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The Nutritional Value of Non-bovine Milk: An Approach from a Health Perspective: A Review

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ABSTRACT

Several nutrients and health-promoting ingredients, including oligosaccharides, lipids, bioactive peptides, premium proteins, minerals and vitamins, are found in higher concentration in non-bovine milk. Because non-bovine milk contains proteins with varying structures and amino acid compositions, it is remarkably diversified. On the other hand, bioactive peptides derived from non-bovine milk offer promising prospects for the advancement of functional foods and other health-related sectors. As a consequence, generating novel products. Peptides derived from non-bovine milk are an intriguing source for functional meals with superior nutritional profiles because of their biofunctionalities and lack of negative effects. Camel milk stands out among these non-bovine milk alternatives because of its exceptional nutritional value, ease of digestion and health-promoting qualities like its ability to fight inflammation, bacteria and hyperlipidemia.

Key words: Biofunctionality, Camel milk, Health benefits, Non-bovine milks, Nutritional significance.

The investigation of non-dairy milks sourced from non-bovine species has garnered attention due to their capacity to satisfy diverse nutritional needs and possess distinct bioactive components. When cow milk is unavailable or meat consumption is restricted, non-bovine animals' milks like goat, sheep, donkey, camel, yak and others as well as those of zebu, horses, mares and reindeer play crucial roles as regular providers of protein, phosphate and calcium.

Non-bovine milk is remarkably diverse due to the presence of proteins with different structures and amino acid compositions. For instance, the casein proteins in goat milk differ from those in cow's milk, which affects how efficiently the milk coagulates. The types and amounts of fat found in non-bovine milk vary; sheep and goat milk, for instance, contain higher concentrations of specific short-chain fatty acids. These variations in fat content can be responsible for variations in flavor, consistency and nutritional value. The nutritional characteristics of non-dairy milk sources also differ. Among them, camel milk stands out because it contains more vitamin C than other varieties of milk. Furthermore, those who are lactose intolerant may benefit from non-bovine milks since they frequently contain less lactose than cow's milk.

Milk is the first food that mammals consume because it gives newborns the nutrition they need to grow and supports their essential physiological functions. Beyond its well-known nutritional advantages, milk has a variety of biological components that support immune system regulation, gut microbiome balance and bone health, all of which are critical for overall health and wellness.

Milk from non-bovine sources has been consumed for thousands of years. The Arabian Peninsula, the Mediterranean region and many European and Asian nations all eat large amounts of goat and sheep milk.

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Mongolia and the Arabian Peninsula are major consumers of camel milk. In Kazakhstan, Mongolia and Northern China, mare milk is drunk. Russia and northern Europe both drink deer milk. The use of milk from other animals in conventional dairy products has declined, despite the fact that cows are still the primary source of milk and that cow husbandry is still widely practiced. However, by better understanding native culture through modern communication, these barriers of states and continents have been broken by the improved quality of some dairy products created from these non-bovine milk sources, as well as the potential health benefits.

According to Food and Agricultural Organization (FAO) of USA, the amount of milk produced worldwide in 2020 was 886.9 million tonnes, which is approximately 2.5 times the amount produced in 1961 (344,184,775 tonnes) and an increase of 11% from the reported figure of 798,476,318 tonnes in 2016. The global production of milk from goats, sheep and camels was just 2.3%, 1.2% and 0.4%,

respectively, despite these remarkable figures. Because they are largely used to create processed dairy products, these species are crucial to rural economies in regions like Southeast Asia and the Mediterranean even though they account for less than 5% of the world's milk supply (Chia *et al*., 2017). donkey, deer and mare milk are not widely traded or consumed, but in certain groups they hold great cultural significance (Wang *et al*., 2017). The composition of milk is influenced by a wide range of factors, including those related to animals, such as species, age, parity, lactation stage, breed, general genetic background and health; farming practices, such as management style, diet and number of offspring; and environmental factors, such as climate, soil and altitude. The physicochemical properties and milk compositions of different species have evolved to satisfy the nutritional, energetic, digestibility and other needs of their offspring.

