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CONTENTS

Donkey Milk – An Overview Of Its Nutritional And Therapeutic Importance

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ABSTRACT

In the recent years, consumer awareness is growing towards therapeutic and health benefits of milk apart from its nutritional value. Milk of species other than cow and buffalo, especially the milk of those species mentioned in traditional medicine literature is gaining importance. Donkey milk is attributed with several health benefits, however information available on it is very much limited and scattered. Available information on the same is collated and presented here. This may generate interest among researchers, academicians and entrepreneurs about donkey milk and its importance. There are 44 million donkeys in the world and out of this 11 million are in China. Donkeys are mostly used for agricultural purposes rather than milch purposes. The donkey milk is reported to have great medicinal value so, it is used for curing of many diseases like cough, surgical wounds, ulcers, arthritis, chikungunya, haemoptysis, etc. It is nearly similar to breast milk, so it is good for human infants who are allergic to cow milk. The donkey milk also helps to make a skin soft and moist, so it is having great scope in cosmetics. In some countries, donkey milk is used for manufacturing products like pule cheese, fermented beverages etc.

Keywords: Donkey milk, nutritional importance, therapeutic benefits, products

INTRODUCTION

Donkey is a ubiquitous, humble animal used mainly for draft purposes. Its slave relationship with masters is well prevalent and acknowledged. The word donkey is used synonymously in a demeaning way for drudgery. However, its liberal character of giving milk beneficial to human infants is being recognized only recently, though this knowledge existed in the society since centuries. Donkey, which is also referred to as ass or jenny, belongs to Equus Genus and Species. The donkey (*Equus asinus*) is a member of the horse family. A mule is the offspring of a pony mare and a donkey stallion, and a hinny is the offspring of a pony stallion and donkey mare. Blench [1] and Polidori and Vincenzetti [2] mentioned the origin of donkey as small gray animal traceable to northern Africa (*Equus africanus*) domesticated there around 4000 BC. Donkey because of its slow gait and mildness finds negative connotation in society even though it is of immense draft utility to humans especially in mountainous regions involving almost no maintenance costs. Humans domesticated it for centuries mostly for transport purposes. Even today, it still remains an important work animal in the developing countries of Africa. In antiquity, donkeys

were used more diversely than today. They were not only used as a work force in agriculture, commerce and the military (draught and pack animals, for riding, milling, pumping etc) but also their milk, skin and meat was used. Due to their physical characteristics, particularly at the shoulder, donkeys are slower and less powerful than horses. Donkeys find mention even in the writings and imagery of the Hindu religion. In Hinduism, the goddess Kaalaraatri's Vahana (vehicle) is a donkey. Donkeys also appear multiple times in Indian folklore as the subject of stories in both the Hitopadesh and the Panchatantra as Jacks and Jennies. Donkey is also Vahana of Shitla Devi a goddess worshipped in northern U.P. and Nepal [3]. Hindu Mythology believes donkey to be having a demonic control or significator of demon. Srimadbhagavata describes a demon in shape of a donkey (Gardabhasur) fighting with Lord Krishna who eventually kills it [4].

Breeds: Livestock breeds in general have a range of colour and other typical characteristics, but in case of donkeys it is not exactly so. Variations occur in its primitive colours and markings (eelstripe on spine, cross on shoulder, "zebrastripes" on the legs etc.). Donkeys can vary in size, the most common being 100cm – 120cm high; the Miniature donkey may be 90cm when adult; and the larger French Poitou and American Mammoth donkeys can stand up to 170cm. Donkeys come in a wide range of colours, from black to white through shades of grey and brown, and also broken colours such as brown and white, and roan. Some donkeys display a cross on their backs, known as dorsal and shoulder stripes, and some also have zebra-like stripes on their legs [5]. As per Domestic Animal Diversity Information System Database of FAO, there are 185 recorded breeds of donkey worldwide [6]. Most of the donkeys existing in India are having typical characteristics and known by the name Indian ass or Indian wild ass [7]. Some of the donkey breeds are listed in Table-1.

