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Camelids: new players in the international animal production context

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Abstract

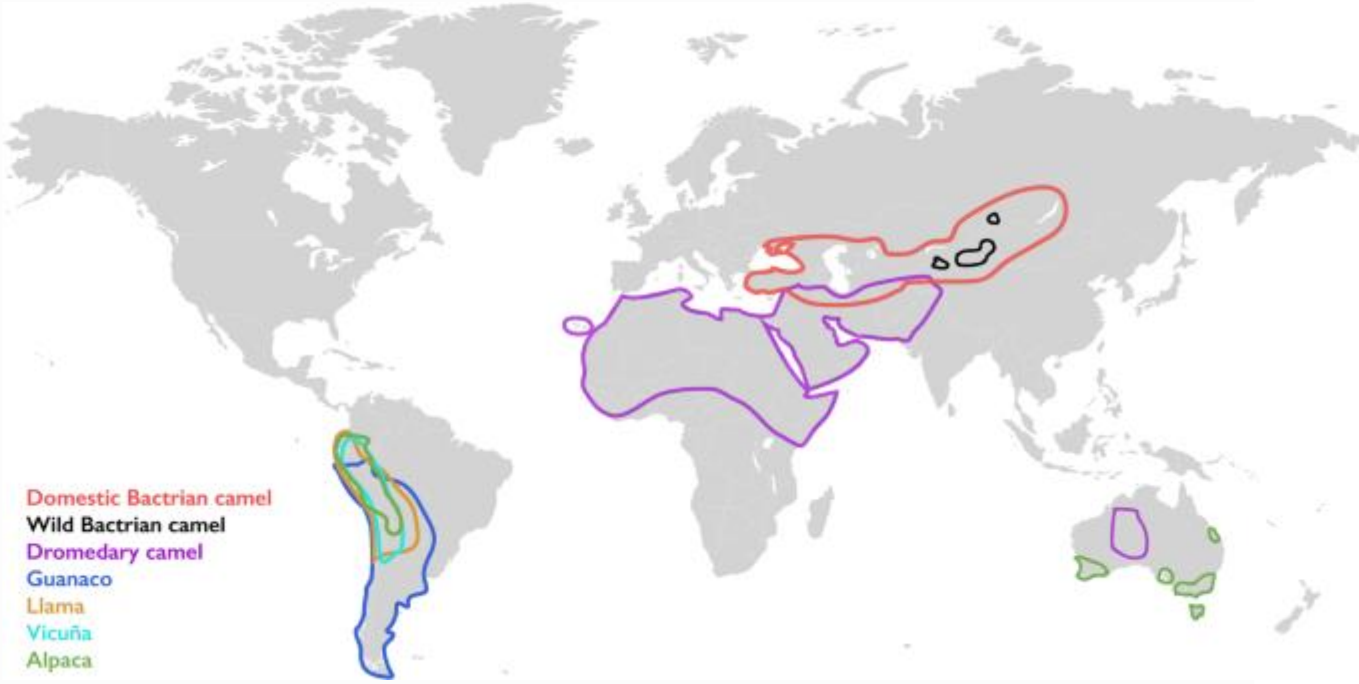
The Camelidae family comprises the Bactrian camel (*Camelus bactrianus*), the dromedary camel (*Camelus dromedarius*), and four species of South American camelids: llama (*Lama glama)*, alpaca (*Lama pacos*) guanaco (*Lama guanicoe*), and vicuña (*Vicugna vicugna*). The main characteristic of these species is their ability to cope with either hard climatic conditions like those found in arid regions (Bactrian and dromedary camels) or high-altitude landscapes like those found in South America (South American camelids). Because of such interesting physiological and adaptive traits, the interest for these animals as livestock species has increased considerably over the last years. In general, the main animal products obtained from these animals are meat, milk, and hair fiber, although they are also used for races and work among other activities. In the near future, climate change will likely decrease agricultural areas for animal production worldwide, particularly in the tropics and subtropics where competition with crops for human consumption is a major problem already. In such conditions, extensive animal production could be limited in some extent to semi-arid rangelands, subjected to periodical draughts and erratic patterns of rainfall, severely affecting conventional livestock production, namely cattle and sheep. In the tropics and subtropics, camelids may become an important protein source for humans. This article aims to review some of the recent literature about the meat, milk, and hair fiber production in the six existing camelid species highlighting their benefits and drawbacks, overall contributing to the development of camelid production in the framework of food security.

