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Benefits of goat, sheep and buffalo milk: A concise review

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Abstract
Background: Milk and its derivatives are vital in human health, particularly in bone development and maintaining essential organ functions. While cow milk is the predominant source of dairy products, non-bovine milk, such as goat, sheep, and buffalo milk, has gained attention for their distinctive nutritional characteristics and health benefits.
Methods: This mini-review was carried out based on studies from the last 5 years, and it sought to summarize these alternative kinds of milk's nutritional and therapeutic properties, highlighting their advantages over cow's milk, particularly regarding macronutrient and micronutrient composition.
Results: Among their benefits, these kinds of milk offer viable alternatives for individuals with lactose intolerance or cow's milk allergy due to their lower lactose content and enhanced digestibility. In addition, some components of goat, buffalo, and sheep milk present anti-inflammatory, antihypertensive, or antidiabetic effects.
Conclusions: Increased consumption and the diversification of non-bovine milk sources could provide a valuable alternative for various age groups and nutritional needs, especially for vulnerable populations.

Keywords: Non-bovine milk, goat milk, sheep milk, buffalo milk, health benefits

Introduction

Milk intake and its derivatives are beneficial across all age groups, particularly for children and adolescents, due to its fundamental role in developing bone mass. These foods are important sources of calcium, vitamin D, proteins, and other nutrients essential for maintaining organ functions. The cow is the leading animal that provides milk. However, individuals with lactose intolerance or cow's milk allergy must avoid this food (Ratajczak *et al.* 2021; Arrichiello *et al.* 2022; Zhu *et al.* 2024) [39, 50].

Milk from various species can provide distinct health benefits due to differences in nutritional composition. In 2023, global bovine, buffalo, goat, and sheep milk production surpassed 900 million tons, with cow's milk making up the largest share, at approximately 81%, followed by buffalo, goat, and sheep milk production (Table 1).

Goat, sheep, and buffalo milk production remains relatively low compared to cow's milk. However, these non-bovine milk are considered excellent alternatives, offering various nutritional benefits and serving as options for individuals with lactose intolerance or cow's milk allergy. Sheep milk, for example, contains significantly higher proteins and fat than cow, goat, and camel milk. Buffalo milk is notably richer in lipids, and lactose content varies among the milk of different ruminants (Penhaligan *et al.* 2022) [33].

The consumption of these kinds of milk is limited by various factors, such as the availability and variety of dairy products from these animals, the relatively higher cost compared to cow's milk, and the cultural preference for cow's milk. Nevertheless, there is growing interest in these milks worldwide, particularly among consumers seeking healthier and more natural options. Products derived from goat, sheep, and buffalo milk, such as cheeses, yogurts, and butter, are becoming more common on supermarket shelves and in specialty stores (EMBRAPA, 2020; Júnior *et al.* 2020; Deshwal *et al.* 2021) [9, 13, 23].

On the other hand, bioactive peptides generated after hydrolysis and other components of non-bovine milk have been reported for therapeutic activities (Kocak *et al.* 2020; Guha *et al.* 2021; Gawai *et al.* 2024) [20, 22, 27]. This study aims to provide a concise overview of the benefits of the main non-bovine milk, highlighting their nutritional characteristics and therapeutic potential.

Table 1. Global annual milk production by origin (2023)

Origin	Milk Production	
	tons	%
Bovine	782,901,752	81.21
Buffalo	150,341,734	15.59
Goat	20,857,811	2.16
Sheep	10,017,335	1.04

Source: FAO (2023) [14].

Materials & Methods

This concise review aims to identify and analyze the nutritional benefits of consuming non-bovine milk, focusing on the nutritional characteristics of buffalo, goat, and sheep milk. The research used databases such as PubMed, Google Scholar, LILACS, SciELO-Br, and institutional sources like IBGE and EMBRAPA. Search terms included "buffalo milk," "goat milk," "sheep milk," "non-bovine milk," and "nutritional characteristics" and their respective translations into English.

Inclusion criteria were established for original articles and reviews published between 2020 and 2025, addressing the nutritional properties and health benefits of buffalo, goat, and sheep milk. Incomplete articles and studies that did not focus directly on non-bovine milk's nutritional or therapeutic characteristics were excluded.