When assessing milk for ingestion by humans, its physicochemical properties which dictate its functional qualities must be considered. Along with influencing sensory aspects and the total value of milk and its derivatives, these qualities also have an impact on later technological elements including yield, stability and structure. Sheep's milk, for instance, is frequently used to make specialty cheeses like the well-known Spanish Manchego.

Large concentrations of numerous nutrients, including oligosaccharides, lipids, bioactive peptides, premium proteins, minerals and vitamins, all of which are beneficial to nutrition and health can be found in non-bovine milk. Various factors influence the types, amounts and compositions of these nutrients, including the animal's breed, age, feed quality and quantity, seasonal changes and environmental conditions (Claeys *et al*., 2014). The properties of camel milk include small fat globules, large levels of lactadherin-like protein, phospholipids, essential fatty acids, unsaturated fatty acids, low cholesterol and saturated fatty acids (Bakry *et al*., 2021). Camel milk stands out among non-bovine milk substitutes for its outstanding nutritional content, easy digestion and health-promoting properties such its antibacterial, anti-inflammatory and anti-hyperlipidemia benefits.

Composition of milk from different mammals

Different essential components, including proteins, lipids, carbohydrates and minerals, are present in the milk of many species and are necessary to support the nutritional needs of neonates. Additionally, milk offers a variety of physiologically active compounds that support various physiological processes for the neonate, such as growth factors, hormones, oligosaccharides, antibacterial peptides, antimicrobial proteins and immunoglobulins. Compositions of milk from different mammals (approximate composition and range of components) are mentioned in Table 1.

Many factors, such as individual traits, lactation stage, age, parity, body weight, feeding schedule, seasonal changes, environmental factors (temperature, humidity), milking intervals, length of dry periods and gestation and health status, particularly cases of mastitis, can affect an animal breed's daily milk production and composition. The composition of milk has a significant role in determining its nutritional value. It also influences many of the physicochemical, sensory and appropriateness of milk products as a primary ingredient in dairy and culinary items. The components of milk from ruminants and non-ruminants differ noticeably (Magan *et al*., 2021).

Table 1: Composition of milk from different mammals (approximate concentration and range).

Species	Energy (kcal/kg)	Ash (g/kg)	Lactose (g/kg)	Fat (g/kg)	Protein (g/kg)	Total solid on dry matter (g/kg)
Cow	590-701	7	48	38	34	127
		6-9	36-55	25-60	29-50	105-137
Buffalo	710-1180	8	48	72	42	169
		7-9	44-52	61-96	7-50	145-184
Goat	580-740	8	44	43	36	132
		7-11	39-63	25-78	25-51	119-163
Sheep	930-1080	9	48	74	57	178
		7-10	37-55	51-90	50-65	152-193
Camel	440-790	8	49	43	36	130
		6-10	31-58	26-67	30-50	108-145
Yak	870-910	8	50	64	49	167
		4-10	33-62	42-108	33-64	92-282
Donkey	320-510	4	66	14	17	95
		4-5	58-74	1-18	14-22	85-117
Red deer	-	1.04-1.18	2.6-6.2	6.6-19.7	5.9-10.6	20.0-30.5
Horse	-	0.3-0.5	5.6-7.2	0.3-4.2	1.4-3.2	9.3-11.6
Human	430-1150	2	71	35	12	125
		2-3	60-90	22-52	8-15	

(Claeys *et al*., 2014; Alichanidis *et al*., 2016; Crowley *et al*., 2017).

Ruminant milk is known for its higher total solids content as well as its high protein, fat and ash content. However, donkey milk frequently has a higher lactose content. At about pH 4.6, the protein called casein separates from milk, although serum proteins remain soluble in this solution. This casein fraction is variable and contains αs1-, αs2-, β- and κ-casein, according to Eigel *et al*. (1984). The major structural forms in which each of these variations exists are determined by genetics; the primary differences are found in the amino acid residues. Moreover, post-translational modification causes seryl residues in caseins to become phosphorylated. The ability of various casein forms to bind calcium and calcium phosphate varies as a result of this phosphorylation.