Introduction

The Camelidae family descends from animals living in North America during the Eocene period (45 million years ago). Camels' ancestors migrated to South America and across the Bering Strait into Central Asia, which has resulted in Old World camels (Bactrian and dromedary camels) and New World camels (South American camels; SAC). Thus, camel evolution has been recently addressed using molecular techniques by Manee et al. (2019).

According to Payne and Wilson (1999), camels in central Asia evolved into the domestic Bactrian camel (*Camelus bactrianus*) and wild Bactrian camel (*Camelus bactrianus ferus*), being both of them commonly known as two-humped camels. Currently, wild Bactrian camels subsist in secluded desert areas such as the Gobi Desert in China. Domesticated Bactrian camels have been reared in several countries in Central Asia, where they played a primary role in transporting the goods. Currently, these animals are also used for meat, milk, and hair fiber production. Domestic Bactrian camels are distributed from Turkey to Mongolia (Fig. 1). The one-humped camel or dromedary camel (*Camelus dromedarius*) evolved from animals similar to Bactrian camels (Burger et al. 2019). Dromedary camels are essentially domestic, and they are distributed in Asia and Africa, from East India to Morocco (Fig. 1). In addition, dromedary camels are distributed in the Canary Islands (Spain) and Central Australia (Fig. 1). Dromedaries are used to provide work and transport in addition to meat, milk, and hair fiber production. Dromedary camels are also used for races in the Persian Gulf region and as pack animals in tourist activities in the Canary Islands (Spain) or Australia.

Fig. 1



Distribution map of the different camel species (domestic Bactrian camel, wild Bactrian camel, dromedary camel, alpaca, llama, vicuña and guanaco)

In South America, guanaco (*Lama guanacoe*) and vicuña (*Vicugna vicugna*) are the two wild SAC species. The estimated population is about 650,000 and 250,000 animals, respectively (FAOstat 2019). The domestication of guanacos and vicuñas led to the establishment of the domestic SAC species, llama (*Lama glama*) and alpaca (*Vicugna pacos*), respectively. According to FAOstat (2019), there are about 5 million llamas and 4.5 million alpacas in South America. Llamas are used as pack animals by Andean native communities. In addition, llamas are also used for meat production. Alpacas are mostly used for the production of fine fibers. South American camels, notably alpacas, have been introduced in other countries, namely Australia and New Zealand where they are used for fiber production. These animals are very popular as pets and show animals in Europe, Canada, and the USA.

Camels have very interesting physiological and adaptive traits (Gerken 2010; Alhidary et al. 2018; Hoter et al. 2019). Indeed, Bactrian and dromedary camels are particularly well adapted to arid environments (Wu et al. 2014). Some of these traits are (a) adipose tissue located in the hump that can be mobilized in case of food scarcity, (b) long and bushy eyelashes to protect eyes from sand and sun daylight, (c) occludable nostrils to avoid sand entrance and reduce the amount of water lost during the respiration process, (d) adapted limbs for sandy conditions, and (e) efficient physiological mechanisms to mitigate heat stress and dehydration. South American camels have also very interesting physiological traits (Wheeler 1995; Vaughan and Tibary 2006; Jiménez et al. 2010). These include (a) tolerance to hypoxia, which allows them to live at very high altitudes; (b) soft footpads adapted to mountain and rocky conditions; (c) thick and isolating hair fiber to protect from cold temperatures; and (d) specific behavioral traits such as kicking and spitting rumen fluid as a protection mechanism against predators. In addition, Bactrian, dromedary, and South American camels have also a digestive system adapted to consume large amounts of fibrous and thorny plants (Dehority 2002). As these species have a three-chamber foregut, they are commonly classified as pseudoruminants (Dehority 2002).

