

Comparative Insights into Bovine and Non-Bovine Milk: Composition, Technology, and Nutritional Perspectives

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Abstract

Milk has long been regarded as a universal food, providing essential nutrients to humans across cultures and generations. While bovine milk, particularly from cows and buffaloes, dominates global dairy production and consumption, non-bovine milks, such as those from goats, sheep, camels, donkeys, and yaks, also play a significant role in human nutrition, especially in regions where they are traditionally consumed. The comparative study of bovine and non-bovine milk is increasingly important considering rising consumer demand for alternatives that address lactose intolerance, protein allergies, and health-conscious dietary choices. The composition of milk varies considerably across species, with differences in macronutrients, protein polymorphisms, lipid profiles, and bioactive compounds. Bovine milk is widely valued for its high yield and suitability for large-scale processing, whereas non-bovine milk often contains higher proportions of short- and medium-chain fatty acids, unique protein structures, and beneficial micronutrients that contribute to better digestibility and enhanced functional properties. Such differences influence not only nutritional outcomes but also technological applications, including cheesemaking aptitude, fermentation potential, and product stability. Beyond composition, factors, such as species, breed, stage of lactation, diet, and environmental conditions, further impact milk quality and processing characteristics. Advances in preservation, packaging, and storage technologies have enabled the utilization of both bovine and non-bovine milk in diverse products, ranging from traditional cheese, butter, and yogurt to modern protein powders, infant formulas, and functional foods. This review synthesizes current knowledge on the comparative insights into bovine and non-bovine milk, focusing on composition, technological properties, and nutritional perspectives. Highlighting their unique attributes and applications, it underscores the growing relevance of non-bovine milk in meeting consumer preferences, supporting sustainable dairy practices, and contributing to human health.

Keywords: Bovine milk, non-bovine milk, milk composition, milk proteins, dairy technology, nutritional perspectives, cheesemaking, functional foods

INTRODUCTION

Milk has been recognized for centuries as one of the most complete natural foods, providing essential nutrients required for growth, development, and overall health. Rich in proteins, fats, carbohydrates, vitamins, and minerals, it plays a pivotal role in the human diet, especially during infancy and early childhood. In addition to its nutritional value, milk also holds cultural, social, and economic significance, being a vital component of food systems worldwide. Globally, bovine milk, primarily from cows and buffaloes, is the dominant source of dairy, contributing most of the milk consumed and processed into a wide variety of products such as cheese, butter, yogurt, and milk powders. However, non-bovine milks, including those from goats, sheep, camels, donkeys, and yaks,

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also contribute significantly, especially in regions where bovine milk is less prevalent or unsuitable due to climatic, cultural, or dietary reasons [1, 2].

In recent years, the demand for non-bovine milk has been increasing due to their unique compositional characteristics and potential health benefits. Many consumers are seeking alternatives to cow's milk because of lactose intolerance, cow's milk protein allergy, or a preference for products with improved digestibility and functional properties. Non-bovine milk often differs in protein composition, fatty acid profile, and micronutrient content, which can influence their digestibility, allergenicity, and suitability for specific dietary needs. For example, goat and camel milk are often reported to be easier to digest, while sheep milk is valued for its high protein and fat content, making it ideal for cheesemaking.

The composition of milk is not uniform but varies widely across species, breeds, and even within individuals, depending on factors, such as stage of lactation, feeding regime, health, and environmental conditions. These variations have important implications not only for nutrition but also for the technological properties of milk. Coagulation ability, heat stability, and microbial activity influence how milk can be processed into different products, from traditional cheeses to modern functional foods. In this context, the comparative analysis of bovine and non-bovine milks provides valuable insights for dairy science and industry.

Beyond composition and technology, milk also has a strong connection to human health. Bioactive peptides, fatty acids, and probiotic cultures derived from milk-based products are increasingly recognized for their roles in supporting digestion, enhancing immunity, and contributing to the prevention of chronic diseases. With growing consumer interest in functional foods and natural health-promoting ingredients, both bovine and non-bovine milks are being re-examined for their potential contributions [3].

At the same time, the dairy sector is facing challenges related to sustainability, climate change, and animal welfare. Non-bovine milks, often sourced from species adapted to arid or high-altitude environments, such as camels and yaks, may offer sustainable alternatives in specific ecological contexts. Their utilization can support local economies and preserve traditional knowledge while meeting modern nutritional and health needs.

