Ciência Rural, Santa Maria, v.52:3, e20210058, 2022
http://doi.org/10.1590/0103-8478cr20210058
ISSNe 1678-4596
FOOD TECHNOLOGY

Challenges and perspectives for exploiting donkey milk in the Brazilian Northeast

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ABSTRACT: *Known as an animal of multiple functions, the Equus asinus has always been used for various purposes, such as entertainment, horseback riding, means of transport, agricultural traction and dairy farming. Although, donkeys are associated with a vast heritage of social, cultural, economic and ecological importance, they have lost their importance in the activities of rural properties, both in the developed economies of European countries and in the Northeast region of Brazil. Specific studies of production systems aimed rational exploitation of the donkey species in Brazil do not exist. New perspectives for the use of donkey in the Brazilian semiarid region through the dairy industry has aroused scientific interest and the interest of investors. The donkey, allied to the low production costs and rusticity of the species, has the capacity to contribute to the economy with products of high biological value and therapeutic characteristics. Thus, this review provided a broad view of the donkey bred in the Northeast of Brazil, observing its characteristics and relevance for the region. The benefits of donkey milk and the need to promote the production and marketing of this milk in the dairy production chain will also be discussed.*
Key words: *Equus asinus, dairy products, nutrition, functional foods.*

Desafios e perspectivas para a exploração do leite asinino no Nordeste brasileiro

RESUMO: *Conhecido como um animal de múltiplas funções, o Equus asinus sempre foi utilizado para diversos fins, tais como entretenimento, cavalgadas, meios de transporte, tração agrícola e produção de leite. Embora os asininos estejam associados a um vasto patrimônio social, cultural, econômico e ecológico, eles perderam importância nas atividades das propriedades rurais, tanto nas economias desenvolvidas dos países europeus como na região Nordeste do Brasil. Não existem estudos específicos de sistemas de produção visando a exploração racional das espécies de asininos no Brasil. Novas perspectivas para o uso do asno na região semiárida brasileira através da indústria leiteira despertou o interesse científico e o interesse dos investidores. O asinino, aliado ao baixo custo de produção e à rusticidade da espécie, tem a capacidade de contribuir para a economia com produtos de alto valor biológico e características terapêuticas. Assim, esta revisão forneceu uma visão ampla do asinino criado no Nordeste do Brasil, observando suas características e relevância para a região. Os benefícios do leite asinino e a necessidade de promover a produção e comercialização deste leite na cadeia produtiva do leite também serão discutidos.*
Palavras-chave: *Equus asinus, produtos lácteos, nutrição, alimentos funcionais.*

INTRODUCTION

Equus asinus, a member of the *Equidae* family, has played a key role in today's world civilization. Donkeys are descendants of African animals (*Equus asinus africanus*). Domesticated around 4,000 years before Christ (B.C.), over the centuries, asses have spread across Asia, India, Southern Europe and to the Americas (CAMILLO et al., 2017; MCLEAN & GONZALEZ, 2018).

As a multi-purpose animal, donkeys have always been used for various purposes, such as entertainment, horseback riding, means of transportation, agricultural traction and dairy farming (RANGEL et al., 2015). In addition, donkeys are still very important for the production of mules and burros (muares), because, endowed with great physical resistance when compared to horses. Donkeys can survive under adverse conditions and be useful in regions where agriculture still depends on animal traction. Thus, donkeys are associated with a vast heritage of social, cultural, economic and ecological importance (MARIANTE & CAVALCANTE, 2006; CAVALLARIN et al., 2015).

Received 01.23.21 Approved 05.18.21 Returned by the author 07.20.21
CR-2021-0058.R1
Editors: Rudi Weiblen Pasquale De Palo

In recent times; however, the donkey lost its importance in the activities of rural areas, both in the developed economies of European countries and in the Northeast region of Brazil, making them vulnerable in terms of sustainability (RANGEL, et al., 2015; RAGONA et al., 2016). This vulnerability of the species in Northeastern Brazil has grown with the decrease in interest in raising donkeys, thus generating a large number of abandoned animals, living in almost wild conditions, becoming one of the main causes of automobile accidents on the region's roads (CARNEIRO et al., 2018).

Local ignorance about the productive potentialities of the donkey species as well as a growing international demand for "ejiao", a type of gelatin found in the skin of donkeys, widely used in traditional Chinese medicine, may further reduce the donkey population in the Northeast region of Brazil. Given this scenario, the scientific community has renewed interest in the species, becoming involved in the recovery of biodiversity, the rescue of some almost extinct breeds and the rediscovery of other activities (MARTINI et al., 2018).