After article selection, data were extracted and organized to present the nutritional and therapeutical properties of buffalo, goat, and sheep milk. Data analysis was qualitative, focusing on each type of milk's health benefits.

Results and Discussion

Non-bovine milk, especially goat, buffalo, and sheep milk, has attracted consumers' attention and, consequently, from food processing industries and researchers due to its health benefits in different areas. Several foods, such as yogurt, butter, ice cream, kefir, and cheese, have been developed and improved from the milk of these non-bovine mammals. Likewise, components of these milks, especially bioactive peptides and fatty acids, also positively affect health and well-being, presenting therapeutic and cosmetic activities. Figure 1 represents the spectrum of benefits from these non-bovine types of milk, as described below.

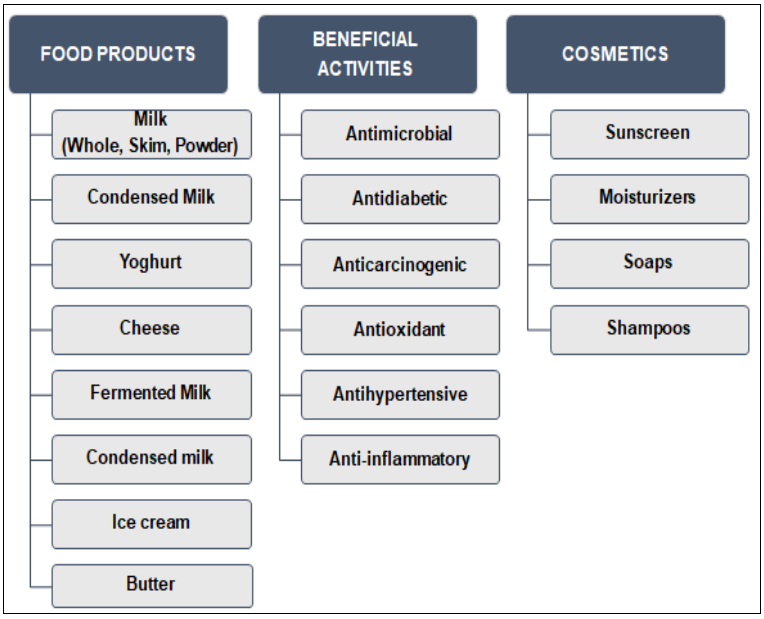

Fig 1: Main food products, cosmetics, and therapeutic effects that can be obtained from goat, sheep, and/or buffalo milk.

Goat Milk

Goat milk is widely recognized for its distinctive nutritional profile, characterized by a composition rich in macro- and micronutrients. One key differentiating factor is its higher content of short- and medium-chain fatty acids, particularly caproic, caprylic, and capric acids. These fatty acids are present in significantly higher concentrations in goat milk than in cow's milk, contributing to the characteristic flavor of goat milk-based products, which is slightly tangy and more pronounced. This fact is especially noticeable in goat cheeses, which contain a higher proportion of these fatty acids than cow or sheep milk cheeses (Flipczak *et al.* 2021; Yu *et al.* 2024) [49].

Nutritionally, goat milk fat is considered more digestible and less allergenic than cow milk fat. This superior digestibility is attributed to the smaller size of fat globules and a higher proportion of low molecular weight fatty acids (Table 2). This structural difference facilitates the action of lipases during digestion, making goat milk an advantageous option for individuals with digestive difficulties. The less allergenicity than cow milk is due to the lower content of β-lactoglobulin and αs1-casein (Kiełczewska *et al.* 2020; Roy *et al.* 2020; Filipczak *et al.* 2021) [15, 25, 41].

In addition to its lipid properties, goat milk contains bioactive peptides derived from milk proteins that offer beneficial biological activities for human health. These peptides show potential for hypertension reduction due to the presence of proline, an amino acid that modulates angiotensin-converting enzyme activity. This inhibitory effect is relevant for blood pressure control and may serve as an adjunct in hypertension treatment (Flis *et al.* 2021; Qiao *et al.* 2022) [16, 38]. Moreover, proline is vital in collagen synthesis, promoting tissue regeneration and accelerating wound healing (Flis *et al.* 2021) [16].