This review article aims to provide comparative insights into bovine and non-bovine milk, focusing on three main aspects: (i) composition, including macro- and micro-nutrients, protein polymorphisms, and lipid profiles; (ii) technological properties and processing potential, such as cheesemaking aptitude and preservation methods; and (iii) nutritional perspectives, emphasizing health benefits, digestibility, and functional properties. By synthesizing current knowledge, the review highlights the distinct attributes of milk from different species and their relevance for dairy science, industry, and public health.

MILK COMPOSITION: BOVINE VS. NON-BOVINE

Milk composition is highly variable among species and even within individual animals, influenced by genetic, physiological, and environmental factors. While bovine milk, particularly from cows and buffaloes, remains the global standard for dairy products, non-bovine milks, such as those from goats, sheep, camels, donkeys, and yaks, are nutritionally and technologically important in many regions. Understanding compositional differences is essential for optimizing processing, improving digestibility, and tailoring dairy products for specific consumer needs.

Macro-Composition

The basic components of milk include water, fat, protein, lactose, and minerals. In cow's milk, water typically makes up about 87%, while buffalo milk contains less water and higher levels of fat and

protein, giving it richer sensory qualities and higher product yield. Sheep milk has the highest concentrations of fat and protein among domestic species, making it ideal for cheesemaking. Goat milk generally contains smaller fat globules, contributing to its characteristic digestibility. Camel milk, while lower in fat and protein than buffalo or sheep milk, has a unique balance of micronutrients and bioactive components. Donkey milk, with its low protein and fat content, resembles human milk more closely, making it a potential substitute for infants with cow's milk protein allergy [4, 5].

Protein Composition and Genetic Polymorphism

Milk proteins are broadly categorized into caseins (about 80%) and whey proteins (about 20%). Caseins play a central role in cheesemaking due to their coagulation properties, while whey proteins are associated with bioactivity and health benefits.

Species differences are evident in both the quantity and type of proteins. Sheep and buffalo milks are protein-rich, whereas camel and donkey milks contain relatively less protein but with higher biological value. Goat milk proteins are structurally distinct and often associated with reduced allergenicity compared to cow's milk.

Genetic polymorphisms in milk proteins, particularly in β -casein, κ -casein, and β -lactoglobulin, significantly influence milk digestibility, allergenicity, and technological properties. For instance, β -casein occurs in multiple variants (A1 and A2), with A2 milk increasingly marketed for its improved digestibility and reduced risk of gastrointestinal discomfort. Non-bovine species predominantly produce A2-type β -casein, which partly explains their better tolerance among sensitive individuals [5].

Lipid Composition

Milk lipids not only contribute to energy supply but also affect flavor, texture, and nutritional value. The fatty acid profile varies widely among species.

Cow's milk fat typically contains higher levels of saturated fatty acids, while goat and sheep milks are richer in medium-chain triglycerides (MCTs), which are more rapidly digested and metabolized. Camel milk contains long-chain unsaturated fatty acids and conjugated linoleic acid (CLA), compounds associated with cardiovascular and metabolic health. Buffalo milk, being richer in total fat, yields a creamy texture highly valued in butter and traditional dairy products.

The size and distribution of fat globules also differ across species, with goat milk having smaller globules that enhance digestibility and limit cream separation. These variations make certain non-bovine milks more suitable for infant nutrition or therapeutic applications [5–7].

Micronutrients and Bioactive Compounds

In addition to macronutrients, milk is a rich source of vitamins (A, D, E, K, and B-complex) and minerals (calcium, phosphorus, magnesium, zinc). Sheep and goat milk generally contain higher levels of calcium and phosphorus than cow's milk, enhancing their nutritional value for bone health. Camel milk is notable for its high vitamin C and iron content, making it an important dietary component in arid regions where fruits and vegetables may be scarce.

Bioactive compounds, including antimicrobial proteins (lactoferrin, lysozyme, lactoperoxidase) and immunoglobulins, are present at varying concentrations. Donkey and camel milks are particularly rich in lysozyme, contributing to their natural antimicrobial activity and longer shelf-life under certain conditions. These bioactive molecules are increasingly being explored for their therapeutic potential, including roles in immune modulation and gut health.

Factors Affecting Milk Composition

Milk composition is not solely determined by species; it is also influenced by several intrinsic and extrinsic factors.