Biodiversity studies are particularly relevant because in Brazil, there are still no clearly defined production systems aiming rational exploitation of the donkey species, which hinders the organization of the production chain of donkey milk and its derivatives.

According to the Food and Agriculture Organization of the United Nations (FAOSTAT, 2018), donkey breeding is in extinction. For Giosuè et al. (2008) and Martini et al. (2014), the donkey is important for the rehabilitation of areas characterized by environmental restrictions and can be a source of income for many marginalized areas and contribute to their preservation.

The exploitation of these animals may gain new perspectives in the Brazilian Semiarid, through the dairy activity, since donkey milk has aroused, in recent years, both scientific and investor interest, due to its high biological value, with emphasis on the therapeutic characteristics, coupled with low production costs and rusticity of the species. Among the characteristics of donkey milk is its similarity to human milk, in aspects related to physical-chemical composition and palatability (ALTOMONTE et al., 2019).

This review provided advances in information on the donkey, with emphasis on the breed reported in the Northeast of Brazil (Nordestino). We present trends in the characteristics of this donkey. Further, there is information on the need to encourage donkey milk production, its applications and the importance of preserving the breed as a source. Within the already-studied properties of donkey milk, specific information related to the Nordestino donkey, as well the quality of its milk is presented. Finally, we discussed the importance of promoting and preserving the Nordestino donkey in order to expand and make donkey milk safely available to consumers and provide the dairy industry with another product option.

Origin and adaptation of donkeys in the world

The Romans believed that the donkey was from Asia, so the term *Asinus*, which in English became the word "ass" (ORHAN et al., 2012). The name in Portuguese for donkey, *jumento,* originates from the Latin *Jumentum*, meaning "one who lets himself be tame and domesticated". Over the years theories of donkey origin have been developed. For Lopez et al. (2005) and Carneiro et al. (2018), *Equus asinus* from Nubia and *Equus asinus somaliensis* from Somalia may be responsible for the currently known species. According to KIMURA et al. (2010), the Nubian donkey was an ancestor of the first cargo donkeys, in contrast to the Somali donkeys which were considered wild. In an investigation of mtDNA and the origin of maternal strains of South American donkeys, Xia et al. (2019) reported that the Brazilian donkey might have Eurasia as its cradle, indicating a complex genetic background of the South American animals.

About its domestication, there are reports of ancient Egyptian monuments presenting figures of asses and beginning with Abraham's trip to Egypt, the words donkey and ass are mentioned more than 500 times in the Bible. Besides these, the Egyptian queen of the Nile, Cleopatra, was known to take a daily bath of donkey milk, as she believed she would keep her skin young (BRUMINI at al., 2016; CUNSOLO et al., 2017).

Considered by many to be more resistant than horses, donkeys can survive with few resources, being adaptable to more arid environments. In addition, they are more tolerant to heat and dehydration, making them suitable for regions with a semi-arid climate (MCLEAN & GONZALEZ, 2018), since the asses that inhabited the desert in olden times were able to survive severe conditions, having their behavior shaped by the climate (BURDEN & THIEMANN; 2015; CAMILLO et al., 2017).

Since the end of the 20th century, the donkey species has suffered a substantial decline in many countries, with the reduction of this number of animals due to the mechanization of transport and agriculture. The donkey species; however, is still important in rural economies and semi-arid areas (ORHAN et al., 2012a; CARNEIRO et al., 2018).

Arrival of donkeys in Brazil and their different breeds

Donkeys arrived in Europe around the year 2000 B.C., but only began to spread through Europe about 400 B.C., imported probably from the Madeira Archipelago and the Canary Islands. The Spanish introduced the donkey species to the American continent in the second half of the 15th century through two of its main routes of territorial and commercial conquest. The discovery of a new world and the establishment of some important trade routes promoted a spread of this animal throughout South America (MARIANTE & CAVALCANTE, 2006; JORDANA et al., 2016; CARNEIRO et al., 2018).

The domestic animal that reached the American continent originated mainly from southern Spain and was brought in ships that sailed to America. During stops in the Canary Islands, the ships took on animals from North Africa (JORDANA et al., 2016; CARNEIRO et al., 2018). Around 1534, according to Mariante and Cavalcante (2006), donkeys arrived in Brazil; in 1549, Thomé de Souza brought more animals to the state of Bahia by way of Cape Verde. The donkey that arrived in Brazil with the colonizers at the time of discovery, had different genetic origins and bred randomly, affected by the environment and by treatment, developing different populations in the Brazilian territory (McMANUS et al., 2010). Today, there are three races originated from the animals brought by the colonizers and adapted to Brazil: the Brazilian, the Pêga and the Northeastern donkey (MARIANTE & CAVALCANTE, 2006; CARNEIRO et al., 2018).

