
Rybczynski, N., Gosse, J.C., Harington, R., Wogelius, R.A., Hidy, A.J., Buckley, M., 2013. Mid-Pliocene warm-period deposits in the High Arctic yield insight into camel evolution. Nat. Commun. 4 (1550), 1–9.
Ryskaliyeva, A., Henry, C., Miranda, G., Faye, B., Konuspayeva, G., Martin, P., 2019. The main WAP isoform usually found in camel milk arises from the usage of an improbable intron cryptic splice site in the precursor to mRNA in which a GC-AG intron occurs. BMC Genet. 20, 14 (10 pp.).
Saleh, S.K., Faye, B., 2011. Detection of subclinical mastitis in dromedary camels (*Camelus dromedarius*) using somatic cell counts, California mastitis test and udder pathogen. Emir. J. Food Agric. 23 (1), 48–58.
Seboussi, R., Faye, B., Askar, M., Hassan, K., Alhadrami, G., 2009. Effect of selenium supplementation on blood status and milk, urine and fecal excretion in pregnant and lactating camel. Biol. Trace Elem. Res. 128, 45–57.

Seifu, E., Abraham, A., Kurtu, M.Y., Yilma, Z., 2012. Isolation and characterization of lactic acid bacteria from Ititu: Ethiopian traditional fermented camel milk. J. Camelid Sci. 5, 82–98.
Soleymanzadeh, N., Mirdamadi, S., Kianirad, M., 2016. Antioxidant activity of camel and bovine milk fermented by lactic acid bacteria isolated from traditional fermented camel milk (Chal). Dairy Sci. Technol. 96 (4), 443–457.
Tibary, A., Anouassi, A., 1997. Theriogenology in Camelidae. Abu Dhabi Printing and Publishing Co, Mina, Abu Dhabi, United Arab Emirates.
Woubit, S., Bayleyegn, M., Bonnet, P., Jean-Baptiste, S., 2001. Camel (*Camelus dromedarius*) mastitis in Borena lowland pastoral area, Southwestern Ethiopia. Rev. Elev. Med. Vet. Pays Trop. 54 (3–4), 207–212.
Yagil, R., 1982. Camels and Camel Milk. FAO, Rome.
Yagil, R., 1985. The Desert Camel. Comparative Physiological Adaptation. Karger Publishers, London, p. 162.
Zarrin, M., Riveros, J.L., Ahmadpour, A., De Almeida, A.M., Konuspayeva, G., Vargas- Bello-Perez, E., Faye, B., Hernandez-Castellano, L.E., 2020. Camelids: new players in the international animal production context. Trop. Anim. Health Prod. 52, 903–913.
Zhang, H., Yao, J., Zhao, D., Liu, H., Li, J., Guo, M., 2005. Changes in chemical composition of Alxa bactrian camel milk during lactation. J. Dairy Sci. 88 (10), 3402–3410.
Zouari, A., Marchesseau, S., Chevalier-Lucia, D., Raffard, G., Ayadi, M.A., Picart-Palmade, L., 2018. Acid gelation of raw and reconstituted spray-dried dromedary milk: a dynamic approach of gel structuring. Int. Dairy J. 81, 95–103.