Small amounts of γ-caseins are also present in milk, as a consequence of plasmin, an alkaline milk proteinase, partially breaking down β-casein. κ-casein exhibits a distinct behavior from αs1-, αs2 and β-caseins, which typically exhibit strong binding to Ca^{2+} and other polyvalent cations, eventually becoming insoluble when [Ca^{2+}] surpasses 6 mmol/L at 20°C. The solubility of κ-casein is not impacted by Ca^{2+} As a result, κ-casein forms spherical aggregates called casein micelles, which can stabilize Ca^{2+} sensitive caseins up to ten times their mass. The size of these micelles varies greatly throughout species.

Milk serum contains a number of nitrogenous compounds that are collectively referred to as Non-Protein Nitrogen (NPN), but in relatively modest levels. Ammonia, urea, short peptides, free amino acids, creatine, creatinine, uric acid and orotic acid are a few of the substances that belong to this group. Nucleotides and nucleosides, which have different physiological roles, particularly in the early stages of life, are also present in the NPN fraction. The species and eating habits of the animal, the herd, the breed, the lactation stage and the season are some of the factors that could impact the amount of NPN in milk. DePeters and Ferguson (1992) reported that the NPN fraction accounts for approximately 5% of the total nitrogen content in cow milk, while in ruminant milk, it may range from 3% to 5%. In general, goat and sheep milk have greater NPN concentrations than cow milk (Tripaldi *et al*., 1998; Park *et al*., 2007). Comparative protein composition profile of milks from non-bovine species is provided in Table 2.

Urea is the primary component of milk and accounts for around half of its total nitrogen content. Free amino acids (FAA), which are more readily absorbed than amino acids linked to proteins, make up roughly 10-20% of NPN in cow milk, 9-10.5% in goat milk and 16% in sheep milk (Tripaldi *et al*., 1998; Park *et al*., 2007). The bulk of other amino acids, which are mostly non-essential amino acids like glutamic acid, glycine and alanine, are surprisingly present in relatively little levels in these FAA. During breastfeeding, the amount of free amino acids (FAA) in all types of milk significantly changes, albeit the consequences vary depending on the particular amino acid.

Glutamic acid is typically the most prevalent type of FAA present in the milk produced by many mammals. One particularly intriguing substance is taurine, which is present in higher concentrations in colostrum and diminishes over the course of nursing. Park *et al*. (2007) state that taurine is involved in growth regulation, membrane stabilization and the synthesis of bile acid, among other functions. Because of these significant functions, taurine is considered a "conditionally essential" amino acid when feeding infants (Rassin *et al*., 1978). Due to cow milk's relatively low taurine content (about 6 mg/kg), taurine is frequently added as a supplement to infant formulas. Goat milk, on the other hand, has more taurine. Comparatively speaking, sheep milk has more taurine than cow milk. Amino acid content (mg/kg) of the milks of non-bovine species is compiled and stated in Table 3.

Bioactive peptides (BAPs)

The Greek word "peptos", which meaning "digested", is where the word "peptide" originates. Specific protein fragments known as "bioactive peptides" have been shown to positively affect physiological functions and medical conditions, potentially affecting overall health and well-being.

Table 2: Comparative protein composition profile from milk of non-bovine species.

Protein fraction	Camel	Goat	Sheep	Yak	Donkey	Red deer	Horse	Human
Total casein (g/kg)	22-48	23-38	41-66	21-40	6-10	~57-84	9.4-13.6	2.4-4.2
αs 1- Casein (% total)	21	4.5-34	7-40	13-32	-	-	2.4	0.77
αs 2- Casein (% total)	9	9-25	12-23	9-18	-	-	0.2	-
β- Casein (% total)	65	24-64	34-62	37-51	-	-	10.66	3.87
κ- Casein (% total)	3-5	10-19	7-23	12-21	-	-	0.24	0.14
γ- Casein (% total)	-	5-6	-	-	-	-	-	-
Total whey protein (g/kg)	6-10	3-12	8-16	11	5-9	~11-15	7.4-9.1	6.2-8.3
α- Lactalbumin (% total WP)	45-53	17-50	13-45	7-20	23-33	-	2.37	1.9-3.4
β- Lactoglobulin (% total WP)	-	34-77	28-72	50-86	30-57	-	2.55	-
Serum albumin (% total WP)	30-41	5-22	6	7-15	6-7	-	-	-
Immunoglobulins (g/kg)	0.55-0.8	0.15-0.5	0.5-0.7	0.1-0.4	1.3	-	-	-
Lactoferrin (g/kg)	0.2-0.9	0.02-0.3	0.7-0.9	0.2-0.7	0.3	-	-	-
NPN (% total N)	6-11	7-12	6-9	6	11-25	-	-	-

(Claeys *et al*., 2014; Alichanidis *et al*., 2016; Crowley *et al*., 2017).