Scientific interest in donkey's milk

Donkeys were never known for milk, so compared with ruminants' milk, donkey milk has been studied less in the past. Donkey milk production figures are not known. On an average, a donkey gives a litre of milk per day; the yield may range from 1 to 2 lit [8]. Unlike in cows and buffaloes, no systematic breeding efforts have been made to enhance milk yield, probably because its milk is not popularly consumed. However, traditional knowledge says that donkey milk is good for human infants who are allergic to mother's milk. This milk also finds mention in Ayurvedic literature as endowed with several good qualities and health benefits. Despite the existence of such vast traditional knowledge, it has to be mentioned that the nutritive value and therapeutic values of milk of our indigenous animals were ignored ever since Operation Flood started, major emphasis laid on enhancing milk yield using foreign breeds. But, in recent years awareness is being created about the health benefits of milk specific to our own breeds. Research interest in donkey milk is increasing because of its compositional similarities with human milk [2].

Donkey's milk has recently aroused scientific interest, especially among paediatric allergologists and nutritionists. This milk is being considered as valid alternative to powdered milk, soy bean milk and infant formulas since its composition in lipids and proteins is very close to human milk.

Mariani [9] studied nutraceutical characteristics of donkey milk and evaluated nutritious and clinical properties. In many countries cow's milk is the most important food allergen in babies and children. Adverse reactions to cow's milk were found in 2-7% of children during the first year of life: 30% of cases at the first

month, 60% before the third and 96% within the twelfth. Symptoms appear even during the breast-feeding because newborn reacts against a small amount of cow milk proteins present in maternal milk. Out of children followed for the first 3 years of life, 56% of cases had recovered from cow's milk allergy at 1-year age, 77% at 2 years and 87% at 3 years age [10]. 25-80% of allergic children have cross sensitivity to the currently used substitute formulae including goats, sheep, soya bean milks and milk hydrolysate. From this point of view donkey milk is considered safe for infants with reports of no allergic reactions to its consumption. The presence of other minor components like lysozyme also aroused lot of scientific interest in donkey milk.

Composition

The donkey milk has higher ash and casein contents than human milk, but less than bovine, goat or sheep milk. The lactose content in donkey milk is also a little less than human milk. The detailed composition is listed in Table-2. The constituents are similar to bovine milk but proportion of major and minor constituents varies. Francesca [11] reported a lactose content of 5.90 – 6.46% in donkey milk. The level of fat in donkey milk ranges from 0.28% to 1.82%. Because of this low level of fat, Carroccio *et al.* [12] suggested the use of donkey milk enriched with medium-chain tryglicerides in a cow milk - free diet in infancy. Dugo *et al.* [13] determined a total of 55 triacylglycerols in donkey milk fat. This knowledge of lipid fraction is very important for characterising donkey milk from a bionutritional point of view. Considering the possible use of donkey milk as a safe and valid alternative for infants affected by cow milk allergy or for other human milk replacers, many studies had been conducted with the aim of better characterizing donkey's milk protein profile [14 - 20]. An accurate determination of total caseins, whey proteins, lysozyme, α-lactalbumin and β-lactoglobulin in donkey, sheep and human milk had been performed by Vincenzetti *et al.* [19] and the data are shown in Table-1. Donkey milk's total protein content is low (13–28 mg/ml), very close to the values for human [21] and mare's milk [22] and therefore it does not produce an excessive renal load of solute. Donkey milk is predominantly rich in whey proteins, such as lactoalbumin and lactoglobulin, which range from 35% to 50% of the total nitrogen fraction, compared to 20% in cow's milk. The total casein content is about 8.7 g/l, which is remarkably close to the amount found in human milk [20-23]. The donkey milk also contains higher amounts of lysozyme (1.0 mg/ml) compared with other kinds of bovine milks. A comparison of camel, donkey and human milks is shown in Table-1. Human milk is particularly rich in lactoferrin: the concentration ranges from 1 to 16g/l in the colostrum while in mature milk it is about 1g/l. In bovine colostrum the amount of lactoferrin is from 0.2 to 5g/l and in the mature milk it is 0.1g/l [24]. The lactoferrin content of donkey milk is 0.08 g/l. Table-4 shows content of lactoperoxidase, lactoferrin and lysozyme from bovine, donkey and human milks. Higher lysozyme content in donkey milk may be noted. Donkey milk has a better mineral profile than human and camel milks (Table-3).

Properties

The physical properties of donkey milk are not much studied. Francesca [11] analysed donkey milk samples from two farms in Italy and reported electrical conductivity, freezing point and pH of donkey milk as 2.39 – 3.16 uS, (- 0.50) - (- 0.61ºC), 6.77 – 6.92. These values for cow milk are 0.003 to 0.010 mhos, -0.555°C and 6.6 [25]. Cow milk has sweet taste whereas donkey milk has sweat taste. It is easily digestible because of its lower casein to whey protein ratio (0, 94) than in cow milk [26]. In fact, in the milk of ruminants this ratio is

four times higher than donkey's milk, and seven times higher than human milk [24].