Despite the important role of Old and New World camels in the livelihood, food security, and economy of the local communities, these species have never been considered major players in the international animal production context. However, changes associated to climate change may modify this scenario in the near future. The objective of this review is to describe major features of Old and New World camels as production animals, particularly in their main productive perspectives (i.e., meat, milk, and hair fiber) and to highlight the potential and opportunities of using camels in the international animal production context.

Bactrian camels

Bactrian camels (*Camelus bactrianus*), also known as double-humped camels, differ from dromedary camels by the number of humps and the ecosystem where they are raised (Fig. 2). As dromedary camels, Bactrian camels are used for meat and milk production. In addition, Bactrian camels are also used for hair fiber production. The number of Bactrian camels is reduced compared with dromedary camels (1 million vs. 34 million animals, respectively; FAOstat 2019). However, in some countries such as Kazakhstan, the number of Bactrian camels represents 85% of the total camel population (Imamura et al. 2017). Bactrian camels are raised mainly in Mongolia (435,000 heads), China (323,000), Kazakhstan (194,000), Uzbekistan (18,000), and Russia

(6400). However, Bactrian camels are also present in other countries such Kirgizstan, Tajikistan, Azerbaijan, Iran, Pakistan, India, Turkey, and Ukraine.

Fig. 2

Domestic Bactrian camel (Kazakhstan)

Meat production perspectives

Adult Bactrian camels weight 700–800 kg in case of females, and up to 1250 kg in case of males (Saipolda 2004). In 2017, about 36,700 tons of Bactrian camel meat was produced, being China (20,668 tons), Mongolia (7122 tons), Kazakhstan (6617 tons), Uzbekistan (2120 tons), and Russia (179 tons) the main leading producers (FAOstat 2019).

Most of the literature regarding meat composition in Bactrian camels is in Russian (Terentyev 1975), Mongolian (Indra et al. 2003), Kazakh (Moussaiev et al. 2007), or Chinese (Zhao et al. 2004). However, recent studies published in English showed that Bactrian camel meat contains 17.0–21.0% protein, 1.80–3.80% fat, and 0.90–1.10% minerals (Raiymbek et al. 2015; Raiymbek et al. 2018). Compared with other livestock species, meat from Bactrian camels contains similar protein levels to those from chickens (21.4%), lambs (20.8%), pigs (20.5%), and veals (20.2%), although meat fat content in Bactrian camels is lower than those from lambs (4.40%) and pigs (5.41%) and similar to chickens (3.08%) and veals (2.87%) (Hernández-Castellano et al. 2013; Cobos and Díaz 2015).

Regarding the amino acid profile, Bactrian camel meat contains similar levels of methionine (6.72%); lower concentrations of glutamate (6.78%), serine (1.66%), histidine (3.55%), tyrosine (2.23%), and tryptophan (0.37%); and higher concentrations of aspartate (12.2%), arginine (7.48%), proline (13.1%), isoleucine (6.07%), and leucine (15.3%) compared with dromedary meat (6.78, 7.49, 3.10, 6.09, 5.34, 0.52, 7.93, 5.80, 9.65, 4.91, and 11.7%, respectively) (Raiymbek et al. 2015). Additionally, Bactrian camel meat contains higher levels of methionine, leucine, and aspartate compared with other species such as those from beef cattle (2.20, 8.50, and 8.90%, respectively), lambs (2.40, 7.20, and 8.60%, respectively), and pigs (2.60, 7.60, and 8.80%, respectively) (Ahmad et al. 2018).

