Mysore J. Agric. Sci., 54 (3) : 42-50 (2020)

A Comprehensive Review on Composition of Donkey Milk in Comparison to Human, Cow, Buffalo, Sheep, Goat, Camel and Horse Milk

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Abstract

The article discusses the bio-chemical composition of donkey milk in comparison to human, cow, goat, sheep, buffalo, camel and horse milk. Cow milk is the most universal milk for infants and adults, but it contains more than 20 proteins (allergens *i.e*., casein and whey protein) that cause allergic reactions. It has lower lactose content, with highest quantity of saturated, mono-unsaturated fatty acids and a higher level of cholesterol, compared to human, donkey and horse milk. In camel milk, Ca content is higher compared to cow, buffalo and sheep milk. Buffalo milk gives higher energy followed by sheep, cow, goat, camel, human, horse and donkey milk. The fat content of donkey milk is lower compared to human, cow, buffalo, sheep, goat, camel and horse milk. Milk composition is not uniform and within the same breed also it varies. It depends on the lactation stage, nutritional diet, environment and genetic factors.

Keywords: Allergens, Breed, Composition, Donkey milk and Human milk

Human milk is considered as nature's best infant food from nutritional, immunological and food safety point of view. Due to the time constraints, health conditions and urbanization, mother may cause the early termination of breast feeding. Commonly, cow milk represents the most common feeding during the infant weaning and early termination, but also the first allergen in life. In many countries, cow milk is the most important food allergen in babies and children. Cow milk is a member of the 'Big-8' food allergens that include egg, soy, wheat, peanuts, tree nuts, fish and shellfish in terms of prevalence (Crittenden and Bennett, 2005). Studies conducted on the serum of children with hypersensitivity to milk have shown that the proteins mainly responsible for allergy are α- and β-caseins (Businco *et al.* 2000). In many countries, cow milk is the most important food allergen in babies and children. Furthermore it has been reported some cases of infant with intolerance to hydrolysed cow milk proteins (Carroccio *et al*., 2000). Cow milk protein allergy (CMPA) may develop also when breastfed infants (BF) start to receive cow's milk formula (CMF) and usually occurs within the first weeks after cow's milk introduction. Manifestations mainly occur at the level of the digestive tract (50 to 60 %), the skin (50 to 60 %) and the respiratory tract (20 to 30 %); they vary from mild-moderate to severe (Sicherer *et al*., 2001). El-Agamy and others (2009) reported that some infants and children allergic to cow milk will have an allergic reaction after ingesting buffalo, goat, sheep, donkey, and horse milk proteins due to the presence of positive immunological cross-reaction with their counterparts in cow milk, but Tesse *et al*. (2009) reported that donkey, camel and goat milk may be good substitutes of human milk. Considering the possible use of alternative milk sources for human in cases of cow milk allergy, the usage of other mammals should be sought. Presently, the human perception is that the milk should have almost all the beneficial nutritional composition, good medicinal properties and no any negative impacts after ingestion. In this regard the objective of this review is to study the compositional value of milk of different species and to discuss their nutritional value. It is very much essential that all should have the knowledge regarding nutritional and medicinal values of milk from different species which will be helpful for their choice or their requirement.

Composition of Milk

The overall average composition of human, cow, buffalo, goat, sheep, camel, horse and donkey milk is

presented in Table 1. Nutritionally, the human milk is comparable to horse and donkey milk, as it contains similar basic chemical compositions compared to other animal milk composition. The article gives information about the chemical composition of different milk sources. The higher fat content is observed in sheep milk followed by buffalo, cow, camel, goat, human, horse and donkey milk. Donkey milk contains lower amount of fat content compared to other milk sources and hence the donkey milk has reduced energetic level as 39.68 kcal compared to other milk sources. Swar (2011) reported that adding 1.6 g of sunflower oil to 100 mL of donkey milk (16 $mL.L^{-1}$) compensates for the low fat and caloric values found in donkey milk and constitutes a formula that is very close to human milk.