The Pêga donkey breed (Figure 1A), like many other native or developed domestic animal breeds reported in Brazil, is of Iberian origin (MARIANTE et al., 2004). Developing mainly in Minas Gerais, the Pêga asses were initially used in the mining industry and for cross- breeding to form hybrid animals (donkey and mules) with great capacity for various jobs. During the genetic selection process, the gait characteristic was fixed and Pêga stallions are highly valued for breeding with gaited mares. The hybrid is an animal with great capacity for work, for saddle-riding or leisure activities and is very admired for its strength, agility, smooth gait and rusticity. This give it a great advantage over its competitors (McMANUS et al., 2010; CARNEIRO et al., 2018), with recognized commercial value throughout the national territory (OLIVEIRA, 2004).

The Brazilian Association of Pêga Donkey Breed Owners is the only association recognized by the Ministry of Agriculture, Livestock and Supply (MAPA). It was founded in 1947, with the purpose of administering and executing, by concession from MAPA, the genealogical registration control, as well as of seeking constant zootechnical improvement of the breed. The Pêga donkey is medium-sized, with a minimum height at the withers of 1.25 and 1.20 meters for males and females, respectively. They are well-proportioned animals, with relatively long, deep trunks and strong, upright limbs. They have a wide variety of coats, the most common being gray dun, roan, and bay dun (ABCJPEGA, 2021).

The animals of the Brazilian breed (Figure 1B). are also denominated as “Paulista”, because of their origin (São Paulo State). They are very similar to the Pêga donkey in size, shape and function. They can make long journeys and work hard in the field; they are very appropriate for riding and can be compared to walking horses when saddled. For many years the Pêga donkey breed standard pattern did not accept many coat colors, thus some of these excluded animals started to be registered as “Paulista”, since this association was not endorsed by MAPA (TORRES & JARDIM, 1992; MARIANTE et al., 2004; CARNEIRO et al., 2018).

Unlike the Pêga and Paulista breeds, the “Nordestino” donkey (Figure 1C) had its selection process based on its adaptability to the climate and vegetation of the semi-arid Northeast. These animals underwent a natural selection process and developed specific characteristics, through random mating; thus, the Nordestino donkey emerged, being used in the region in various activities (NOBRE, 1980; CASTELLETTI et al., 2004; CARNEIRO et al., 2018). They are small animals, with height varying from 1.00 to 1.20m, regardless of sex. The body is elongated, with a straight back and oblique croup. This donkey can have several coat colors, with predominance of gray dun, bay dun and gray (ORHAN et al., 2012a).

In the middle of the 20th century the working population of this breed suffered reduction principally due to the indiscriminate slaughter of donkeys for exportation of meat, hide and derivatives to Europe and Japan (MARIANTE & CAVALCANTE, 2006). The last survey conducted by the Brazilian Institute of Geography and Statistics (IBGE), held in 2012, registered the largest number of donkeys in the Northeast region of Brazil, with 812,467 animals (IBGE, 2012), probably mostly donkeys of the Nordestino donkey, characteristic of the region.

Another factor for the reduction of this population in the Northeast of Brazil was the mechanization of the agricultural sector, which culminated in a decrease in the use of donkeys, resulting in the probable loss of genetic variability of

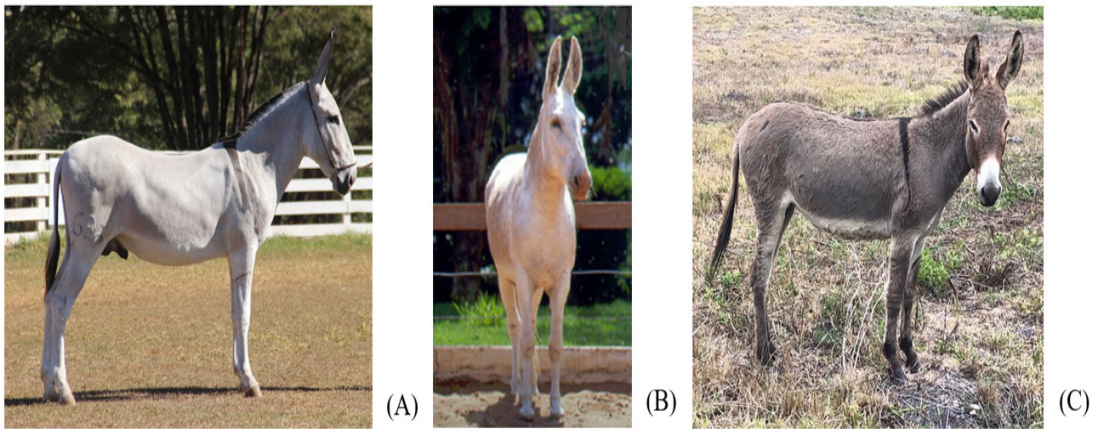

Figure 1 – *Equus asinus* the Pêga, Brazilian e Nordestino donkey. Legend: (A) Pêga donkey breed, ABCJPÊGA (2021); (B) Brazilian breed, adapted from Leonardo Daniel de Almeida, photo by Arthur Mariante (2009); (C) Nordestino donkey, photo by personal file (2019).