Regarding the fatty acid (FA) profile, polyunsaturated fatty acid (PUFA) levels are lower in Bactrian camel meat (9.60%) compared with dromedary camel meat (17.7%), while similar monounsaturated fatty acid (MUFA) levels have been described for Bactrian and dromedary camels (35.4 and 37.9%, respectively) (Raiymbek et al. 2019). Specifically, Bactrian camel meat contains lower levels of palmitic acid (26.9%) and palmitoleic acid (3.20%) and higher levels of myristic (8.60%), oleic (29.8%), and linoleic acid (10.0%) than dromedary camel meat (29.0, 8.60, 8.10, 26.7, and 7.50%, respectively) (Raiymbek et al. 2019). In addition, cholesterol concentrations in Bactrian camel meat are slightly higher (0.54 g/kg) than those from dromedary camel meat (0.49 g/kg). Compared with other livestock species, meat from Bactrian camels contains higher levels of palmitic acid and lower levels of oleic acid compared with meat from beef cattle (25.0 and 36.1%, respectively), lambs (22.2 and 32.7%, respectively), and pigs (23.2 and 32.8%, respectively). Linoleic acid levels in meat from Bactrian camels are lower than those from beef cattle and lambs (2.40 and 2.70%, respectively) and higher than those from pigs (14.2%) (Wood et al. 2004).

Dairy production perspectives

In 2017, Bactrian camels produced about 21,000 tons of milk (FAOstat 2019). While the Bactrian camel population represents 2.70% of the total amount of Old World camels worldwide, milk production from these camels only represents 1.80% of the total milk produced by Old World camels. Milk yield in Bactrian camels differs among countries. For instance, Bactrian camels yield about 300 kg (17-month lactation) in Mongolia (Saipolda 2004), being 2 to 4 kg/day the highest milk yield in the lactation peak (Indra et al. 2003). In China, Bactrian camels yield 0.25 to 1.50 kg/day in addition to the milk consumed by the calf (Zhang et al. 2005), which represents about 645 kg per lactation (Surong 2019). Higher milk yields have been recorded in those Bactrian camels raised in Kazakhstan (850–1700 kg; Baimukanov et al. 2017) and Russia (1827 kg; Indra et al. 2003). However, milk yield in Bactrian camels is lower than dromedary camels. In a recent study, Baimukanov et al. (2017) described lower milk yields in Bactrian camels (1270 kg/year) than dromedary camels (3601 kg/year). Hybridization between Bactrian and dromedary camels is commonly performed in these countries to increase milk yields from camels (Faye and Konuspayeva 2012). For instance, Baimukanov et al. (2017) described how milk production in Bactrian and dromedary hybrids ranged from 2251 to 2927 kg/year.

Despite low milk yields, consumption of Bactrian camel milk is prevalent in Central Asia (Accolas et al. 1978; Konuspayeva and Faye 2011). Regarding the nutritive aspects of Bactrian camel milk, Faye et al. (2008) showed that Bactrian camel milk contains 6.67% fat, which is similar to the fat content in sheep milk from sheep (6.39%) and higher than the fat content in goat and cow milk (4.47 and 3.26%, respectively) (Hernández-Castellano et al. 2016). The fatty acid profile of Bactrian camel milk is characterized by caprylic (0.53%), lauric (1.24%) myristic (15.4%), iso-heptadecanoic (0.55%), and oleic (18.8%) acids (Konuspayeva et al. 2008). Compared with other species, milk from Bactrian camels contains lower caprylic and lauric acids compared with milk from goats (2.92 and 4.52%, respectively), sheep (1.87 and 3.99%, respectively), and cows (1.39 and 3.64%, respectively). However, oleic levels in milk from Bactrian camels are similar to those found in milk from goats (18.7%) and lower to those found in milk from sheep and cows (20.2 and 22.4%, respectively) (Markiewicz-Keszycka et al. 2013). Cholesterol concentrations in milk from Bactrian camels are higher (0.37 mg/kg) (Konuspayeva et al. 2008) than in cow milk (0.81 mg/kg) (Faye 2015). In addition, Faye et al. (2008) showed that Bactrian camel milk contains high concentrations of vitamin C (0.18 g/L), calcium (1.30 g/L), and phosphorus (1.07 g/L).