The lactose content in horse and donkey milk is quite similar to human milk compared to camel, buffalo, sheep, cow and goat milk. The high content of lactose is responsible for the good palatability and facilitates the intestinal absorption of calcium that is essential for infant's bone mineralization (Dugo *et al*., 2005). The protein content in sheep milk is higher than the buffalo, cow, goat, camel, horse, donkey and human milk. The lower protein content in donkey and human milk avoids an excessive renal load of solute. The ash content in buffalo milk is highest followed by sheep, camel, cow, goat, horse, donkey and human milk, whereas in human milk it is lowest. Milk contains 87 per cent of water, so it is a good source of water in the diet. In general, the water content in donkey milk is higher followed by human, horse, camel, cow, goat, buffalo and sheep milk. The water content of milk varies from one type to another type of milk, animal and their species. The milk composition differs considerably due to genetic factors, physiological factors, nutritional factors, frequency of milking, and environmental conditions. The greatest changes in composition occur during lactation as reported by Kalyankar *et al*. (2016).

On an average, mineral elements account for 4 per cent of total body mass and part of every tissue, liquid, cell and organ in the human body. There is a sufficient evidence that minerals, both independently or in proper balance with other minerals, have structural, biochemical and nutritional functions that are very important for overall human health, both mental and physical. Further more, they act as catalysts for many biological reactions in the body, including muscle contraction, transmission of nerve impulses and utilization of nutrients from food (Vahcic *et al*., 2010). The average concentration of major elements in buffalo, camel, sheep, goat, cow milk is higher in relation to human, horse and donkey milk (Table 2). The iron content in human milk is almost similar to the other milk sources, except donkey milk. The chemical form of mineral elements in milk is important because it determines their absorption in the intestine and their biological utilization. The mineral composition of milk is not constant because it depends on lactation phase, nutritional status of the animal and environmental and genetic factors as reported by Zamberlin *et al*. (2012).

TABLE 1

Basic chemical composition of human, cow, buffalo, goat, sheep, camel, horse and donkey milk

Composition	Human	Cow	Buffalo	Goat	Sheep	Camel	Horse	Donkey
W.C. (%, w.b.)	86.80 - 90.50	87.80	82.40	87.80	81.60	88.44	89.86	90.63
Fat (%)	2.10 - 4.00	3.60	7.10	3.60	7.30	3.60	1.21	0.76
Protein (%)	0.90 - 1.90	3.20	5.00	3.20	5.70	2.95	2.14	1.91
Lactose (%)	6.30 - 7.00	4.70	4.60	4.70	4.60	4.30	6.37	6.30
Ash (%)	0.20 - 0.30	0.70	0.90	0.70	0.80	0.71	0.42	0.40
Energy (kcal)	47.70 - 71.60	64.00	102.30	64.00	89.80	61.40	48.00	39.68

W.C.: Water content; w.b: Wet basis; (Claeys *et al*., 2014; Kumar *et al*., 2016; Ahmad *et al*., 2013; Sabahelkhier *et al*., 2012; Swar, 2011; Nayak *et al*., 2020)

TABLE 2

Concentration of major mineral elements in human, cow, buffalo, goat, sheep, camel, horse and donkey milk

Minerals (mg.L^{-1})	Human	Cow	Buffalo	Goat	Sheep	Camel	Horse	Donkey
Ca	276.00	122	178.59	1340	197.5	1050 - 1570	929.00	466.68
Mg	38.00	12	18.29	160	195	80.00 - 160.00	81.00	248.88
K	713.00	152	920 - 1820	1810.00	1380.00	1240 - 1790	871.00	2009.67
Na	159.00	58	350 - 950	410.00	390.00	360 - 730	174.00	910.55
Fe	2.00	0.08	0.42 - 2.0	0.70	1.00	0.42 - 2.00	1.90	3.74
Zn	4.60	0.53	1.50 - 7.30	5.60	6.00	1.50 - 7.30	2.10	28.66

(Fiecko *et al*., 2020; Kapadiya *et al*., 2016; Kumar *et al*., 2016; Balthazar et al., 2017; Nayak et al., 2020)

Calcium content is rich in camel milk compared to all other milk sources and the Ca is important for the development and maintenance of skeletal integrity and prevention of osteoporosis (Kalyankar *et al*., 2016).

Majority of the neuro transmitters is composed of amino acids and can influence biological functions related to brain-body interactions. Physiological concentrations of amino acids and their metabolites are known to be protective against cardio vascular diseases and degenerative diseases of the brain (Takahashi *et al*., 2011). The average total essential amino acids concentration in buffalo, sheep, horse, cow, and donkey milk are almost similar except goat milk (Table 3). High concentration of essential amino acid leucine is observed in human milk and lower concentration is notified in buffalo milk followed by sheep, horse, donkey, cow, goat and camel milk. Leucine plays a distinct role in protein metabolism and the translation initiation pathway of muscle protein synthesis. It is also involved in reversible phosphorylation of proteins that control m RNA binding to the 40S ribosomal subunit (Anthony *et al*., 2001). The proline content was higher in goat milk followed by camel, cow, human, donkey, horse, sheep and buffalo milk which affects the production of haemoglobin (Molik *et al*., 2012).