the species, restricting the capacity of adaptation. Due to decrease in the use of this animal, they started to be abandoned by their owners and many were found on roads and highways, leading to many accidents in this region (CARNEIRO et al., 2018).

Donkey world livestock, characteristics and behaviors

Donkeys adapt to living in either large or small groups or alone. They come together to breed or when the availability of natural resources is abundant. The average lifespan of a donkey is 25 to 30 years. Animals from the United States, for example, live an average of 28 years; lifespan in developing countries is reduced when they are used as working animals (MCLEAN & GONZALEZ, 2018).

The average size of the animal varies considerably from 0.9 m to 1.6 m among the different breeds reported in the world. Gestation is approximately 12 months, with lactation period between 45 and 200 days (MADHUSUDAN et al., 2017). During gestation, the energy requirements could be met better, aiming at a better lactation period; however, little research has been carried out to establish the protein, vitamin and mineral requirements of the donkey. To be used in the production of milk, meat and skin, these animals must be fed on a special diet and be healthy. Even though donkeys are considered disease resistant animals, they are subject to parasites and tumors (VALLE et al., 2017; MCLEAN & GONZALEZ, 2018; SALARI et al., 2020).

Domesticated donkeys have played a key role in the expansion of human populations, as well as in commercial activities throughout human history. To this day, donkeys contribute to the livelihoods of millions of people in developing countries (CAMILLO et al., 2017).

Data from the Food and Agriculture Organization of the United Nations (FAOSTAT) in its last monitoring in 2017 showed that there were about 46 million donkeys in the world (Figure 2) (FAOSTAT, 2018).

In 2017, Asia had approximately 15 million donkeys, of which 4.5 million were in China (Figure 2). Africa, conversely, seemed to be the continent with the most donkeys, 23.8 million, of which, five million were in Ethiopia (MARTIN-ROSSET, 2018). There were 0.39 million donkeys in Europe, but this population was the subject of various scientific studies made available in literature, countries like Italy (0.20 million), Greece (0.19 million) and Croatia (0.02 million). In the Americas, there were about 6.7 million donkeys, of which 0.84 million were concentrated in Brazil.

From the countries mentioned, mainly China and Italy, donkeys are milked, with a view to using milk for various purposes, especially as a substitute for human breast milk in infant formulas or for newborns with allergies to cow's milk protein (MARTINI et al., 2017; MARTIN-ROSSET, 2018). Donkeys are also valued for their meat and leather in some regions of Europe and China (CAMILLO et al., 2017; MARTIN-ROSSET, 2018).