Hair fiber production perspectives

Besides its use for working (i.e., pulling and carrying heavy goods) or sportive activities (i.e., races), Bactrian camels are also reared for hair fiber production, especially in Mongolia and China (Chapman 1991). Hair fiber from Bactrian camels is very thin fine (20–23 μm), similar to that of merino wool, and it is considered a high-quality natural fiber. One of the main Bactrian camel breeds used for hair fiber production is the Alxa Bactrian camel (China), with a production of hair fiber about 5–6 kg in females and up to 12.5 kg in males. Hair fiber from this breed is characterized by long and strong fiber and light color (Surong 2019). In recent years, production of hair fiber from Bactrian camels has been considerably increased due to high demand by Europe and North America (Faye 2015).

Dromedary camels

Dromedary camels (Fig. 3) represent 95% of all Old World camels (Faraz et al. 2019). Most dromedary camels are distributed in the Horn of Africa, the Middle East, Pakistan, India, and the harsh and arid areas of North and West Africa. Dromedary camels are used for meat, milk, and hair fiber production as well as for transportation and agriculture labors (Faraz et al. 2013).

Fig. 3

Dromedary camel (Iran)

Meat production perspectives

Dromedary camels' capability to use low-quality feeds has made them one of the main animal protein sources in several tropical countries (Faraz et al. 2019; Hernández-Castellano et al. 2019). Based on its importance, several studies have focused on dromedary camel meat quality and composition (Kadim et al. 2008; Kadim et al. 2014). Dromedary camel calves are born with approximately 35 kg BW; however, this value fluctuates based on breed and region (Kadim et al. 2014). Average daily gain in dromedary camel calves is lower than dairy calves and limited to 500 g/day. Adult dromedary camels can weigh up to 650 kg BW (7–8 years old). Depending on the slaughtering age, dromedary carcasses can range from 125 to 400 kg with a carcass dressing ranging from 55 to 70% (Kadim et al. 2014).

Intramuscular fat in meat from dromedary camels ranges from 5.20–7.00% (Dawood and Alkanhal 1995; Al-Owaimer 2000; Kadim et al. 2006). However, intramuscular fat content is affected by animal age, and therefore higher intramuscular fat percentages are observed in meat from 5- to 8-year-old dromedary camels (10.5%) than from 1- to 3-year-old dromedary camels (4.40%). Dromedary camel meat contains more PUFA than beef cattle (Dawood and Alkanhal 1995). As showed by Rawdah et al. (1994), the FA profile in dromedary camel meat is based 51.5% saturated fatty acids (SFA), 29.9% MUFA, and 18.6% PUFA. The most abundant fatty acids in dromedary camel meat are palmitic acid (26.0%), oleic acid (18.9%), and linoleic acid (12.1%) (Rawdah et al. 1994). In addition, dromedary camel meat contains lower cholesterol (0.50 g/kg) than other livestock species such as beef cattle (0.59 g/kg), sheep (0.71 g/kg), and goat (0.63 g/kg) (El-Magoli et al. 1973; Kadim et al. 2008; Kadim et al. 2013). Meat protein content in dromedary camel is similar to beef cattle (22.7 and 22.5%, respectively; Ahmadpour et al. 2014). Among the essential amino acids, lysine and leucine are the most abundant (8.45 and 8.41 g/16 g N, respectively) and methionine the less abundant (2.41 g/16 g N; Dawood and Alkanhal 1995). Similar values have been reported for buffalo meat (Ziauddin et al. 1994).

Based on these facts, dromedary camel meat is considered a healthy animal meat source (Schönfeldt and Gibson 2008) and its consumption might reduce the risk of suffering atherosclerosis, obesity, and hypercholesterolemia, and decline the risk of cancer (Chizzolini et al. 1999).

Dairy production perspectives

Among domestic animals, dromedary camels need to overcome extreme climate conditions for generation and preservation of the offspring. Nourishing young calves in harsh climate conditions characterized by feed and water scarcity has increased the research interest on camel milk biosynthesis and composition.

Despite milk production in dromedary camels being low, this milk is extremely important in arid places, being an excellent source of proteins for humans living in such areas (Konuspayeva et al. 2009). Average dromedary milk yield is not very consistent and rarely exceeds 25 kg/day (Nagy and Juhasz 2016). The absence of genetic selection, lack of uniform milking method, and use of traditional rearing systems are some of the factors that affect the wide variation among animals (Wernery et al. 2004; Wernery 2006; Wernery et al. 2006).