Vitamins are physiological, biochemical, and metabolic bioactive compounds occurring in milk. Vitamins are contained in milk, have specific biological functions in the body. The vitamin content of milk is highly variable and depends on feeding regime. The level of water soluble vitamins (B_1, B_2, B_3, B_{12}, C) is mostly influenced by the feed than the level of fat-soluble vitamins (A and E) as reported by Kalyankar *et al*., (2016). Vitamins in different milk sources are presented in Table 4. Vitamin C (helps in formation of protein as reported by Devaki and Raveendran, 2017) is majorly observed in camel milk compared to human, horse, buffalo, goat, sheep, cow and donkey milk. Donkey milk has highest amount of niacin and vitamin E content compared to sheep, goat, human, buffalo, horse, cow and camel milk (Table 4). The lower content of vitamin E and B12 is observed in goat milk which leads to goat milk anemia as reported by Park *et al*., 2007. Niacin is rich in donkey milk compared to human, cow, buffalo, sheep, goat, camel and horse milk. Williams and Ramsden, 2005; Fricker *et al*., 2018 outlined that niacin helps in growth and maintenance of the central nervous system (CNS), whereas the vitamin E is very effective in the prevention of various diseases such as atherosclerosis, oxidative stress, cancer and cataract reported by Rizvi *et al*., 2014.

Human milk fat differs from cow, buffalo, goat, sheep, camel, horse and donkey milk fat significantly in fatty acid profile (Table 5). The higher total saturated fatty acids are found in goat milk followed by cow, donkey, buffalo, sheep, camel, human and horse milk. Butyric acid was lower in human milk and it was comparable to donkey milk. Low concentrations of butyric acid contribute to the inhibition in vitro of the human cancer cell lines, although caproic, caprylic and capric acids could reduce body weight and body fat as reported by

TABLE 3
Amino acids in human, cow, buffalo, goat, sheep, camel, horse and donkey milk

Amino acids (g.100g^{-1})	Human	Cow	Buffalo	Goat	Sheep	Camel	Horse	Donkey
Essential amino acids								
Tyrosine	4.70	4.50	3.85	4.80	3.7 - 3.8	3.10	4.30	4.36
Lysine	6.20	8.10	7.49	8.20	7.7 - 7.8	4.00	8.00	6.10
Iso Leucine	10.10	8.70	5.71	7.10	4.60	4.90	9.70	3.19
Methionine	1.80	1.80	0.92	3.50	2.70	2.00	1.50	2.90
Phenyl Alamnine	1.80	1.50	4.71	6.00	4.2 - 4.3	4.00	1.20	6.39
Threonine	4.60	4.50	5.71	5.70	4.2 - 4.4	4.10	4.30	3.19
Valine	6.00	4.80	6.76	5.70	6.2 - 6.4	4.10	4.10	4.65
Leucine	10.10	8.70	9.79	8.20	9.7 - 9.9	6.10	9.70	9.30
Total	45.30	42.6	44.94	49.20	43.00 - 43.90	32.30	42.8	40.0
Non-essential amino acids								
Alanine	4.00	3.00	n/a	3.60	n/a	2.10	3.20	4.94
Aspartic Acid	8.30	7.80	n/a	7.40	n/a	6.90	10.40	3.77
Histidine	2.30	3.00	n/a	5.00	n/a	2.10	2.40	6.68
Proline	8.60	9.60	n/a	14.60	n/a	12.00	8.40	8.43
Trypotophan	1.80	1.50	n/a	n/a	n/a	n/a	1.20	1.16
Arginine	4.00	3.30	n/a	2.90	n/a	2.00	5.20	11.62
Glutamic Acid	17.80	23.20	n/a	19.30	n/a	18.10	20.10	11.04
Serine	5.10	4.80	n/a	5.20	n/a	4.30	6.20	5.81
Glycine	2.60	1.80	n/a	2.10	n/a	2.10	1.90	5.23
Cystine	1.70	0.60	0.58	0.6	0.8 - 0.9	1.90	0.60	1.16
Total	56.20	58.60	0.58	60.70	0.8 - 0.9	51.50	59.6	59.84

n/a: not analyzed; (Guo *et al*., 2007; Bar³owska *et al*., 2011; Dimitrov *et al*., 2007; Kamal *et al*., 2007; Gerchev *et al*., 2005; Nayak *et al*., 2020)