Nutritional importance

In addition to meeting the complete nutritional requirements of the neonate, mammalian milk serves several physiological functions, including protective (immunoglobulins and other antibacterial agents), digestive aids (enzymes and enzyme inhibitors, binding or carrier proteins) and growth factors/hormones [27]. Milk has a fundamental nutritional importance in infancy. Breast milk of a healthy, well-nourished woman is the best reference for nutritional requirements during the early neonatal period [28]. Commercial infant formulas have been developed as normal nutritional substitutes for breast milk and mimic the levels and types of vitamins, minerals and other nutrients present in human milk. Despite this, differences in response to infection, development of allergies and atopic diseases have been reported in formula-fed compared with breast-fed infants [29]. When a mother cannot breastfeed, or chooses not to breastfeed, the use of a milk substitute must provide the best option to meet the nutritional and health needs of the infant. Cows' milk is widely used as a substitute for human milk but, in an increasing number of cases, it can lead to an abnormal immunological response [30]. Hence, in the last few years, milk from non-bovine mammals has been studied to identify the best natural substitute for human milk [29,31,32]; . Donkey's milk has been successfully used in clinical studies on children with Cow Milk Allergy, and found to provide relief from the allergy along with nutritional adequacy and good palatability [8,33]. Due to its similarity in chemical composition to human milk, donkey milk is considered a valid alternative for infants with severe IgE - mediated cow's milk protein allergy [34 - 36]. Most studies revealed that casein and β- lactoglobulin are the main allergens in cow milk. For human beings cow's milk represents the most common feeding during the infant weaning, but also the first allergen in life. One of the main allergens in children is β-lactoglobulin that is the major whey protein in cow milk while it is absent in human milk. In donkey milk the content of β-lactoglobulin is approximately 40% of the whey proteins equal to the level in mare milk and lower than that in cow milk. This condition may be related to the hypoallergenic characteristic of donkey milk. The mechanism for tolerance may be related to the specific levels of the major allergenic components in the milk. Donkey's milk has three genetic variants for β-lactoglobulin: one presents three amino acid substitutions while the others have two amino acid exchanges. Donkey milk β-lactoglobulin is a monomer whereas this protein is a dimer in ruminant's milk. Mansueto *et al.* [36] made a review of ass's milk in relation to cow milk allergy.

According to Guo *et al.* [16] the percentages of 8 essential amino acid in the protein of donkey milk were higher than those of mare and cow milk; the milk also had higher levels of Ser, Glu, Arg, and Val and a lower level of Cys. As a result, donkey milk exhibited unique nutritional characteristics and has optimal potential to be used as a new dietetic food and breast milk substitute.

The donkey's milk was also characterized by low fat and energy values (1719.2kJ·kg^{-1}), a high polyunsaturated fatty acids (PUFA) content of mainly α-linolenic acid (ALA) and linoleic acid (LA), a low n-6 to n-3 FA ratio or LA/ALA ratio, and advantageous values of atherogenic and thrombogenic indices [37]. Among the minor PUFA, docosahexaenoic (DHA), eicosapentanoic (EPA), and arachidonic (AA) acids were present in very small amounts (<1%). In addition, the AA/EPA ratio was low (0.18). The fat and energy values also decreased during lactation. The fatty acid

patterns were affected by the lactation stage and showed a decrease in saturated fatty acids content and an increase in the unsaturated fatty acids content. The n-6 to n-3 ratio and the LA/ALA ratio were approximately 2:1, with values <1 during the last period of lactation, suggesting the more optimal use of milk during this period. These high level of unsaturated/saturated fatty acids and PUFA-n3 content and the low n-6/n-3 ratio suggest the use of donkey's milk as a functional food for human nutrition and its potential utilisation for infant nutrition as well as adult diets, particular for the elderly. Swar [38] recommended addition of sunflower oil @ 1.6% to donkey milk to make its composition similar to human milk in all respects.