Dromedary camels have longer lactation periods than dairy cows, and they may last up to 24 months (Yagil and Yagil 2000; Wernery 2006). In the last 20 years, milking machines specifically designed for dromedary camels have caused increased milk yield as well as improved milk hygiene (Wernery 2006; Wernery et al. 2006; Ayadi et al. 2018). Based on a meta-analysis published by Konuspayeva et al. (2009), dromedary camel milk contains on average 3.35% protein, 3.82% fat, 4.46% lactose, 0.79% ash, and 12.5% dry matter. Interestingly, water content in dromedary camel milk is similar to human milk (Wernery 2006; Zibaee et al. 2015), and remains constant under extreme heat-stress conditions (Wernery 2006; Al haj and Al Kanhal 2010). However, there are other factors such as physiological stage, feeding conditions, milk yield, genetic and/or health status that may affect milk quality and composition in dromedary camels (Musaad et al. 2013).

Milk proteins are considered one of the main allergens for humans (Rona et al. 2007; Vargas-Bello-Perez et al. 2019). For instance, β-casein, β-lactoglobulin, lactoferrin, and immunoglobulins from cow milk are common allergens for infants (Khalesi et al. 2017; Mati et al. 2017). Dromedary camel milk is characterized by reduced β-caseins content and the absence of β-lactoglobulin, which contributes to the reduced allergy in dromedary camel milk consumers (Konuspayeva et al. 2009). Ehlayel et al. (2011) showed 80% children (6–12 months old) with cow milk allergy showing no allergy to camel milk.

Regarding fatty acids, dromedary camel milk is characterized by reduced short-chain FA and increased long-chain FA compared with cow milk (Zibaee et al. 2015). Thus, the high content of PUFA (5.60%) and MUFA (39.9%) in dromedary camel milk contributes to enhance the positive effects on human health (Narmuratova et al. 2006; Konuspayeva et al. 2008). The main fatty acids present in dromedary camel milk are oleic (28.4%), palmitic (21.2%), stearic (13.8%), and myristic (12.1%), respectively. Dromedary camel milk is also rich in both lipo- and hydro-soluble vitamins, such as vitamin A, E, D, B, and C (Kumar et al. 2015; Zibaee et al. 2015). For instance, dromedary camel milk contains 34.2 mg/L of vitamin C, being this concentration 3 to 5 times higher than in milk from dairy cows (Stahl et al. 2006). In addition, dromedary camel milk contains higher insulin concentrations (52.0 U/L) than cow milk (16.3 U/L) (Singh 2001). Based on this fact, Agrawal et al. (2005) suggested that consumption of dromedary camel milk could have beneficial effects in patients suffering diabetes (type II). Besides its nutritional properties, dromedary camel milk also contains antibacterial and antiviral enzymes such as lactoferrin, lactoperoxidase, caseins, peptidoglycan recognition protein, N-acetyl-glucosaminidase, lysozymes, and immunoglobulins (Kumar et al. 2016).

Hair fiber production perspectives

Hair fiber is another valuable product obtained from dromedary camels. Although all other camelids produce higher quality hair fiber than dromedary camels, hair fiber from dromedary camels is highly appreciated by consumers because of its luster, softness, warmth, and natural color (Sharma and Pant 2013). However, these characteristics are affected by age as young dromedaries produce thinner and softer hair fiber than adults. Dromedary camel hair fiber is mainly used for clothes, veils, carpets, and blankets (Yam and Khomeiri 2015). In addition to hair fiber, dromedary camels provide long hair, commonly used for clothes manufacturing.

South American camelids

South American camelids (SAC) are widely distributed in South America, being alpacas (*Lama pacos*; Fig. 4a), llamas (*Lama glama*; Fig. 4b), and vicuñas (*Vicugna vicugna*; Fig. 5a) distributed from Ecuador to northern Argentina and Chile, while guanacos (*Lama guanicoe*; Fig. 5b) are found from southern Peru and Paraguay to Argentina and Chile (Saeed et al. 2018). In addition, animal production systems in the Peruvian and Bolivian Altiplano are mostly based on llamas and alpacas (Fernández-Baca 2005).