TABLE 4
Vitamin concentration in human, cow, buffalo, goat, sheep, camel, horse and donkey milk

Vitamins (µg.100 mL^{-1})	Human	Cow	Buffalo	Goat	Sheep	Camel	Horse	Donkey
B_3-Niacin	147 - 178	50 - 120	80 - 171	187 - 370	300 - 500	0.77	70 - 140	1.3 (mg.100g^{-1})
A	30 - 200	17 - 50	69	50 - 68	41 - 50	5 - 97	9.3 - 34	BLOQ:100 (µg.100 g^{-1})
B_1-Thiamine	14 - 17	28 - 90	40 - 50	40 - 68	28 - 80	10 - 60	20 - 40	BLOQ:0.1 (mg.100g^{-1})
B_{12}-Cyanoco balamine	0.03 - 0.05	0.27 - 0.7	0.3 - 0.4	0.06 - 0.07	0.30 - 0.71	0.2	0.3	BLOQ:0.5 (µg.100 g^{-1})
B_2- Riboflavine	20 - 60	116 - 202	100 - 120	110 - 210	160 - 429	42 - 168	10 - 37	BLOQ:0.1 (mg.100g^{-1})
C- Ascorbic	3500 - 0000	300 - 2300	1000 -2540	900 -1500	425 -6000	2400-18400	1287 - 8100	<0.50 (mg.100g^{-1})
E- α-tocopherol	300 - 800	20 - 184	190 - 200	0.04 (mg. 100 g^{-1})	120	21 - 150	26 - 113	1.46 (mg. L^{-1})

BLOQ: Below limit of quantification; (Medhammar *et al*., 2012; Claeys *et al*., 2014; Nayak *et al*., 2020).

The Mysore Journal of Agricultural Sciences

TABLE 5

Fatty acids in human, cow, buffalo, goat, sheep, camel, horse and donkey milk

Composition (%)	Human	Cow	Buffalo	Goat	Sheep	Camel	Horse	Donkey
Butyric acid (C4:0)	0.02	3.14	3.90	1.27	4.06	ND	0.18	0.60
Caproic acid (C6:0)	0.09	2.17	2.33	3.28	2.78	0.10	0.28	1.22
Caprylic acid (C8:0)	0.19	1.41	2.41	3.68	3.13	0.10	2.45	12.80
Capric acid (C10:0)	1.46	3.25	2.40	11.07	4.97	0.10	6.67	18.65
Lauric acid (C12:0)	5.53	3.63	30.9	4.45	3.35	0.89	5.83	10.67
Myristic acid (C14:0)	6.40	11.62	28.02	9.92	10.16	7.32	6.37	5.77
Palmitic acid (C16:0)	25.40	24.9	12.58	25.64	23.1	18.80	22.74	11.47
Total saturated fatty acid (C4-18)	46.60	67.73	65.86	70.42	65.17	51.9	47.40	67.60
Palmitoleic acid (C16:1)	2.24	1.03	1.93	0.99	0.68	3.51	4.45	2.37
Oleic acid (C18:1)	40.25	24.81	24.10	24.17	26.01	28.10	25.15	9.65
Total mono-unsaturated fatty acid (C16:1-22:1)	43.55	27.3	26.43	25.67	24.29	39.60	31.14	15.80
Linoleic acid (C18:2)	8.84	2.81	2.04	2.72	1.61	1.85	14.94	8.15
Linolenic acid (C18:3)	0.05	0.86	0.68	0.53	0.92	1.81	7.05	6.47
Total poly-unsaturated fatty acids (C18:2-18:3)	9.85	5.25	2.67	4.08	2.45	8.46	22.01	16.60

ND: not detected; (Fiecko *et al*., 2020; Talpur *et al*., 2008; Konuspayeva *et al*., 2008; Nayak *et al*., 2020)