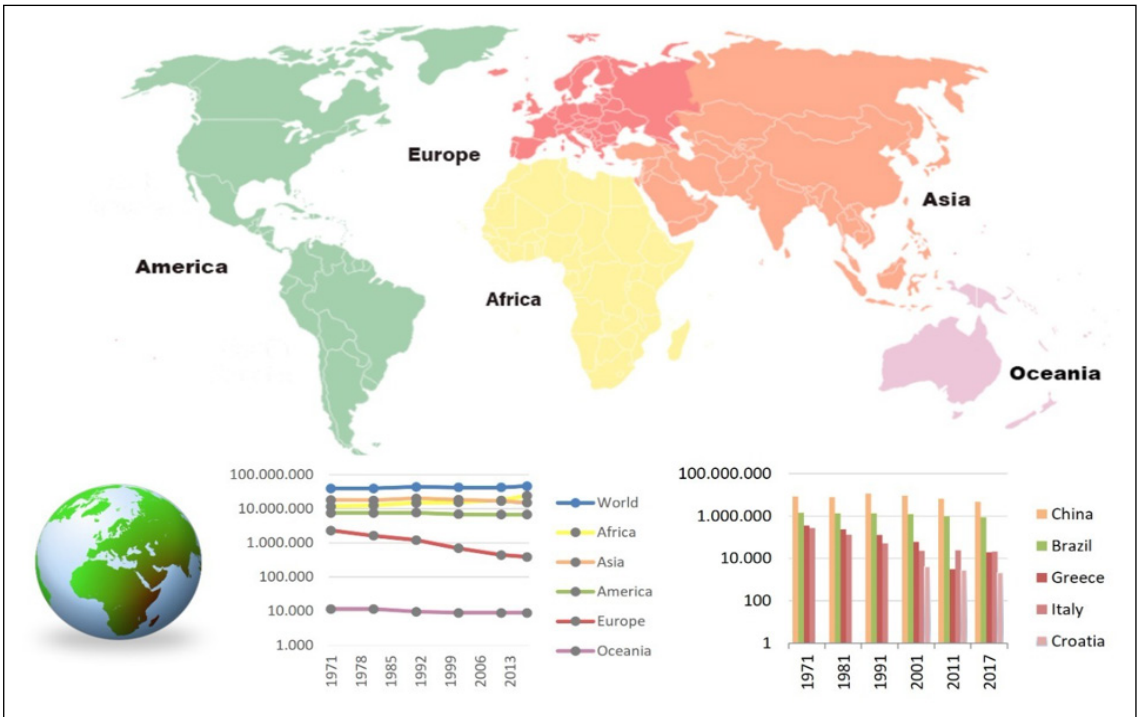

Figure 2 - Donkey population on the continents and around the world (1971 - 2017) in estimated number (millions). Adapted from FAOSTAT (2018).

Donkey livestock in Brazil

The donkey has always played an important role in animal husbandry, being used in regions where farming still depends on animal traction (RAGONA et al., 2016). Also, due to the great physical resistance of donkeys when compared to horses and their ability to survive under adverse conditions, they have always been used for the production of muares [burros and mules] (TORRES & JARDIM, 1992; ORHAN et al., 2012b).

Despite the valuable contributions that donkeys make to society, particularly in emerging areas, as well as their increasing use for food production, little is known about the proper care and management of this species, with their well-being often neglected (VALLE, et al., 2017; MCLEAN & GONZALEZ, 2018). The latest survey of donkey population in Brazil indicated a headcount of 902,716, of which 87.4% were concentrated in the Northeast region (IBGE, 2012). Of this herd, there was a decrease in the percentage of variation in all regions of Brazil (Figure 3). As of 2013, donkeys and burros have no longer been registered by IBGE due to the lack of information sources and administrative records to support the estimates (IBGE, 2013). However, the breeding of these animals may gain new perspective for dairy production, since recent studies have shown that donkey milk can be used in children with allergies to bovine milk protein and in the diet of the elderly (BARNI et al., 2018; YVON et al., 2018; ALTOMONTE et al., 2019).

For McLean and Navas Gonzalez (2018) new products from donkey use are being explored, for instance, the meat and skin of the donkey (*Ejiao*). These uses have increased the value of donkeys in many developing regions of the world. In South America, the prospects of meat production since 2017 have been concentrated in the northeastern region of Brazil, with all the exports going to China. Recently, the Asian market has exponentially increased the consumption of donkey meat, making this product an alternative economic investment for small Brazilian farmers, thus improving their family income, as well as expanding the local employment network through the installation of abattoirs centers (CARNEIRO et al., 2018). However, in Brazil, there is still no definition of production systems aiming rational exploitation of the species. The preservation of the species is still the focus of debate, and effective breeding programs

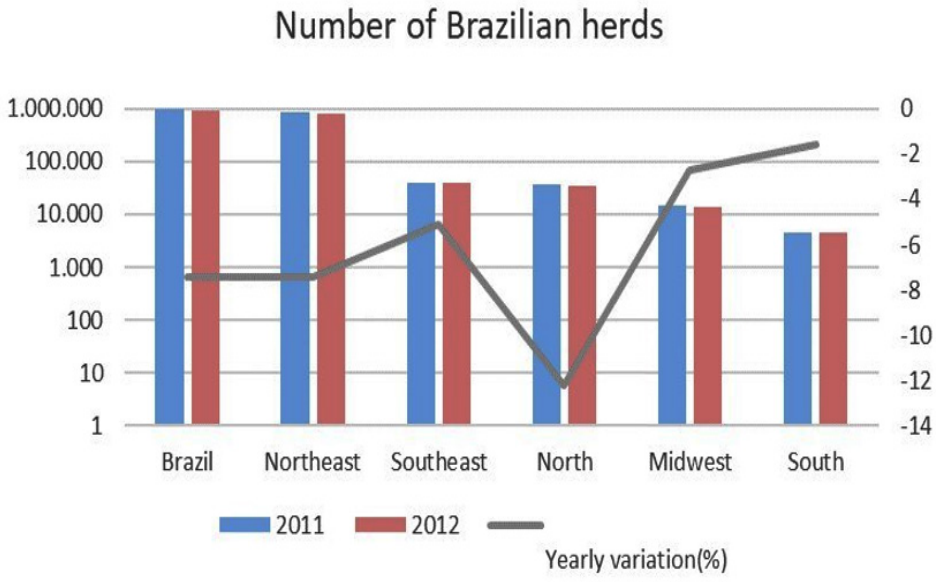

Figure 3 - Effect of the donkey herd (thousand) in Brazil by region (2011 - 2012). Adapted from *Instituto Brasileiro de Geografia e Estatística* (2012).

and regulations by local authorities are needed, which hampers the organization of the production chain of donkey milk or meat and its derivatives (RANGEL et al., 2015).