These bioactive peptides can be made in a number of ways, such as: (i) by hydrolyzing digestive enzymes; (ii) by using proteases that are derived from plants or microorganisms that cleave enzymatically during food preparation; or (iii) by processing or industrial procedures that expose materials to heat, acids, or alkalis (Kitts and Weiler, 2003).

The inherent amino acid composition and sequencing affect how the bioactive peptides work. These active sequences can consist of two to twenty amino acid residues and many of the peptides have more than one purpose. Non-bovine milk naturally has a spectrum of bioactivity because the mammary gland releases lysozyme, lactoferrin, growth factors and hormones in their active forms (Meisel and FitzGerald, 2003).

Biofunctionalities of non-bovine milks

Non-bovine milk is a good alternative for human milk, particularly for people who are allergic to cow's milk. Research into alternative mammalian sources has resulted from this. Many societies, especially those in desert regions, rely heavily on camels. They are resilient to harsh weather and are essential to transportation, athletics and the production of milk and meat, all of which support human livelihoods and food security. Yassin *et al*. (2015) claim that camel milk's antimicrobial, immunomodulatory, anti-diabetic and anti-carcinogenic properties are widely recognized.

Donkey milk has become more well-known as a natural nutritional and medical supplement because of its similar composition to human milk and potential biological benefits, such as anti-inflammatory, anti-aging, antibacterial and anti-allergic effects (Li *et al*., 2022). Because of its superior digestibility and unique properties, such as its anti-inflammatory, antibacterial, bifidogenic and anti-atherogenic properties, goat milk is growing in popularity (Sonu *et al*., 2020). The fact that its chemical composition is comparable to cow's milk contributes to its increasing acceptability.

A lot of attention has been paid in recent years to the study of bioactive peptides generated from non-bovine milk because of their many possible health advantages and practical uses. Animal milks other than cow's milk, like those from sheep, goats, camels, donkeys and other mammals, have gained importance because they are abundant in bioactive peptides, which are short sequences of amino acids that have a variety of physiological effects. These peptides have several properties, such as immunomodulatory, antioxidant, antimicrobial and antihypertensive effects. They make intriguing candidates for application in a range of nutritional and therapeutic situations as a result.

When milk proteins are broken down enzymatically to form bioactive peptides, these active fragments are released. By closely analyzing the complex mechanisms underlying this enzymatic breakdown, scientists are able to generate unique peptides with precise biofunctionalities. This rigorous approach leads to the development of innovative functional food ingredients and therapeutic therapies, while also improving our understanding of basic biochemical processes.

Table 3: Amino acid content (mg/kg) of the milk of non-bovine species.

Amino acid	Goat	Sheep	Camel	Yak	Donkey	Horse	Human
Alanine	1.60-7.73	5.25	2.19-9.61	1.40	2.19	3.2	4.0
Arginine	1.91-13.49	3.65	0.34-1.22	1.60	0.34	5.2	4.0
Aspartic acid	1.34-5.19	1.86	0.93-1.34	3.30	1.34	10.4	8.3
Cystine	-	1.80	0.01	0.40	0.01	0.6	1.7
Glutamic acid	25.00-43.51	28.37	17.15-19.26	10.50	17.15	20.1	17.8
Glutamine	10.07-27.42	10.66	5.55	-	-	-	-
Glycine	21.83-32.41	11.63	0.30-1.38	1.20	1.38	1.9	2.6
Histidine	2.23-2.33	1.24	0.62-0.88	1.20	0.88	2.4	2.3
Isoleucine	0.26-2.15	0.26	0.80-1.18	2.40	0.80	3.8	5.8
Leucine	0.26-2.67	0.46	0.66-3.17	4.30	3.17	9.7	10.1
Lysine	3.21-5.48	2.63	2.77-3.58	3.80	3.58	8.0	6.2
Methionine	1.43	0.30	0-0.78	1.10	0.78	1.5	1.8
Phenylalanine	2.00	0.25	1.93	2.20	1.93	4.7	4.4
Phosphoserine	5.55-8.77	-	2.59-11.29	-	2.59	-	-
Proline	1.61-1.79	0	1.15-2.99	4.60	1.15	8.4	8.6
Serine	0-9.45	0.32	0-1.32	2.30	1.32	6.2	5.1
Tryptophane	1.77	-	-	-	-	1.2	1.8
Threonine	0-3.31	5.00	1.55-3.60	1.90	3.60	4.3	4.6
Tyrosine	1.45-4.50	1.45	0-1.13	2.20	1.13	4.3	4.7
Valine	5.79-6.32	1.29	0.23-2.60	2.60	2.60	4.1	6.0