Rasmussen *et al*., 2010 and Foglietta *et al*., 2014. The total mono unsaturated fatty acids are higher in human, camel, horse, cow, buffalo, goat, sheep and donkey milk. The total poly unsaturated fatty acids were higher in horse and donkey milk compared to human, camel, cow, sheep, goat and buffalo milk. The total poly unsaturated fatty acids are majorly comprised of linoleic and linolenic acids (Recio *et al*., 2009). The levels of long-chain n-6 to n-3 (mainly LA compared with ALA) fatty acids are important, particularly n-3 fatty acids, in maintaining cardio vascular health (Griffin 2008) and they influence the ratios of ensuing eicosanoids and metabolic functions. The unsaturated or short chained fatty acids in horse and donkey milk are higher compared to other milk sources, which is interesting from a nutritional point of view. The linoleic acid is more in horse, human and donkey milk compared to other milk sources and the higher amount of these compound helps in lowering the risk of cardio vascular diseases, carcinogenesis, diabetes and osteoporosis and modulation of the immune system as revealed by Barlowska *et al*., 2011.

Milk proteins appear to be an exciting link between nutrition, dietetics and therapy. In fact, milk contains a variety of bioactive compounds with special properties associated with the development, growth and survival of infants beyond those provided by nutrition alone (Polidori and Vincenzetti, 2012). Highest amount of casein is observed in goat milk followed by cow, sheep, buffalo, camel, horse and donkey milk, whereas lowest whey protein content is observed in cow milk, followed by goat, sheep, camel, buffalo, horse, donkey and human milk. The cow milk casein and whey protein content is quite similar to camel, buffalo, goat and sheep milk (Table 6). An average high level of protein, fat and calcium by casein unit in milk makes it an excellent matrix for cheese

TABLE 6

Proteins in human, cow, buffalo, goat, sheep, camel, horse and donkey milk

Composition (%)	Human	Cow	Buffalo	Goat	Sheep	Camel	Horse	Donkey
Casein	26.06	77.23	68.93 - 73.00	77.50	70.60	52-87	50.00	47.28
Whey protein	53.52	17.54	24.90 - 28.14	20.00	21.70	20-25	38.79	36.96

(Guo *et al*., 2007; Pasquini *et al*., 2003; Potocnik *et al*., 2011; Park *et al*., 2007; Abdullahi, 2019

production (Barlowska *et al*., 2011). Cow, goat, buffalo, sheep and camel milk have higher content of casein/whey protein compared to other milk sources. The casein and whey protein combination of human milk is slightly similar to donkey and horse milk compared to cow, buffalo, goat, sheep and camel milk. An average, donkey milk contains a low level of total protein and a low casein/whey protein ratio (average of 1.3) reported by Tidona *et al*., 2011. This ratio is believed to play a crucial role in the sensitization to cow milk protein fraction, reducing the allergenic capacity, lower the value and lower the allergenic capacity (Lara-Villoslada *et al*., 2005). Restani *et al*., 2002;

Monti *et al*., 2007; Swar 2011, conducted in vivo study on donkey milk tolerability test and it revealed that it was well tolerated by children with cow milk protein allergy (CMPA) in terms of clinical tolerability.

Cow milk is most universal in human nutrition and the present review revealed the nutritional composition of some different milk sources such as human, cow, buffalo, sheep, goat, camel, horse and donkey milk. Majorly cow milk is largely consumed in practice due to required nutritional composition present in it and has good yield with huge population. The other milk sources are little nicked in their usage due to the less awareness and availability. The present study gives an idea regarding the nutritional compositions of different milk sources. It is clear from the review that the donkey and horse milk nutritional composition is almost similar to the human milk nutritional composition and the infants who are orphan or deprived from mother's milk, even malnutrition could take use of it for their overall health and body development. Allergic reactions of donkey milk and horse milk is lower due to lower protein composition compared to cow, camel, buffalo, sheep, goat and almost similar protein composition compared with human milk. Compared to all milk sources, the fat content of donkey milk is lower. Donkey milk digestibility is higher compared to cow milk and it is similar to human milk due to the good amount of whey proteins in it. It is evident from the review that the donkey milk can be considered the closest natural milk to human milk.

The authors gratefully acknowledge the Department of Science and Technology (DST), Science and Engineering Research Board (SERB), Grant No. EEQ/ 2017/000677 for providing the financial support.

REFERENCES

ABDULLAHI, A., 2019, Camel Milk - A Review. *J. Animal Sci. & Livestock Prod.,* **3** (1:5) : 13 - 18.