Therapeutic benefits

It is reported that donkey milk was used even by Hippocrates, father of medicine, as a remedy in treatment of arthritis, cough, surgical wounds and ulcers. Queen Cleopatra of Egypt reportedly used it in bathing to keep her skin soft and moist. Avicenna who wrote a famous medical encyclopedia in 10^{th} century advised using it to strengthen teeth and in treatment of cough, haemoptysis, ulcers, wounds and ascites [39]. It is currently used in Sudan as a native medicine to treat whooping cough and in India to treat chikungunya, probably because of its high immunoglobulin content [38]. Donkey's milk contains omega-3 fatty acids which are essential for human growth and development. The acids which are presently being supplemented through cod liver oil are important for normal functioning of brain and other vital organs.

Additionally, donkey milk is a strong vasodilator, making it potentially useful in the prevention of atherosclerosis [40]. It exerts an *in vitro* suppressing action against human lung tumors [41]. Ashokkumar *et al*. [42] produced crude bacteriocin from cell free extracts of *L. paracasei* isolated from donkey milk. It exhibited inhibitory activity against *Salmonella typhi* followed by *Escherichia coli, Klebsiella pneumoniae, and Pseudomonas aeruginosa*.

Products from donkey milk

Products from donkey milk are limited in number unlike those from bovine milk because of its typical smell and flavor as well as low TS content. However, products from donkey milk may be important from nutritional and therapeutic point of view. Fermented beverage from donkey milk using *Lactobacillus rhamnosus* and *Lactobacillus casei* cultures was reported by Chiavari *et al*. [43].

Donkey milk could also be valorised as a good base ingredient for probiotic and therapeutic food preparations. Pasteurised donkey milk has been inoculated with some strains of *Lactobacillus rhamnosus*, with probiotic properties [44,45]: *Lb. rhamnosus* strains remained highly viable after 15 days of storage at 4^{o}C and at low pH (3.7-3.8). The high lysozyme content only partially influenced the growth of the strains tested without any significant effect on their acidifying activity [43, 46]. This observation is important for preparation of fermented products from donkey milk. Texture and flavour of fermented donkey milk, may be a constraint to the acceptability of the products, so fortification with Na-caseinate, pectin, and threonine or the addition of flavours can enhance the rheological and sensory quality [43, 47].

Chiavari *et al.* [43] reported a process for preparation of a fermented beverage from donkey milk which included homogenization, LTLT pasteurization, cooling, inoculation with *L. casei* @10% level, incubation at 37^{o}C for about 48 h, cooling to 4^{o}C, breaking the coagulum and bottling and storage at 4^{o}C. Use of

different strains produced different aromas and flavours like boiled vegetable flavor, toasted seeds flavor, grassy flavor etc. But, the *L. casei* strain AT 194 produced beverage with a more balanced aromatic olfactory profile in the individual descriptors. Inoculum level used was high because starter organisms needed to overcome the antibacterial influence of high lysozyme content of donkey milk. The workers also recommended deodorization process before pasteurisation so that the final product would have minimum undesirable aroma and flavor. In France and Italy it is used as a substitute and in manufacture of beauty soaps and creams. Liquid ass milk was subjected to spray drying in which milk was heated to 55-60^{o}C under vacuum. This evaporated milk was then sprayed through very fine nozzles to mist it in air at high temperature [48]. 'Onalat' is a brand of Tetrapak ready-to-drink donkey milk and also donkey milk based hypoallergenic dietary supplement powder being produced by Eurolactis group [49] (Fig.1-3). Donkey milk is also used in cheese making. Not much information is available on cheese making properties of donkey milk, however yield of cheese (4%) from donkey milk is much less than that of bovine milk (10-11%).

It is reported that donkey milk cheese known as Pule cheese is being prepared from the milk produced by Balkan donkeys maintained in Zasavica Special Nature Reserve in Serbia. Pule cheese is reported to be most expensive of all cheeses [50].

CONCLUSION

Human milk is the best food for children under one year of age. The chemical composition of human milk has been used as a guide for the preparation of infant formulas and/or human milk replacers. But, unlike infant formulas, the composition of human milk is not uniform. Significant changes in the composition of breast milk occur not only among individual women, but also throughout the day, throughout the lactation period, with changes in maternal diet and as a result of other external factors such as exercise or metabolic illnesses. Donkey milk can be considered the closest natural milk to human milk, and the results obtained by pediatric scientists seem to confirm the nutritional value of this milk, known from ancient times in many countries of the world. Considering its unique nutrient profile and economic potential, donkey milk could surely be exploited to fulfill the nutritional requirements of a section of consumers and to increase the income of donkey farmers as well. It is suggested that beneficial attributes of donkey milk be explored further so that avenues can be opened for preparation of value added milks and products for the benefit of consumers. Dairy industry may gear up for procuring and processing of such milks in future. Hope, by this way donkey gets its due share of recognition and respect by therapeutic properties it offers to humans through its milk!