(Barlowska *et al*., 2011; Alichanidis *et al*., 2016).

Nutritional Significance of Non-bovine milk

Non-bovine milks are mostly found in specific geographic locations and ecosystems across the globe (Barlowska *et al*., 2011). According to Tsakalidou and Papadimitriou (2016), the production of non-bovine milk in non-Western countries employs over 150 million milk producers and offers both essential nutrition and food security, as well as a significant source of income for households. From 2000 to 2019, the percentage growth rate of milk generated by minor mammalian species, such as goats (48.91%), camels (70.87%) and sheep (25.35%), exceeded the growth rate of cow's milk (46.31%), despite the fact that cow's milk remains the primary source of milk produced globally.

Dairy products made from camels, goats and sheep, as well as their non-bovine milk, provide several nutritional and health benefits. Camel milk (CM) has been shown to have numerous therapeutic and medicinal effects, including the capacity to lower cholesterol, inhibit ACE, prevent diabetes and prevent cancer (Gammoh *et al*., 2020). Goat milk (GM) has gained a lot of interest since it is less allergenic, easier to digest and has a superior nutritional profile than cow milk, all due to its lower levels of αs1-casein and β-lactoglobulin (Kumar and Sharma, 2016).

Additionally, goat milk fat is easier to digest and can help manage low mineral bone density, metabolic diseases, anemia and cholesterol imbalances because it contains more short- to Medium-Chain Fatty Acids (MCFA) and smaller diameter globules (3.2-3.6 µm) (Nayik *et al*., 2021). Sheep milk is becoming more widely used to make dairy products like cheese, yogurt and ice cream. This is significant for the economies of the Mediterranean region, sub-Saharan Africa, the Middle East and East and Southeast Asia (Balthazar *et al*., 2017).

It is a need of time to give these significant but underutilized nutrient sources maximum consideration in order to assess their suitability for food formulations and potential for export. Non-bovine milk has garnered a lot of attention lately because to its purported health benefits and the desire to incorporate it into baby formulas because it is less allergic than cow milk (Nudda *et al*., 2020; Prosser *et al*., 2021). Processing companies have been interested in non-bovine milks and their derivatives in recent years, as evidenced by the growing diversity of commercialized non-bovine milk products.

CONCLUSION

Non-bovine species have fewer numbers in the animal population and are not as economically significant, there is comparatively less research being done on these milks and their derivatives. Due to their bio functionalities and lack of side effects, peptides made from non-bovine milk are an interesting source for functional meals with better nutritional profiles. Interestingly, bioactive peptides from the milk proteins of goats and sheep are now well characterized, although less is known about peptides originating from other minor dairy animal species. For those who are allergic to cow's milk, nonbovine milk is an excellent substitute for human milk. Non-bovine milk contains high quantities of many components that are good for nutrition and health, such as oligosaccharides, lipids, bioactive peptides, premium proteins, minerals and vitamins. Non-bovine milk is remarkably diverse due to the presence of proteins with different structures and amino acid compositions. Interestingly, non-bovine milk provides an important and long-lasting way to support human health and wellbeing in general but need to explore these in a much detailed and scientific way.

Conflict of interest

All authors declared that there is no conflict of interest.

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