AHMAD, S., ANJUM, F. M., HUMA, N., SAMEEN, A. AND ZAHOOR, T., 2013, Composition and physico-chemical characteristics of buffalo milk with particular emphasis on lipids, proteins, minerals, enzymes and vitamins. *The J. Animal & Plant Sci.,* **23** (S1) : 62 - 74.

ANTHONY, J. C., ANTHONY, T. G., KIMBALL, S. R. AND JEFFERSON, L. S., 2001, Signaling pathways involved in translational control of protein synthesis in skeletal muscle by leucine. J. Nutr., **131** (3) : 856 - 860.

BALTHAZAR, C. F., PIMENTEL, T. C., FERRAO, L. L., ALMADA, C. N., SANTILLO, A., ALBENZIO, M.., MOLLAKHALILI, N., MORTAZAVIAN, A. M., NASCIMENTO, J. S., SILVA, M. C., FREITAS, M. Q., SANT'ANA, A. S., GRANATO, D. AND CRUZ, A. G., 2017, Sheep milk: physico chemical characteristics and relevance for functional food development. *Comprehensive Reviews in Food Sci. & Food Safety,* **16** (2) : 247 - 262.

BARLOWSKA, J., SZWAJKOWSKA, M., LITWINCZUK, Z. AND KROL, J., 2011, Nutritional value and technological suitability of milk from various animal species used for dairy production. *Com. Rev. Food Sci. Food Safety,* **10** (6) : 291 - 302.

BUSINCO, L., GIANPIETRO, P. G., LUCENTI, P. J., LUCARONI, F., PINI, C., FELICE, D. I., IACOVACCI, P., CURADI, C. AND ORLANDI, M., 2000, Allergenicity of mare's milk in children with cow's milk allergy. *J. Allergy Clin. Immunol.,* **105** (5) : 1031 - 1034.

CARROCCIO, A., CAVATAIO, F., MONTALTO, G., D'AMICO, D. AND ALABRESE, L., 2000, Intolerance to hydrolysated cow's milk proteins in infants: characteristics and dietary treatment. *Clin. Exp. Allergy.* **30** (11) : 1597 - 1603.

CLAEYS, W. L., VERRAESA, C., CARDOENA, S., DE BLOCK, J., HUYGHEBAERT, A., RAESD, K., DEWETTINCK, K. AND HERMANBE, L., 2014, Consumption of raw or heated milk from different species: An evaluation of the nutritional and potential health benefits. Food Control. **42** (42) : 188 - 201.

CRITTENDEN, R. G. AND BENNETT, L. E., 2005, Cow's milk allergy: *A complex disorder. J. Am. Coll. Nutr.,* **24** (S6) : 582 - 591.

DEVAKI, S. J. AND RAVEENDRAN, R. L., 2017, Chapter 2; Vitamin C: Sources, Functions, Sensing and Analysis. *Intech.,* pp. 3 - 20.

DIMITROV, T., MIHAYLOVA, G., BOYCHEVA, S., NAYDENOVA, N. AND TSANKOVA, M., 2007, Changes in the amino acid composition of buffalo milk after chemical activation of its lactoperoxidase system. *Ital J. Anim. Sci.,* **6** (S2) : 1050 - 2.

DUGO, P., KUMM, T., L. O. M., CHIOFALO, B., SALIMEI, E., FAZIO, A., COTRONEO, A. AND MONDELLO, L., 2005, Determination of tryacylglycerols in donkey milk by using high performance liquid chromatography coupled with atmospheric pressure chemical ionization mass spectrometry. *J. Sep. Sci.,* **28** (9-10) : 1023 - 1030.

EL-AGAMY, E. I., NAWAR, M., SHAMSIA, S. M., AWAD, S. AND HAENLEIN, G. F. W., 2009, Are camel milk proteins convenient to the nutrition of cow milk allergic children. *Small Rumin. Res.,* **82** (1) : 1 - 6.

FIECKO, R. P. AND KAMELSKA-SADOWSKA, A. M., 2020, The comparison of nutritional value of human milk with other mammal's milk Nutrients, **12** (1) : 1 - 18.

FOGLIETTA, F., SERPE, L., CANAPARO, R., VIVENZA, N., RICCIO, G., IMBALZANO, E., GASCO, P. AND ZARA, G. P., 2014, Modulation of butyrate anticancer activity by solid lipid nanoparticle delivery: an in vitro investigation on human breast cancer and leukemia cell lines. *J. Pharm. Sci.,* **17** (2) : 231 - 247.