Table 2: Nutritional composition of cow, goat, sheep, and buffalo milk

	Origin			
Components	**Cow**	**Sheep**	**Goat**	**Buffalo**
Total Fat (%)	3.3	7.4	5.9	3.8
Saturated Fat (% of total fat)	55.7-72.8	57.5-74.6	59.9-73.7	62.1-74
Monounsaturated Fat (% of total fat)	22.7-30.3	23.0-39.1	21.8-35.9	24.0-29.4
Polyunsaturated Fat (% of total fat)	2.4-6.3	2.5-7.3	2.6-5.6	2.3-3.9
Conjugated Linoleic Acid (% of total fat)	0.7	0.5	1.2	0.6
Cholesterol (mg/100g fat)	-	246.0-330.8	326.2-357.4	-
Fat Globule Diameter (μm)	2.8-4.6	3.0-4.6	2.6-3.7	4.1-8.7
Total Protein (%)	3.4	4.4	5.5	3.7
Casein (g/L)	24.6-28	41.8-52.6	23.3-46.3	32-40
α_{s1}-casein (g/L)	8.0-10.7	2.4-22.1	0.0-13.0	8.9
α_{s2}-casein (g/L)	2.8-3.4	6.0	2.3-11.6	5.1
β-casein (g/L)	8.6-9.3	15.6-39.6	0.0-29.6	12.6-20.9
κ- casein (g/L)	2.3-3.3	3.2-12.23	2.8-13.4	4.1-5.4
β-lactoglobulin (g/L)	3.2-3.3	6.5-13.5	1.5-5.0	3.9
α-lactalbumin (g/L)	1.2-1.3	1.0-1.9	0.7-2.3	1.4
Diameter of casein micelles (nm)	150-182	180-210	180-301	176-180
Lactose (%)	4.8	4.8	4.8	4.5
Galactose (%)	4.0	3.3	0.3	0.6
Energy (kJ/100 ml)	316.9-373.0	345	593.2	301.8
Calcium (mg/100 ml)	119.8	183.9	181.7	130.4
Potassium (mg/100 ml)	145	101.6	120	181

Adapted from Roy *et al.* 2020; Penhaligan *et al.* 2022 and Pérez-Núñez *et al.* 2024 [33, 35, 41].

Goat milk is also rich in minerals, particularly calcium, magnesium, and phosphorus, essential for bone and dental health and metabolic and physiological processes (Siddiqui *et al.* 2024) [44]. Studies have also highlighted beneficial effects on cardiovascular health and weight management due to the rapid metabolism of medium-chain fatty acids (Kao *et al.* 2020) [26]. Goat milk has also been shown to improve insulin sensitivity, offering potential benefits for individuals with diabetes (Gong *et al.* 2020; Pertiwi & Fatchiyah, 2020) [21].

Furthermore, goat milk has antioxidant and anti-inflammatory properties, modulating the immune system and potentially benefiting individuals with chronic inflammatory conditions (Kao *et al.* 2020; Panchal *et al.* 2020; Voronina *et al.* 2023; Alkaisy *et al.* 2023) [1, 26, 31, 48]. Antimicrobial and carcinogenic effects associated with CLA were also been described (Cakir & Tunali-Akbay *et al.* 2021; Rubin *et al.* 2021; Sansi *et al.* 2022) [6, 40, 42]. However, it is essential to note that goat milk may not be a completely safe alternative for individuals allergic to cow's milk due to possible cross-reactivity between the two (Roy *et al.* 2020) [41].

Even the cosmetics industry has recently incorporated goat milk in shampoos, soaps, and skincare products. Studies have shown that capric and caprylic acids contribute to the formulation of moisturizing creams with sun protection properties (Basudkar *et al.* 2022; Thakur *et al.* 2024) [5, 45].

Buffalo Milk

Buffalo milk is second in the ranking of the volume of milk produced worldwide and is widely recognized for its superior nutritional profile and numerous health benefits. Its composition, rich in proteins, provides all essential amino acids, making it a high-quality protein source that is easy to digest (Lima *et al.* 2020; Vargas-Ramella *et al.* 2021; Pantoja *et al.* 2022; FAO, 2023) [14, 28, 30, 46].