- *Species and Breed*: Different breeds within the same species show variation in fat and protein levels.
- *Stage of Lactation*: Colostrum is richer in proteins and immunoglobulins, while mature milk stabilizes in composition.
- *Animals' Age and Health*: Older animals and diseased conditions alter nutrient balance.
- *Feeding Regime and Season*: Pasture-based diets enhance levels of omega-3 fatty acids and fat-soluble vitamins. Seasonal changes affect both yield and nutrient profile.

Table 1 shows clear differences between bovine and non-bovine milks. Buffalo and sheep milk are richer in fat and protein, making them ideal for cheesemaking. Goat milk, with smaller fat globules and distinct proteins, is easier to digest and less allergenic. Camel milk provides unique nutrients suited to arid regions, while donkey milk, low in fat and protein but high in lactose, closely resembles human milk and benefits infants with cow's milk protein allergy. Yak milk, high in fat and protein, supports nutrition in high-altitude environments. These variations highlight the nutritional diversity and technological potential of non-bovine milks.

Table 1. Comparative composition of bovine and non-bovine milks (average values per 100 g).

Species	Water (%)	Fat (%)	Protein (%)	Lactose (%)	Ash (%)
Cow	87.0	3.5	3.2	4.8	0.7
Buffalo	82.0	7.0	4.2	4.9	0.8
Goat	86.5	4.1	3.5	4.5	0.8
Sheep	81.0	7.0	5.6	4.8	0.9
Camel	86.0	3.5	3.5	4.8	0.8
Donkey	90.0	1.5	1.8	6.2	0.5
Yak	82.5	6.0	4.9	4.7	0.8

FACTORS INFLUENCING MILK QUALITY

Milk quality is not a fixed trait but the outcome of complex interactions among genetic, physiological, environmental, and management factors. These determinants affect both bovine and non-bovine species, influencing not only yield but also composition, processing potential, and nutritional properties. Understanding these factors is essential for optimizing milk utilization across species [4, 5, 7].

Species and Breed Differences

Species are the most important determinant of milk composition. Cow and buffalo milks differ significantly, with buffalo milk containing more fat and protein, while goat and sheep milks provide higher levels of medium-chain fatty acids and minerals. Camel and donkey milks are closer in composition to human milk, supporting their use in specialized diets. Within species, breeds also influence milk characteristics; for example, Jersey cows produce milk with higher fat and protein content than Holstein cows, and local goat breeds often yield milk with distinct fatty acid profiles adapted to regional environments.

Stage of Lactation

Milk composition changes throughout lactation. Colostrum, secreted in the first days after parturition, is rich in proteins, especially immunoglobulins, and bioactive compounds that enhance immunity. As lactation progresses, protein and fat concentrations gradually decrease while lactose levels stabilize. Late lactation milk tends to have higher fat but lower yield. These shifts are consistent across both bovine and non-bovine species, although the degree of change varies, influencing processing qualities such as coagulation and cheesemaking potential.

Age and Health of the Animal

The age of the animal can affect milk yield and nutrient profile. Younger animals typically produce milk with slightly higher protein and fat, while older animals may display reduced nutritional quality

due to declining physiological efficiency. Health is another critical factor. Mastitis, a common udder infection, alters milk composition by reducing lactose and increasing somatic cell counts, enzymes, and salts, which negatively affect processing and sensory properties. Non-bovine species are also prone to such health-related changes, although severity depends on management practices.

Feeding Regime and Nutrition

Diet plays a central role in determining milk quality. Pasture-based diets generally increase the proportion of unsaturated fatty acids and bioactive compounds such as conjugated linoleic acid (CLA) and omega-3 fatty acids. Concentrate-based diets may increase milk yield but often dilute beneficial fatty acids. Supplementation with minerals and vitamins directly influences milk micronutrient content, such as selenium-enriched feed, to enhance antioxidant properties of milk. In arid zones, camels adapt to sparse vegetation but still produce milk with valuable nutrients, demonstrating the resilience of non-bovine species to feeding constraints [8].

Seasonal and Environmental Influences

Milk composition is sensitive to seasonal changes. Summer often results in lower fat and protein due to heat stress, while winter and spring milks are typically richer in solids. Seasonal variation in pasture quality also affects fatty acid composition and vitamin content. Environmental factors, such as altitude, temperature, and humidity, have significant effects; for instance, yak milk produced in high-altitude regions contains higher fat and protein to meet energy demands in extreme climates. Similarly, camel milk composition reflects adaptation to desert environments, with higher levels of water and vitamin C.