Donkey milk production

Donkey milk production may vary depending on genetic, environmental and physiological factors, with milk production and composition influenced by factors related to management regime, delivery order and physiology (MARTINI et al., 2014; RANGEL et al., 2015). According to D'Alessandro and Martemucci (2012), in comparison with ruminants, horses have a low storage capacity, with only a yield of 2 liters of milk. In general, horses require a large number of milking per day with a shorter interval between milking (D'ALESSANDRO & MARTEMUCCI, 2012). In comparison, the donkey milk yield can be said to be relatively low, producing on average only 100-150 kg of milk in every lactation period (MARTINI et al., 2014; LI et al., 2018), this quantity being considered low for processing (MARTIN-ROSSET, 2018), thus suggesting the need for improvements in the production of donkey milk.

Ragusana asses in Milo, Italy, milked twice a day, produced 489 kg of milk in 295 days of lactation (GIOSUÈ et al., 2008). D'Alessandro and Martemucci (2012), identified the peak lactation of the Martina Franca breed asinine between 24 and ± 82 days of lactation, with the total milk yield at the beginning of lactation of 98 to 121 liters.

Further studies on the galactopoietic process, milk production, and on udder storage during donkey lactation are needed (GIOSUÉ et al., 2008; D'ALESSANDRO & MARTEMUCCI, 2012), aiming to improve quality and enable donkey milk to enter the dairy market with competitiveness.

For some other animal species, there is no extensive information on their milk distribution; it is estimated; however, that the total contribution of donkey milk is less than 0.1% of world production (KARABAGIAS & HALATSI, 2017; SPADA et al., 2020). In view of the low production, donkey milk is generally sold in Europe as fresh pasteurized milk, with a market price ranging from 12 to 16 euros per liter. In addition, due to seasonal variations in market demand, a limited quantity of milk is retained for the production of soluble milk powder (ALTIERI et al., 2016).

In Brazil, despite having large herds in several regions, the sale of donkey is unlegislated, making it difficult for producers to enter the dairy market. However, it is known that this milk is available for sale as the milk has become associated with health aspects, helping to improve several diseases.

Donkey milk, nutritional and functional characteristics

Since ancient Rome the use of donkey milk was known and for a long time it was used as a medicine prescribed mainly for infant nutrition, with widely known therapeutic properties (CUNSOLO et al., 2017). Small dairy animals are known for their nutritional and economic importance in many countries. The donkey, camel, elk, alpaca, among others, are dairy animals that can be considered "species with underexploited potential to contribute to food security, health and nutrition" (CONTE & PANEBIANCO, 2019).

Compared to ruminant milk, which accounts for the largest milk production in the world, donkey milk has been little studied. However, the interest of the scientific community has been renewed, aiming at the recovery of the biodiversity of the different breeds existing in the world and the rediscovery of the use of milk, some recent studies are cited in table 1. For MARTINI et al. (2017) donkey milk is also becoming increasingly common as a productive farming alternative. Italy has become one of the cradles of research on the characteristics and nutritional quality of donkey milk; data are also available in the literature on milk from donkeys raised in China (JIANG et al., 2018; MIAO et al., 2020), Greece (MALISSIOVA et al., 2016), France (YVON et al., 2018) and the Balkans (GUBIC et al., 2016).

Current interest in donkey milk as a commercial product is due to its nutritional character and potential functional and therapeutic properties. Donkey milk is described as white, fine, with a slightly sweet taste and milky smell (MALISSIOVA et al., 2016). It is an excellent source of lactose, proteins, minerals, vitamins and polyunsaturated fatty acids (COSENTINO et al., 2015; MARTINI et al., 2017; JIANG et al., 2018; ALTOMONTE et al., 2019). It has a mean total protein content of 1.5-1.8% and lactose content (5.8-7.4%), being similar to human milk, while the fat content is lower (0.2-1.8%) compared to breast milk (3.5-4.0%) (UNIACKE-

Table 1 - Summary of studies on aspects of the evaluation of the nutritional and functional potential of donkey milk in different countries.

