Exploring the Potential of Yak Milk: Composition, Nutrition Properties, and Applications

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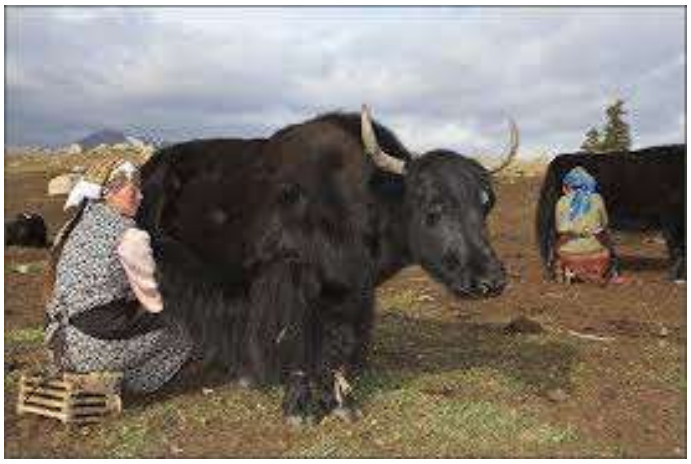
Yaks, large, long-haired mammals native to high-altitude regions of Central Asia, are vital for their livelihoods and cultural heritage (Wiener et al., 2003). Yak milk, a valuable resource, is essential for the diets and economies of yak-rearing communities. Traditionally, yak milk is recognized as a highly nutritious and therapeutic food, providing essential sustenance for human and animal consumption. Studies have explored its macro- and micronutrient profiles, highlighting its rich content of proteins, fats, vitamins, and minerals. Yak milk's unique characteristics, including high-fat content and rich flavour, make it suitable for the production of dairy products, such as butter, cheese, and yoghurt (Guo et al., 2014).

Traditional methods of yak milk processing, such as fermentation and churned-butter production, have been practised for centuries. The economic significance of yak milk extends to the production of products like butter, cheese, and yoghurt, providing opportunities for income generation and local economic development (Dong et al., 2003). However, challenges persist in genetic improvement, optimal feeding and management practices, and product diversification opportunities. Addressing these challenges and exploring the untapped potential of yak milk will contribute to scientific knowledge, sustainable agriculture, and economic growth in yak-rearing regions.

Yak Milk Composition

Yak milk, a unique and valuable dairy product, possesses a distinct composition that sets it



apart from other types of milk. It is known for its rich content of essential macronutrients and micronutrients. The composition of yak milk is influenced by factors such as breed, diet, and environmental conditions. The unique environment in which yaks graze, characterized by high altitudes and harsh climates, contributes to the distinct composition of their milk (Li, 2011). The comparative milk composition of yak milk and other species of milk is depicted in Table 1.

Yak milk typically contains a higher proportion of fat compared to cow's milk, making it creamier and imparting a distinctive flavour. The fat content in yak milk can range from 6% to 7.5%, contributing to its creamy texture and mouthfeel. It contains lactose about 4.0–5.9%. While, it contains a higher amount of protein than cow's milk, with an average protein content of 4.5% to 5.5%. These proteins are composed of various essential amino acids necessary for human nutrition. The amino acid profile of yak milk is characterized by a balanced ratio of essential and non-essential amino acids,

making it a valuable source of high-quality protein (Ma et al., 2013).

Table 1 Average comparative composition per 100 g of milk of yak, camel, cow and human milk (modified from Kalwar et al., 2023)

Component (gm/100 gm of milk)	Yak	Camel	Cow	Human
Fat	6.5	4.5	4.0	4.0
Protein	5.1	3.5	3.4	1.9
Lactose	4.4	4.4	4.8	6.5
Minerals	0.8	0.7	0.7	0.2
Solid-Not-Fat	10.4	8.6	9.0	7.3
Total solids	16.9	12.8	13.3	12.1

Yak milk is also a good source of vitamins and minerals. It contains higher levels of certain vitamins such as vitamin A, vitamin E and vitamin B_6 compared to cow's milk (Singh et al., 2023). Yak milk has 32.8 mg/L of vitamin C, and this quantity rises with altitude (Cui et al., 2014). The vitamin D content is also high in yak milk compared to cow milk. this can be due to longer UV exposure as yaks live in high-altitude areas. These vitamins play crucial roles in maintaining overall health and supporting various physiological functions. Yak milk's mineral content is influenced by environmental factors, with higher altitudes resulting in higher Mn and Fe content, which is beneficial for infants. It also contains more calcium and phosphorus than human milk, and has the highest zinc content, making it suitable for infant diets. (Ma et al., 2017). It provides essential amino acids necessary for growth, repair, and maintenance of body tissues, while the higher fat content in yak milk serves as an energy source and contributes to fat-soluble vitamin absorption (Kalwar et al., 2023).

Yak milk contains sphingolipids, phospholipids, and oligosaccharides, which benefit yak calves and humans. It also contains beneficial probiotics like *Lactobacillus rhamnosus, Lactobacillus plantarum* strain As21*, and Kluyveromyces marxianus* PCH397, with significant potential for human health (Wang et al., 2023).

Yak Milk Products in Traditional and Modern Era

Yak milk serves as a versatile raw material for the production of various dairy products, both traditional and modern, offering a range of culinary delights and economic opportunities. In traditional contexts, yak milk has been used to produce revered products such as yak butter and churpi. Yak butter, made through churning yak milk, holds cultural significance and is widely used in cooking, tea preparation, and religious rituals (Ma et al., 2013, Silk et al., 2014). Churpi, a fermented cheese-like product, is another traditional delight derived from yak milk. Churpi is known for its long shelf life, and nutritional richness, and is consumed as a snack, grated over dishes, or incorporated into soups and stews (Wiener et al., 2003).