Management and Housing Systems

Hygiene, milking practices, and housing conditions directly impact microbial quality and shelf life of milk. Proper housing reduces disease risk and stress, leading to higher yield and improved composition. Hand-milking versus machine-milking methods may also influence microbial load. In developing regions, non-bovine milk is often collected under traditional systems, which can increase microbial contamination, while modern practices ensure safer and more consistent quality.

TECHNOLOGICAL PROPERTIES AND DAIRY APPLICATIONS

Milk's versatility as a raw material lies in its unique biochemical and physical characteristics. Its proteins, fats, sugars, and minerals interact during processing, enabling the production of a wide range of dairy products. However, the technological properties of milk vary considerably between bovine and non-bovine species, influencing its suitability for cheesemaking, fermentation, and other applications. Understanding these differences is essential for optimizing product development and ensuring quality [9].

Processing Characteristics

The processing behavior of milk depends on key factors such as heat stability, foaming ability, and coagulation properties.

- *Heat Stability:* Cow and buffalo milk generally tolerate pasteurization and UHT processing well. Camel milk, however, has lower heat stability, making it more challenging to process at high temperatures.
- *Foaming Ability:* Goat and donkey milks have superior foaming properties, which are advantageous in specialty dairy beverages.
- *Coagulation:* Bovine milk coagulates efficiently with rennet, forming firm curds suitable for cheesemaking. In contrast, camel milk exhibits weak rennet coagulation, requiring specialized techniques or coagulants for cheese production.

These processing differences determine which products are best suited to each type of milk.

Cheesemaking Aptitude

Cheese is one of the most significant value-added dairy products, and its yield and quality depend heavily on milk composition.

- *Cow Milk*: It produces a wide variety of cheeses, from soft to hard types, due to its balanced protein and fat content.
- *Buffalo Milk*: with higher fat and protein, yields richer and creamier cheeses, such as mozzarella, with higher productivity.
- *Goat Milk*: imparts a distinctive flavor to cheeses, and its smaller fat globules improve texture and digestibility.
- *Sheep Milk*: is highly prized for artisanal cheeses, like Roquefort, Manchego, and Pecorino, thanks to its high protein and fat content.
- *Camel Milk*: This presents challenges for cheesemaking due to weak coagulation and lower casein content; nonetheless, innovations in enzyme use and starter cultures are enabling camel milk cheese production.
- *Donkey Milk*: Due to its very low protein and fat content, it is unsuitable for cheese but finds use in cosmetic and functional food formulations.
- *Yak Milk*: produces high-fat, dense cheeses, such as “chhurpi,” valued in Himalayan regions for their shelf stability.

Fermented Dairy Products

Fermentation enhances the nutritional, sensory, and functional qualities of milk. Species differences significantly affect fermentation outcomes.

- *Yogurt and Kefir*: Cow and buffalo milk are commonly used, but goat and sheep milk yield thicker, creamier products with higher probiotic viability.
- *Traditional Products*: Fermented camel milk beverages (e.g., “shubat”) are consumed in Central Asia, while yak milk produces butter tea and fermented drinks unique to Himalayan cultures.
- *Microbiological Diversity*: Non-bovine milk often harbor diverse lactic acid bacteria, contributing to unique flavors and potential probiotic effects.

Fermentation also improves digestibility and reduces lactose content, expanding dairy’s reach to lactose-intolerant populations [10, 11].

Other Dairy Products

Besides cheese and fermented products, milk is processed into butter, ghee, milk powders, infant formulas, and protein products.

- *Butter and Ghee*: Buffalo and yak milk, with their high fat content, are especially suitable for butter and ghee production.
- *Milk Powders*: Cow milk dominates global milk powder production due to scalability, but camel and goat milk powders are gaining market interest for specialty nutrition.
- *Protein Products*: Whey proteins from cow and goat milk are widely used in sports nutrition and functional foods. Sheep and camel milk emerge as alternative sources of bioactive peptides.
- *Infant Formulas*: Donkey and goat milk are being explored for infant formulas due to their similarity to human milk in protein and fat structure.

Implications for Industry

The technological differences between bovine and non-bovine milk have both challenges and opportunities for the dairy sector. While bovine milk remains the backbone of industrial dairy production, non-bovine milk offers niche markets with unique nutritional and sensory advantages. Innovations in processing technologies, including enzyme modification, starter culture development, and advanced preservation methods, are helping to overcome limitations in non-bovine milk processing and expanding their commercial potential.