Milk type	Breed	Country	Conclusions	Research
Raw milk and pasteurized milk	Amiata donkey	Italy	Raw milk and pasteurized milk demonstrated high vitamin D content and pasteurization did not affect vitamin D3 absorption.	MARTINI et al. (2017)
Raw milk	"Les Ânes d'Autan", Graulhet and "La ferme du Hitton", Biran	France	DM consumption exerts an anti-inflammatory effect on rats, restoring endogenous levels of antimicrobial peptides that contribute, to reduce microbiota imbalance.	YVON et al. (2018)
Lysozyme isolated from whey	*	China	Lysozyme DM improved colon and mucosal damage with inflammation in colitis mice. It inhibited the expression of tumor necrosis factor-α and interleukin-13. It increased the diversity of intestinal flora.	JIANG et al. (2018)
Raw milk	*	Italy	DM is a feeding solution in most children with CMPA in terms of tolerability and palatability.	BARNI et al. (2018)
Pasteurized milk	Amiata donkey	Italy	The DM was considered a suitable alternative for children with IgE-CMPA and FPIES-CMPA because of the 68 patients who made the TPO only 1 reacted. Therefore, it can be a suitable alternative for the first 6 months of life, if adequately supplemented.	SARTI et al. (2019)
Raw milk	*	Italy	The proteomics identified a set of 94 genetic products, of these, 41% have documented antimicrobial activity or are responsible for the transfer of passive immunity.	SPADA et al. (2020)
Colostrum and mature milk	Dezhou	China	Both colostrum and mature milk reduced the size of the primary tumor and the relative weight of the liver and lung organs in 4T1 mice without affecting the body weight of the rats. They inhibited growth and metastasis of 4T1 rat tumors, inducing apoptosis.	LI et al. (2020)

*Breed not identified in the study.

LOWE & FOX, 2011; ALTOMONTE et al., 2019; SPADA et al., 2020), figure 4.

Donkey milk has a lower protein content than ruminant milk, ranging from 13 to 28 g/L, while in terms of biomolecular composition it is quite similar to human milk (POLIDORI & VINCENZETTI, 2012; GUBIC et al., 2016; SPADA et al., 2020). The low amount of protein in donkey milk contributes to a low kidney load, similar to the protein reported in breastfed newborns (SALIMEI & FANTUZ, 2012; RAGONA et al., 2016), figure 4. For use as a dietary substitute, having low protein content is important because protein intake during childhood due to the long-term effect on renal function, with the risk of overweight and obesity. In human milk, the protein content is naturally decreased during lactation to meet the changing protein needs of full-term babies; donkey milk has the same tendency towards decreasing in protein during lactation (ALTOMONTE et al., 2019).

The lipid fraction of milk is characterized by high levels of essential fatty acids and low saturated fatty acids (CUNSOLO et al., 2017; ALTOMONTE et al., 2019). In addition, donkey milk contains antimicrobial factors such as lactoferrin, lactoperoxidase and high amounts of lysozyme (COSENTINO et al., 2015; JIANG et al., 2018; MARTINI et al., 2019), suitable for preventing infections in the intestine of infants (ALTIERI et al., 2016) and elderly individuals (AMATI et al., 2010). Studies have proven the antiviral and anti-stress activity (VINCENZETTI et al., 2017) of this milk, the presence of compounds that promote an inhibitory effect in tumors (LI et al., 2020) and low allergenicity when compared to cow's milk, so that it can be used in children with allergy to cow's milk protein (CUNSOLO et al., 2017; SARTI et al., 2019), figure 4.

The lactose content of donkey milk, about 7 g/100g, according to Martini et al. (2014), is similar to human milk and about 4.6% higher than bovine milk. The high lactose content in donkey milk is also responsible for its good taste as reported in a sensory test performed by Barni et al. (2018) with children allergic to cow's milk protein, contributing to a higher rate of approval among children (POLIDORI & VINCENZETTI, 2012; ALTOMONTE et al., 2018; SARTI et al., 2019), making it a good substitute for milk formulas. Lactose is a nutrient that stimulates intestinal absorption of minerals such as calcium and phosphorus, important minerals for the bone mineralization phase and in the prevention of osteoporosis, besides providing a substrate for the growth of intestinal flora and having a relevant role as probiotic due to the presence of oligosaccharides that are present in large quantities in breast milk (YVON et al., 2016; ALTOMONTE et al., 2019; LICITRA et al., 2019).