FRICKER, R. A., GREEN, E. L., JENKINS, S. I. AND GRIFFIN, S. M., 2018, The Influence of nicotinamide on health and disease in the central nervous system. *Int. J. Tryptophan Res.,* **11** (1) : 1 - 11

GERCHEV, G., MIHAYLOVA, G. AND TSOCHEV, I., 2005. Amino acid composition of milk from Tsigai and Karakachanska sheep breeds in the central Balkan mountains. *Biotech. Animal Husbandry.* **21** (5Y6) : 111 - 115.

GRIFFIN, B. A., 2008, How relevant is the ratio of dietary n-6 to n-3 poly unsaturated fatty acids to cardio vascular disease risk. *Curr. Opin. Lipidol.,* **19** (1) : 57 - 62.

GUO, H., PANG, K., ZHANG, X., ZHAO, L., CHEN, S., DONG, M. AND REN, F., 2007, Composition, physio chemical properties, nitrogen fraction distribution and amino acid profile of donkey milk. *J. Dairy Sci.,* **90** (4) : 1635 - 1643.

KALYANKAR, S. D., KHEDKAR, C. D., PATIL, A. M. AND DEOSARKAR, S. S., 2016, Milk : Sources and Composition. In : Caballero, B., Finglas, P. and Toldra, F. (Ed.). *The Encyclopedia of Food and Health,* pp : 741 - 747.

KAMAL, A. M., SALAMA, O. A. AND EL-SAIED, K. M., 2007. Changes in amino acids profile of camel milk protein during the early lactation. *Int. J. Dairy Sci.,* **2** (3) : 226 - 234.

KAPADIYA, D. B., PRAJAPATI, D. B., JAIN, A. K., MEHTA, B. M., DARJI, V. B. AND APARNATHI, K. D., 2016, Comparison of Surti goat milk with cow and buffalo milk for gross composition, nitrogen distribution and selected minerals content. **9** (7) : 710 - 716.

KONUSPAYEVA, G., LEMARIE, E., FAYE, B., LOISEAU, G. AND MONTET, D., 2008, Fatty acid and cholesterol composition of camel's (Camelus bactrianus, Camelus

dromedarius and hybrids) milk in Kazakhstan. *Dairy Sci. Technol.,* **88** (3) : 327 - 340.

KUMAR. H., YADAV, D., KUMAR, N., SETH, R. AND GOYAL, K., 2016, Nutritional and nutraceutical properties of goat milk- A review. *Indian J. Dairy Sci.,* **69** (5) : 513 - 518.

LARA-VILLOSLADA, F., OLIVARES, M. AND XAUS, J., 2005, The balance between caseins and whey proteins in cow's milk determines its allergenicity. *J. Dairy Sci.* **88** (5) : 1654 - 1660.

MEDHAMMAR, E., WIJESINHA-BETTONI, R., STADLMAYR, B., NILSSON, E., CHARRONDIERE, U. R. AND BURLINGAME, B., 2012, Composition of milk from minor dairy animals and buffalo breeds: a biodiversity perspective. J. Sci. Food & Agric., **92** (3) : 445 - 474.

MOLIK, E., BONCZAR, G., MISZTAL, T., ZEBROWSKA, A. AND ZIEBA, D., 2012, The effect of the photoperiod and exogenous melatonin on the protein content in sheep milk. In: Hurley WL (Ed), Milk protein. 1st ed. Rijeka: Intech, pp. 15 - 45.

MONTI, G., BERTINO, E., MURATOREMC., COSCIA, A., CRESI, F., SILVESTRO, L., FABRIS, C., FORTUNATO, D., GIUFFRIDAMG, AND CONTI, A., 2007, Efficacy of donkey's milk in treating highly problematic cow's milk allergic children: an in vivo and in vitro study. Pediatr Allergy Immunol., **18** (3) : 258 - 264.

NAYAK, C. M., RAMACHANDRA, C. T., NIDONI, U., HIREGOUDAR, S., RAM, J. AND NAIK., 2020, Physico-chemical composition, minerals, vitamins, amino acids, fatty acid profile and sensory evaluation of donkey milk from Indian small grey breed. *J. Food Sci. Technol.,* **57** (8) : 2967 - 2974.

PARK, Y. W., JUAREZ, M., RAMOS, M. AND HAENLEIN, G. F. W., 2007, Physico-chemical characteristics of goat and sheep milk. *Small Rum. Res.,* **68** (68) : 88 - 113.