PRESERVATION, PACKAGING, AND STORAGE

Milk is highly perishable, and its preservation is essential to maintain safety, nutrition, and quality. While bovine milk preservation methods are well standardized, non-bovine milk present unique challenges due to compositional and regional differences.

Microbial Quality

All fresh milk is susceptible to microbial contamination. Bovine milk, often produced under hygienic systems, shows better microbial consistency, while goat, sheep, camel, and yak milk – commonly collected in traditional settings – tend to have higher variability. Species, such as camel and donkey, naturally contain antimicrobial proteins, like lysozyme, which delay spoilage [12, 13].

Preservation Methods

- *Thermal Treatments:* Pasteurization and UHT are effective for most milk, though camel milk has poor heat stability.
- *Nonthermal Methods:* Techniques, like microfiltration, high-pressure processing, and UV treatment help preserve heat-sensitive non-bovine milk.
- *Traditional Methods:* Boiling and spontaneous fermentation remain common in rural regions.

Packaging

Conventional packaging includes pouches, bottles, and cartons. Aseptic cartons extend shelf life for UHT products, while innovations, such as antimicrobial and eco-friendly packaging, are emerging for goat and camel milk markets.

Storage

Refrigeration (4–6°C) keeps milk safe for up to a week, while freezing or drying significantly extends storage. Sheep and yak milk are traditionally preserved as dried cheeses, while goat and camel milk powders are increasingly used in nutrition markets.

Challenges and Opportunities

Non-bovine milk require tailored approaches: camel milk destabilizes under heat, donkey milk spoils quickly despite antimicrobials, and buffalo/sheep milk risk fat oxidation. Advances in nonthermal preservation and smart packaging provide new opportunities to improve shelf life and expand marketability [14, 15].

NUTRITIONAL AND HEALTH PERSPECTIVES

Milk is widely regarded as a complete food, providing energy, macronutrients, and essential micronutrients. However, the nutritional and health impacts differ considerably between bovine and non-bovine milks due to variations in protein structure, fat profile, and bioactive compounds.

Digestibility and Allergenicity

Cow's milk proteins, particularly casein and β -lactoglobulin, are common allergens. Goat and donkey milk, with lower levels of these proteins and smaller fat globules, are more digestible and often better tolerated by individuals with cow's milk protein sensitivity. Donkey milk, in particular, closely resembles human milk, making it suitable for infants with allergies.

Lipid Composition and Fatty Acids

Fat profiles differ among species, influencing both nutrition and health benefits:

- *Sheep and Buffalo Milk:* are rich in short- and medium-chain fatty acids, beneficial for quick energy release.
- *Goat Milk:* contains more medium-chain triglycerides (MCTs), which enhance digestibility and metabolic efficiency.
- *Camel Milk:* is lower in cholesterol and has higher unsaturated fatty acids, contributing to cardiovascular health.

Lactose Content and Intolerance

Lactose intolerance affects a large portion of the global population.

- *Cow and Buffalo Milk:* contain 4.5–5% lactose, which can cause discomfort in intolerant individuals.

- *Camel and Goat Milk*: are easier to digest due to slower gastric emptying and bioactive compounds that may aid lactose metabolism.
- *Donkey Milk*: This is higher in lactose, which supports probiotic growth but limits consumption by lactose-intolerant adults.

Bioactive and Functional Properties

Non-bovine milk is increasingly valued for their functional components:

- *Camel Milk*: This shows antidiabetic, antimicrobial, and antioxidant properties linked to insulin-like proteins and immunoglobulins.
- *Sheep and Goat Milk*: These are rich in bioactive peptides with potential antihypertensive and anti-inflammatory effects.
- *Donkey Milk*: This contains high levels of lysozyme, supporting gut health and immune defense.
- *Yak Milk*: provides dense nutrition adapted to high-altitude environments, with strong antioxidant potential [16, 17].

PROCESSING, DISTRIBUTION, AND MARKET POTENTIAL

Milk's transformation into a variety of products and its distribution across markets are central to the dairy industry. While cow's milk dominates global processing and trade, non-bovine milk are increasingly gaining traction, driven by nutritional, cultural, and economic factors.