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Table-1: Some of world's donkey breeds

Country	Name of donkey breed
Australia	Australian Donkey, Irish Donkey
China	Biyang, China North, Dezhou, Guangling, Huaibei, Jiami, Jinnan, Kulun, Liangzhou, Linxian, Qinghai, Qinqyang, Shanbei, South-west, Subei, Taihang, Xinjiang, Yangyuan, Yunnan
Cyprus	Cyprus donkey
Egypt	Egypt Baladi, Hassawi, Masri, Saidi
Somalia	Somali Wild Ass
Ethiopia	Abyssinian Donkey, Jirnrna, Nubian wild ass, Ogaden, Sennar
France	Berry Black, Berry Grey, Bourbonnais Donkey, Cotentin Donkey, Norman donkey, Poitevin, Provence donkey
India	Indian Wild Ass
Iran	*Anger*, Benderi, Iranian Onager, Kashan, Hamadan
Italy	Amiatina, Asinara, Cariovilli, Grigio Siciliano, Miniature Mediterranean, Pantesco, Ragusano, Romagnolo
Kenya, Tanzania	Masai
Sri Lanka	Mannar, Puttalam Buruwa
Tibet, Nepal	Kiang
Tunisia	Tunisian
Turkey	Anatolian, Karakaçan, Merzifon
USA	American Mammoth Jack, Miniature, Standard
Yemen	Qirmani, Sibbianl

(Source: en.wikipedia.org/wiki/List_of_donkey_breeds)

Table -2: Range of variation of chemical composition and pH values of donkey, human and cow milk

	Donkey	Human	Mare	Sheep	Cow	Camel
Total Solids (g/100g)	8.8-11.7	11.7-12.9	9.3-11.6		12.5-13.0	---
Protein (g/100g)	1.5-1.8	0.9-1.94	1.5-2.8		3.1-3.8	3.46
Caseins (g/100 g)	0.64–1.03	0.32–0.63	0.94-1.2	3.9	2.46-2.80	2.65
Whey proteins (g/100 g)	0.49–0.80	0.68–1.31	0.74-0.91	1.7	0.55-0.70	0.81
b-lactoglobulin (g/100 g)	0.375	---	---	0.277	---	---
a-lactalbumin (g/100 g)	0.180	0.22	---	0.163	---	---
Non-protein nitrogen g/100 g	0.18-0.41	0.26-0.32	0.17-0.35	---	0.1-0.19	---

Casein Nitrogen %	47.28	26.06	50	---	77.23	---
Whey protein %	36.96	53.52	38.79	---	17.54	---
Non-protein nitrogen %	15.76	20.42	11.21	---	5.23	---
Lysozyme (g/100g)	0.10	ND	---	Trace	---	---
Fat (g/100g)	0.3-1.8	2.1-4.0	0.5-2.0		3.5-3.9	4.0
Lactose (g/100g)	5.8–7.4	6.3–7.0	5.8-7.0	---	4.4-4.9	4.86
Ash (g/100g)	0.3-0.5	0.2-0.3	---	---	0.7-0.8	---
pH	7.0-7.2	7.0-7.5	7.18	---	6.6-6.8	---

Source: [16, 19, 20, 48, 51]

Table -3: Mineral content of donkey milk (mg/kg)

Mineral	Donkey	Human	Camel	Cow
Ca	676.7	34	109	1043-1283
P	487.0	16	76	930-992
K	497.2	62	179	1212-1681
Chloride	336.7	--	--	772-1207
Na	218.3	10	58	391-644
Mg	37.3	3	14	97-146

Source: [21, 48, 52]

Table -4: Content of lactoperoxidase, lactoferrin and lysozyme from bovine, donkey and human milk

Milk	Lactoperoxidase (mg/L)	Lysozyme (g/L)	Lactoferrin (g/L)
Human	0.77	0.12	0.3–4.2
Donkey	0.11	1.0	0.080
Bovine	30–100	Trace	0.10
Camel	-	0.000003-0.000065	0.0095-0.025

Source: [51]

Fig.1: Pule cheese *(Source: en.wikipedia.org/wiki/Pule_cheese)*

Fig.2: Donkey milk

Fig.3: (b) Donkey milk powder *(Source: www.eurolactis.com/en/)*