Regarding lipid content, buffalo milk has a significantly higher fat concentration than cow's milk (Table 2), with a higher prevalence of saturated fatty acids. However, it also contains beneficial fatty acids such as conjugated linoleic acid (CLA) (Lima *et al.* 2021) [28]. This makes buffalo milk nutritionally rich, and its high-fat content makes it an excellent raw material for cheese production. Despite having more fat than cow's milk, it has a slightly lower cholesterol content, likely due to differences in fat globule size (Vargas-Ramella *et al.* 2021). It is important to note that the nutritional profile can vary significantly depending on the buffalo's feeding systems and management practices, influenced by factors such as diets and farming conditions (Vargas-Ramella *et al.* 2021) [46].

Buffalo milk is a crucial source of fat-soluble vitamins, including vitamins A, D, E, and B12. In terms of minerals, it stands out for its high calcium, phosphorus, magnesium, and potassium content, which are essential for bone, muscle, and nervous system health (Garau *et al.* 2021; Pacheco *et al.* 2022; Emakpor *et al.* 2024) [11, 19, 29]. Additionally, buffalo milk contains bioactive compounds, such as immunoglobulins and enzymes, with potential immunomodulatory, anti-inflammatory, and antioxidant properties (Amr & Farid, 2024) [2]. Notably, beta-lactoglobulin (b-LG), a protein in buffalo whey, helps reduce blood pressure. This protein is a significant source of bioactive peptides with antihypertensive, antioxidant, and antimicrobial actions. These peptides are inactive in the intact b-LG precursor but can be released through enzymatic proteolysis, either *in vivo* or *in vitro* (Emakpor *et al.* 2024) [11].

Buffalo milk has a significant production worldwide (Table 1). India is one of the largest global producers of buffalo milk, contributing significantly to global milk production (Cavali & Pereira, 2020; Siddiqui *et al.* 2024) [7, 44, 34]. Buffalo milk is also widely accepted in Pakistan, Egypt, and Nepal, where dairy products from buffalo milk, such as dahi, ghee, and yogurt, are consumed. Additionally, buffalo milk has gained popularity in the Mediterranean, particularly for mozzarella cheese production, and is considered a potential substitute for those with cow's milk allergies. Italy, for example, is renowned for its buffalo mozzarella (Baltazar *et al.* 2024; Siddiqui *et al.* 2024) [4, 44]. These observations highlight the disparities in agricultural practices and economic conditions across countries and the cultural role of buffalo milk in different societies.

In Brazil, the buffalo herd is estimated to exceed 1.5 million animals (EMBRAPA, 2021) [13]. However, despite the growing global interest in this product, the country's buffalo milk production does not yet stand out significantly on the global stage. This phenomenon can be attributed to a lack of in-depth knowledge regarding best management practices and the anatomical and physiological peculiarities of buffaloes, which affect both milk production and meat quality, consequently impacting the production of dairy products.

Sheep Milk

Sheep milk is widely recognized for its high nutritional value, constituting an excellent source of proteins, vitamins, minerals, and beneficial lipids for health. Due to its nutritional value and biological activities, the demand for sheep milk for the production of various fermented and non-fermented products, such as cheese, yogurt, sweet milk, and ice cream, is steadily growing (Dalabasmaz *et al.* 2023; Siddiqui *et al.* 2024) [8, 44].

Sheep milk exhibits significant differences in nutritional composition compared to cow's milk (Table 2). This milk is particularly rich in high-quality proteins, which are easily digestible and contain all the essential amino acids needed for proper bodily function. Additionally, sheep milk has a higher viscosity and a lower freezing point than cow's and goat's milk. This higher viscosity can also be attributed to a significant water retention capacity through hydrogen bonds in the milk proteins (Siddiqui *et al.* 2024) [44].

Regarding lipid content, sheep milk is characterized by many healthy fats, including essential fatty acids such as omega-3 and omega-6. These compounds have been widely associated with cardiovascular health, brain function, and immune system modulation. Furthermore, sheep milk is an excellent source of B vitamins, including vitamin B12, riboflavin (vitamin B2), and niacin (vitamin B3), which play key roles in energy metabolism, brain function, and nervous system health (Flis & Molik, 2021) [16].

Flis *et al.* (2023) [18] highlight that sheep milk is particularly rich in polar lipids (PLs), essential for forming and maintaining biological membranes. These lipids are crucial in energy storage, cellular structure, and molecular signaling. Furthermore, PLs found in sheep milk contribute to intercellular cohesion in the skin, promoting protection against harmful substances and assisting in the mechanical properties of the epidermis.