Fig. 4

Alpaca (A1 and A2; Chile) and llama (B1 and B2; Ecuador)
Fig. 5

Vicuña (A1 and A2; Ecuador) and guanaco (B1 and B2; Chile)
South American camels have exceptional physiological characteristics that allow them to adapt to adverse environments (Gerken 2010). Due to the adaptability to the environment, they have been raised as livestock species for meat, milk, and fiber production.

Meat production perspectives

Meat from llamas and alpacas is one of the major protein sources for Andean rural communities (Perez et al. 2000). Llama and alpaca meat is rich in iron and zinc (32.6 and 44.4 mg/kg, respectively) (Polidori et al. 2007). In addition, meat from llamas and alpacas is low in fat (0.49 and 2.05%, respectively) and cholesterol (0.51 to 0.56 g/kg, respectively), especially if compared with meat from other livestock species (Cristofanelli et al. 2004). Moreover, meat from alpacas contains 51 g SFA/100 g of total intramuscular fat and 2.05 g n−3 fatty acids/100 g of total intramuscular fat (Salva et al. 2009). These facts are particularly attractive for local and international markets, representing a substantial income for small- and medium-scale local producers (Mamani-Linares and Gallo 2014). Technological quality parameters such as carcass pH and temperature, drip loss, thawing loss, expressible juice, total cooking loss, evaporating cooking loss, and cooking drip loss in alpaca and llama meat are similar to those reported for conventional meats (Salva et al. 2009; Mamani-Linares and Gallo 2014). Several studies performed in Australia have reported that alpaca carcasses have low fat covering which makes these carcasses susceptible to cold-induced shortening during processing (Smith et al. 2015). Therefore, these carcasses are commonly aged up to 10 days and electro stimulated to improve tenderness.

Interestingly, slaughtering age and gender do not affect alpaca meat color. Thus, meat from these animals has unique color characteristics. According to the CIELab system, alpaca meat has a characteristic color (L* 38.3; a* 11.7 and b* – 0.78), which could be used to detect frauds, especially in markets with meat from multiple species (Smith et al. 2016). Based on the above-mentioned facts, SAC meat production has a high growth potential in the near future (Smith et al. 2019).

One of the main limitations for the production and commercialization of meat from SAC is the presence of macroscopic *Sarcocystis aucheniae* cysts (1–5 mm cysts), which leads to carcass refusal by the sanitary authorities and/or devaluation of its commercial value (Franco et al. 2018). Consumption of infected raw or undercooked meat can furthermore cause foodborne illness to the consumers in the form of gastroenteritis and diarrhea (Franco et al. 2018). This is therefore an important issue to address in order to increase the value and importance of this meat in the Andean markets.

Cristofanelli et al. (2004) suggested that improving breeding systems of SAC would be a suitable strategy to stimulate the economy in the Andean regions. These authors reported that compared with alpaca, llama has higher BW (46 vs. 63 kg at 25 months of age, respectively), warm carcass weight (24 vs. 31 kg, respectively), cold carcass weight (23 vs. 30 kg, respectively), carcass length (71 vs. 130 cm, respectively), length of hind leg (70 vs. 75 cm, respectively), and length of front leg (60 vs. 68 cm, respectively). Therefore, llama seems to be better suited for meat production in the Andean countries than alpacas. Accordingly, alpaca production systems should focus on fiber, and then use animals that need to be replaced for meat production.

Hence, SAC meat production should be promoted at the local South American markets as an alternative product in pastoral systems with limited growth potential. This is of particular importance in high-altitude regions where conventional livestock species such as cattle or sheep cannot cope so well. In the rest of the World (excluding Australia), SAC are used as pets, and consequently, meat consumption from these animals is not expected to grow significantly in the future.