From a sensory point of view, donkey milk has proved to be a positive alternative in clinical

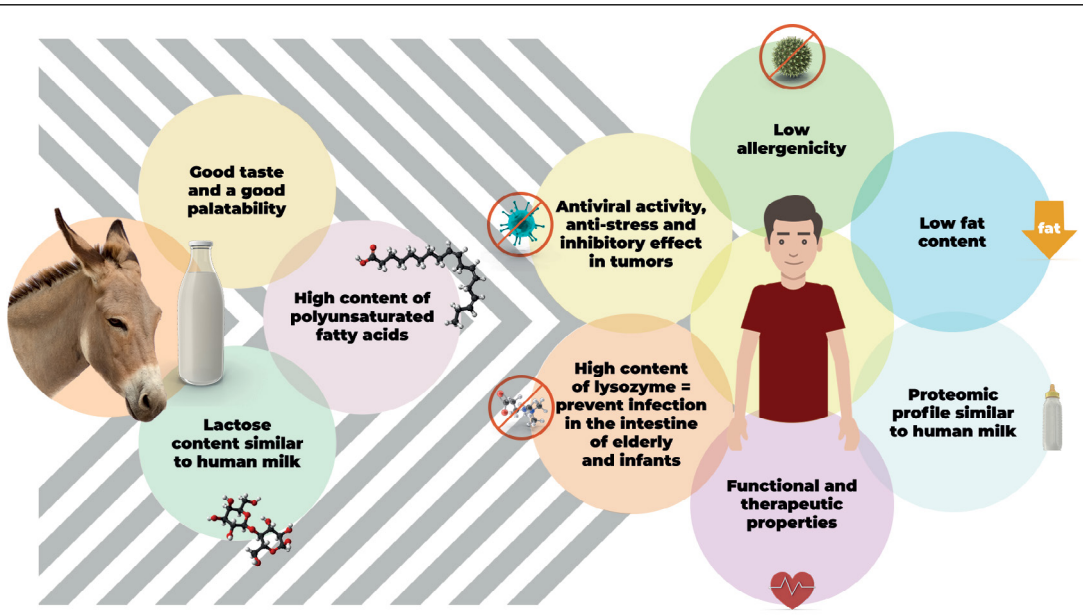

Figure 4 - Summary of the characteristics and benefits of donkey milk.

studies conducted with children allergic to cow's milk protein, where it was well tolerated, and provided both nutritional adequacy and good palatability (BARNI et al., 2018; SARTI et al., 2019). In addition, donkey milk also proved to be promising in its ability to regulate the immune response of elderly people (AMATI et al., 2010).

Due to its differentiated composition and attractive nutritional properties (SALIMEI & FANTUZ, 2012; BRUMINI et al., 2016), the use of donkey milk for functional cheese production would be interesting. However, UNIACKE-LOWE & FOX (2011) reported the formation of a very weak curd from donkey milk, which was considered as not suitable for cheese production.

In European countries donkey milk is receiving growing interest, appreciated by people who try new foods and are interested in locally produced products (CLAEYS et al., 2014). In addition, the current cosmetic market has sought products based on natural ingredients, with compounds that ensure skin hydration and prevent the degradation of epidermal cells (COSENTINO et al., 2015), characteristics that are found in donkey milk.

Due to these nutritional and marketing advantages, countries such as China and Italy have been striving to increase donkey milk production, establishing breeding centers for donkeys and incentives for milk production, which can be exploited to meet nutritional requirements and as a source of income for donkey producers, increasing the economic importance of this species in livestock production (CAMILLO et al., 2017).

The structuring of the dairy production chain in the semi-arid region is a challenge, where participative and joint actions of the various segments interested and involved in the agro-industrial systems, which includes the University, are indispensable.

Studies on the characteristics of the donkey milk of the Nordestino donkey, aspects of lactation of the animal, milk volume, functional properties and its benefits are already being conducted in several states in Northeast Brazil. More studies are still needed to understand the safety and improvement of milk quality to integrate donkey milk into the dairy industry in Brazil.

CONCLUSION

Donkeys are very important in regions where transport and agriculture still depend on animal traction. The Northeastern breed of donkey is an animal that has lost its purpose within the farms;. However, its numbers; although not registered, are still large enough that they can contribute to the building of new perspectives for this breed in Brazil.

With the valorization and consequent expansion of the donkey in the Northeast of Brazil, the production and commercialization of the Nordestino milk, will strengthen family agriculture, environmental sustainability of the activity, income generation, competitiveness in the food market, food and nutritional security and economic and social development, besides being a new product for the Brazilian dairy industry. The nutritional characteristics of donkey milk and its functional potential can add value to the advancement of the Nordestino donkey in the future.

ACKNOWLEDGEMENTS

This study was financed in part by the Coordenação de Aperfeicoamento de Pessoal de Nível Superior (CAPES) – Brazil – Finance Code 001.

DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

All authors also contributed to the design and writing of the manuscript. All authors critically reviewed the manuscript and approved the final version.

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