Regarding composition, PLs are primarily located in milk's membrane of fat globules. Research demonstrates that sheep milk is one of the richest sources of phospholipids, which are vital for the integrity of the skin's stratum corneum. Additionally, sphingolipids in sheep milk exhibit bacteriostatic properties and can modulate inflammatory responses (Flis et al, 2021) [16].

Due to bioactive PLs, sheep milk has gained relevance in the nutraceutical and pharmaceutical industries. It has potential applications in wound healing treatments, particularly for patients with diabetic foot ulcers (Flis *et al.* 2023) [18]. Sheep milk and its products also present antibacterial and anti-inflammatory effects and can be a source of peptides with antihypertensive and antidiabetic activities (El-Bayoumi, 2021; Pipaliya *et al.* 2024) [12, 36].

In terms of global production, Greece, Turkey, and Spain are notable producers of sheep milk, primarily used in the production of traditional cheeses like feta, which may be made from a blend of sheep's and goat's milk (Popescu *et al.* 2022; Kaczyński *et al.* 2023) [24, 37].

Adulteration as a risk behind the benefits

In many countries, the price of buffalo, goat, and sheep milk and its derivatives is higher than that of cow milk. These factors and the seasonality of production can lead to an increase in fraud involving the adulteration of these products. Adulteration is an illegal practice related to the addition of components with lower commercial value or lower quality to products with higher quality to increase their quantity or extend their useful life and, with this, generate illicit financial gain for the trader (Shalileh *et al.* 2023; Patil *et al.* 2024) [32, 43].

The most common alterations in milk and derivatives from goat, buffalo, and sheep are the addition of water or cow's milk, as the latter is easy to obtain and has lower added value than milk from other ruminants. However, there is a high risk for the most sensitive consumer, given cow's milk's high allergenicity compared to other kinds of milk (Viana *et al.* 2020; Pereira *et al.* 2021) [34, 47]. It has also been reported that other substances, many of them harmful to health, can be added to milk to extend shelf life or increase fat or protein content, such as melamine, sodium hypochlorite, hydrogen peroxide, and formaldehyde, among others (Patil *et al.* 2024) [32].

Therefore, the analysis of adulteration of non-bovine milk becomes essential to avoid health problems for the consumer and to ensure the quality and authenticity of the intrinsic value of the products. Currently, both traditional and more modern methods, such as polymerase chain reaction, immunoassays, optical biosensors, and different spectroscopy techniques (Pereira *et al.* 2021; Patil *et al.* 2024; Du *et al.* 2025) [10, 32, 34] are able to detect these possible adulterations in the milk of non-bovine origin.

Conclusions

Although the world's contribution to the global production of goat, sheep, and buffalo milk is relatively modest compared to bovine milk, these products play a significant role in various regions, particularly economically disadvantaged areas. Besides their distinct characteristics and flavors, which cater to consumers from different socioeconomic backgrounds, non-bovine milk is receiving increasing global attention due to its potential nutritional and therapeutic benefits. The demand for alternative food sources, richer in essential nutrients, has driven the production and consumption of these milks, particularly in the context of growing awareness about health issues such as food intolerances and allergies. However, different components in non-bovine milk from goats, sheep, and buffalo have also attracted attention in the therapeutic fields. New bioactive peptides, for example, obtained from these milks can be used as ingredients of functional and nutraceutical foods with specific therapeutic properties, such as antimicrobial, antioxidant, antihypertensive, and immunomodulatory.

Beyond the nutritional and therapeutical benefits, diversifying milk sources offers important market opportunities, mainly when diets based solely on bovine products may not be viable or desirable. The increase in production and consumption of these alternative milk can contribute to the development of new dairy products adapted to the needs of specific audiences, such as those with health conditions requiring restrictive diets.Continued improvement in understanding the nutritional properties of these types of milk and their effects on human health opens up new possibilities for research, making it a promising area for developing healthier and more accessible dairy products.

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Conflicts of interest
The authors declare no competing interests.

Authors' contributions
All author contributed equally to design and conduct the work. All authors read and approved the final manuscript.

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