Dairy production perspectives

Milk yields in SAC are very low compared with dairy cows (Larico-Medina et al. 2018). However, milk from SAC contains higher protein, fat, and lactose levels than cow milk, which makes this type of milk very interesting for dairy products manufacturing. Alpaca milk has on average 3.68% fat, 4.53% protein, and 6.00% lactose contents (Chad et al. 2014), while llama milk has on average 4.70% fat, 4.23% protein, 5.93% lactose contents (Riek and Gerken 2006). Similarly, vicuña milk contains 4.8% fat, 4.30% protein, and 7.05% lactose while guanaco milk has 5.50% fat, 5.00% protein, and 5.44% lactose (Medina et al. 2019).

Regarding fatty acid profile in milk from SAC, Medina et al. (2019) found that all of them contain less than 1% of short-chain fatty acids. Within SFA, palmitic acid was the most abundant (> 25%), followed by stearic acid (> 10%) and myristic acid (> 10%) in all SAC species. Interestingly, levels of rumenic acid, also known as conjugated linoleic acid, in milk from these species range from 1.05–1.64%. Rumenic acid is a unique FA that can only be found in both milk and meat from ruminants. This fatty acid has received particular attention due to the positive effects on human health (Vargas-Bello-Perez and Larrain 2017). Despite the studies mentioned above, data on the nutritional quality of SAC milk is scarce. Due to its potential as an alternative to cow milk, researchers should focus on describing the nutritional properties of SAC milk and its impact on human health (Pauciullo and Erhardt 2015).

Hair fiber production perspectives

In SAC, hair fiber harvesting does not require advanced technology. This fact makes that fiber production represents one of the main economic incomes in productive systems with low primary productivity, such as the Andean highlands and Patagonia (Lichtenstein and Vila 2003). Domestic SAC, especially alpacas, have a wide variety of coat colors, which makes the species valuable for fiber production. Among all possible colors, white is the most valuable for the industry. Consequently, current breeding strategies are focused on selecting those animals producing white fibers (Anello et al. 2019).

Fiber production from SAC is focused on alpacas, with also some relevant fiber production from Guanacos and Vicuñas. There are several factors such as age, breed, and fiber color that affect fiber diameter (higher in darker fleece) (McGregor and Butler 2004). For instance, llama fiber can be classified as baby (< 19 µm; 4.60% of the total production), super thin (19–21.9 µm; 43.4% of the total production), thin (22–24.9 µm; 35.8% of the total production), medium (25–29 µm; 13.6% of the total production), and thick (> 30 µm; 2.60% of the total production) in Argentina (Frank et al. 2006). In New Zealand and Australia, the diameter of alpaca hair fiber ranges from 28.0 to 31.9 µm and from 17.7 to 46.6 µm, respectively (Wuliji et al. 2000; McGregor and Butler 2004).

The main limitations of fiber production in these species are the length of the wick and the presence of a double fiber layer. Consequently, it is necessary to perform a dehairing fleece processing which causes around 45% production losses (Frank et al. 2006). This fact requires actions to improve industrial processing and to optimize harvest and selection of the fleece to minimize losses due to fiber processing (Frank et al. 2006).

Concluding remarks

Camelids are among the most adaptable domestic animals. Indeed, these animals are well adapted to harsh ecosystems such as the African, Asian, or Australian deserts (dromedary camels), the central Asian plains and deserts (Bactrian camels) or the Andean mountains and the Altiplano plateaus (SAC). In such regions, these animals are essential for the economy and food security of local populations.

In the near future, climate change might decrease agricultural areas for animal production worldwide. In these conditions, extensive animal production would have to be limited to some extent to semi-arid rangelands. In such regions, camels will become an important protein source for humans. Furthermore, their adaptation traits would lead to more sustainable animal production systems with reduced greenhouse gas emissions compared with conventional livestock species and fewer needs for animal production inputs such as infrastructures, water, and feed supplementation during feed scarcity periods. In this review, we have focused on the major aspects related to meat, milk, and fiber production in the four domestic camel species (i.e., Bactrian camel, dromedary camel, llama, and alpaca) as they will become important players in the international animal production context.

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Ethics declarations

Conflict of interest

The authors declare that they have no conflict of interest.