Processing Trends

Bovine milk processing is well established, producing a wide range of products such as cheese, butter, yogurt, milk powders, and infant formulas. Non-bovine milk, although traditionally consumed in local regions, is gradually being incorporated into modern processing lines.

- *Buffalo Milk*: This is widely processed into high-fat dairy products such as mozzarella, paneer, and ghee.
- *Goat and Sheep Milk*: These are mainly used for artisanal cheeses, yogurt, and specialty powders.
- *Camel milk*: This is processed into pasteurized milk, powders, and increasingly, functional beverages and cosmetics.
- *Donkey Milk*: This is less suitable for large-scale processing but finds niche applications in infant nutrition and skincare.
- *Yak Milk*: This remains tied to traditional high-altitude products such as butter tea, cheese, and dried curds.

Distribution Systems

Distribution depends on infrastructure, preservation methods, and consumer demand:

- *Bovine milk* benefits from advanced cold chains and global trade networks.
- *Non-bovine milk* often face challenges due to limited production scale, shorter shelf life, and lack of species-specific preservation technologies.
- Growing investments in UHT, drying, and powdered milk production are enabling wider distribution of goat, camel, and sheep milk in international markets.
- Online platforms and specialty stores are becoming important channels for premium non-bovine dairy products [18].

Market Potential

Global demand for alternative dairy is increasing due to health awareness, lactose intolerance, and consumer interest in functional and artisanal foods (Table 2).

- *Goat and sheep cheeses*: These have strong markets in Europe, North America, and the Middle East.
- *Camel milk*: has growing recognition as a functional food, particularly in the Middle East, Africa, and Asia.

- *Donkey milk*: This remains a luxury product, marketed mainly for cosmetics and hypoallergenic formulations.
- *Yak milk products*: hold regional economic importance and niche export potential [4].

Table 2. Demand for alternative dairy.

Milk Type	Processing Applications	Distribution Strength	Market Potential
Cow	Wide range: cheese, butter, yogurt, powders, infant formula	Strong global cold chain, advanced logistics	Dominant global dairy market
Buffalo	High-fat products (mozzarella, paneer, ghee)	Strong in South Asia, Italy, Middle East	Regional staple with growing export demand
Goat	Cheese, yogurts, specialty powders	Limited but improving via specialty stores and exports	Rising demand for hypoallergenic and artisanal products
Sheep	Premium cheeses (Roquefort, Manchego, Pecorino)	Niche exports, strong local markets in Europe	High-value artisanal and gourmet markets
Camel	Pasteurized milk, powders, functional drinks, cosmetics	Expanding in Middle East, Africa, Asia	Functional food niche, growing international interest
Donkey	Infant nutrition, cosmetics, luxury soaps	Very limited, mostly local artisanal	Luxury niche with high-value cosmetic applications
Yak	Butter, cheese, dried curds, butter tea	Mostly local due to remote production areas	Regional importance, small export potential

CONCLUSIONS

Milk remains one of the most essential and versatile foods worldwide, providing not only nutrition but also cultural and economic value. While bovine milk dominates global production and trade, non-bovine milk – such as those from buffalo, goat, sheep, camel, donkey, and yak – offer unique opportunities to diversify dairy systems. Each species contributes distinct compositional, technological, and nutritional traits that shape their roles in human diets and dairy applications. Comparative analysis show that buffalo and sheep milk, rich in fat and protein, excel in cheesemaking and high-energy products. Goat milk stands out for its digestibility and reduced allergenicity, while camel milk is increasingly valued for its functional properties and adaptation to arid environments. Donkey milk, due to its similarity to human milk, holds promise for infant nutrition and specialty products, whereas yak milk sustains communities in high-altitude regions with nutrient-dense traditional foods. Despite these advantages, challenges remain in preservation, processing, and large-scale commercialization of non-bovine milk. Heat instability (camel), low protein content (donkey), and fat oxidation (sheep, buffalo) limit industrial use. However, advances in nonthermal preservation, innovative packaging, and tailored processing technologies are opening new possibilities. Looking ahead, consumer interest in functional foods, sustainable diets, and artisanal products will continue to drive demand for non-bovine milk. Integrating scientific research with market innovation can help unlock their full potential, offering healthier choices and supporting diverse farming systems worldwide. In conclusion, both bovine and non-bovine milk are essential pillars of dairy science. Their complementary strengths highlight the importance of preserving traditional knowledge while embracing modern innovations to build a more resilient, sustainable, and health-oriented dairy future.

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