In modern times, yak milk has expanded its applications to include a broader range of dairy products. Yak milk powder, obtained through the spray-drying of fresh yak milk, provides a convenient and shelf-stable form of yak milk, preserving its nutritional properties and enabling easy storage and transport (Silk et al., 2014). Yak cheese, with its unique flavour profile and nutritional attributes, has gained popularity among consumers. Yak cheese production involves curdling and ageing yak milk to achieve a firm and savory cheese, which can be enjoyed on its own, grated over dishes, or used in various culinary creations (Silk et al., 2014, Ma et al., 2017).

Yak yoghurt, a fermented dairy product, has also emerged as a modern application of yak milk. Yak yoghurt offers a tangy flavour, smooth texture, and probiotic benefits. It is produced by fermenting yak milk with specific bacterial cultures, providing a source of beneficial bacteria for digestive health and offering a delightful snack or ingredient in desserts and smoothies (Silk et al., 2014).

The diverse range of traditional and modern yak milk products not only contributes to culinary enjoyment but also supports economic growth in yak-rearing regions. These products provide opportunities for value addition, income generation, and cultural preservation, fostering sustainable agricultural practices and promoting local economies.

Therapeutic properties of yak milk

Yak milk has been found to possess therapeutic properties, including antimicrobial, immunomodulatory, anticarcinogenic, antihypertensive, antioxidant, anti-hypoxic effects, etc. Potential health benefits of yak milk on human health are shown in Figure 2.

The antimicrobial peptides present in yak milk have demonstrated inhibitory effects against various pathogens, suggesting its potential as a natural preservative or antimicrobial agent (Lin et al., 2018, Wang et al., 2023). The immunomodulatory factors in yak milk have shown promise in regulating immune responses and supporting immune function (Kulyar et al., 2021). Additionally, yak milk contains antioxidants that help combat oxidative stress and reduce the risk of chronic diseases (Wang et al., 2023).

Yak milk is also regarded as hypoallergenic compared to cow's milk due to its different protein composition, making it a potential alternative for individuals with cow milk allergies or lactose intolerance (Wang et al., 2023). Yak milk has been found to possess potential anticancer properties, with cytotoxic effects against cancer cells and promising bioactive peptides. It also has antibacterial properties, with peptides derived from yak milk showing inhibitory effects against various bacteria (Kulyar et al., 2021). Yak milk's bioactive peptides with angiotensin-converting enzyme (ACE) inhibitory activity may help lower blood pressure, potentially offering a natural alternative to hypertension management. Additionally, yak milk has been investigated for its potential anti-fatigue effects, improving exercise performance, reducing fatigue, and enhancing endurance capacity. Furthermore, yak milk has been associated with improved bowel movement and constipation relief due to its high fat content and bioactive compounds (Kalwar et al., 2023).

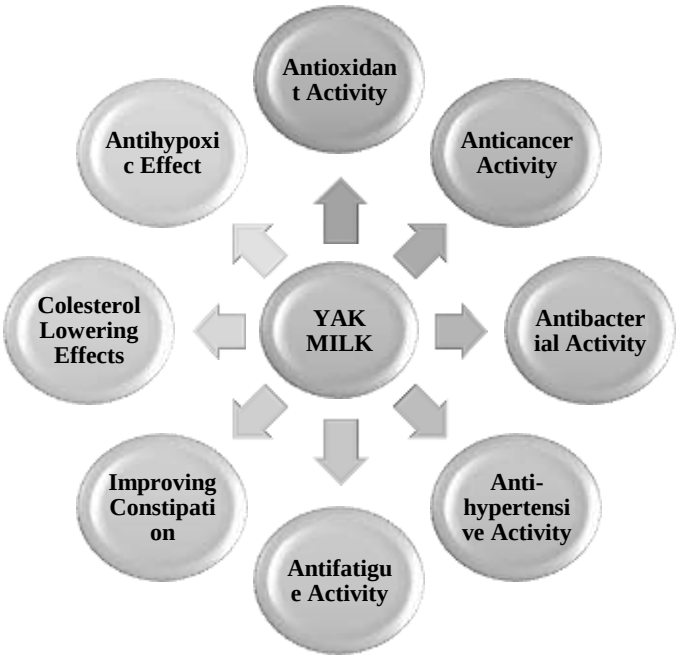


Figure 1: Potential health benefits of yak milk

While further research is needed to fully explore the potential of yak milk in the health industry, it's unique composition and bioactive components make it an intriguing ingredient for functional foods, nutraceuticals, antimicrobial agents, sports nutrition, and pharmaceutical

applications. Incorporating yak milk and its derivatives into health-focused products can provide a natural and valuable resource for promoting wellness, supporting immune function, and addressing specific health needs.

Conclusion

In conclusion, the exploration of yak milk's potential has revealed its remarkable composition, nutritional properties, and diverse applications in the food and health industries. Yak milk stands out with its unique nutritional profile, including higher levels of proteins, fats, vitamins, and minerals compared to cow's milk. Moreover, yak milk contains bioactive compounds that offer antimicrobial, immunomodulatory, and antioxidant effects, which hold promise for therapeutic applications

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