PASQUINI, M., TOMMEI, B. AND MATTII, S., 2003, Buffalo milk: proteins electrophoretic profile and somatic cell count. *Italian J. Ani. Sci.,* **2** (S1) : 299 - 301.

POLIDORI, P. AND VINCENZETTI, S., 2012, Protein profile characterization of donkey milk. In: Hurley WL, editor. Milk Protein. pp : 215 - 232.

POTOCNIK, K., GANTNER, V., KUTEROVAC, K. AND CIVIDINI, A., 2011, Mare's milk: composition and protein fraction in comparison with different milk species. Mljekarstvo. **61** (2) : 107 - 113.

RASMUSSEN, N., ANDERSEN, J. H., JESPERSEN, H., MOURITSEN, O. G. AND DITZEL, H. J., 2010. Effect of free fatty acids and lysolipids on cellular uptake of doxorubicin in human breast cancer cell lines. Anticancer Drugs, **21** (7) : 674 - 677.

RECIO, I., FUENTE, M. A., JUAREZ, M. AND RAMOS, M., 2009, Bioactive components in sheep milk. Y. W. Park (Ed.), Bioactive components in milk and dairy products, Wiley-Blackwell, Ames, IA., pp : 83 - 104.

RESTANI, P., BERETTA, B., FIOCCHI, A., BALLABIO, C. AND GALLI, C., 2002, Cross-reactivity between mammalian proteins. *Ann. Allergy Asthma Immunol.,* **89** (S1) : 11 - 15.

RIZVI, S., RAZA, S. T., AHMED, F., AHMAD, A., ABBAS, S. AND MAHDI, F., 2014, The role of vitamin-e in human health and some diseases, **14** (2) : 157 - 165.

SABAHELKHIER, M. K., FATEN, M. M. AND OMER, F. I., 2012, Comparative determination of biochemical constituents between animals (goat, sheep, cow and camel) milk with human milk. *Res. J. Recent Sci.,* **1** (5) : 69 - 71.

SICHERER, S. H., NOONE, S. A., KOERNER, C. B., CHRISTIE, L., BURKS, A. W. AND SAMPSON, H. A., 2001, Hypoallergenicity and efficacy of an amino acid-based formula in children with cow's milk and multiple food hypersensitivities. *J. Pediatr.,* **138** (5) : 688 - 693.

SWAR, M. O., 2011, Donkey milk-based formula: A substitute for patients with cow's milk protein allergy. *Sudan J. Paediatr.,* **11** (2) : 21 - 24.

TAKAHASHI, T., TODA, E., SINGH, R. B., MEESTER, F. D., WILCZYNSKA, A., WILSON, D. AND JUNEJA, L. R., 2011, Essential and non-essential amino acids in relation to glutamate. *The open Nutraceu. J.,* **4** (1) : 205 - 212.

TALPUR, F. N., BHANGER, M. I., KHOOHARO, A. A. AND MEMON, G. Z., 2008, Seasonal variation in fatty acid composition of milk from ruminants reared under the traditional feeding system of Sindh, Pakistan. *Livest. Sci.,* **118** (1) : 166 - 172.

TESSE, R, PAGLIALUNGA C, BRACCIO S. AND ARMENIO L., 2009, Adequacy and tolerance to ass's milk in an Italian cohort of children with cow's milk allergy. *Ital. J. Pediatr.,* **35** (19) :

TIDONA, F., CRISCIONE, A., GUASTELLA, A. M., BORDONARO, S., MARLETTA, D., 2011, Gross composition and nutritional properties of donkey milk produced in Sicily. Chemical composition and nutritional properties of salted milk produced in Sicily. *Sci. Tecn. Latt. Cos.,* **62** (1-2) : 217 - 221.

VAHCIC, N., HRUSKAR, M., MARKOVIC, K., BANOVIC, M. AND BARIC, I. C., 2010, Essential minerals in milk and their daily intake through milk consumption. Mljekarstvo, **56** (127) : 77 - 85.

WILLIAMS, A. AND RAMSDEN, D., 2005, A Double Edged Sword. *Parkinsonism Relat. Disord.,* **11** (7) : 413 - 420.

ZAMBERLIN, S., ANTUNAC, N., HAVRANEK, J. AND SAMARZIJA, D., 2012, Mineral elements in milk and dairy products. *Mljekarstvo*, **62** (2) : 111 - 125.

(*Received :* July, 2020 *Accepted :* August, 2020)