Therapeutic potential of Yak Milk: Unveiling its health benefits and remedial applications

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Introduction

The yak is an extraordinary animal due to its unique physical and structural features that enable it to thrive in harsh mountain environments with challenging climates. Herding communities consider yaks to be the "mighty livestock" because they are deeply embedded in their traditions, socioeconomic activities, and culture. Yak (*Peophagus grunniens L.*) is a distinct bovine species that exists in harsh landscapes, having emerged about two million years ago, and provides indigenous peoples with meat, milk, butter, cheese, wool, fibre, leather, fuel, and travel necessities. Milk and its derivatives are among the most vital protein sources generated by the mammary glands of mammals, supplying complete dietary nutrition, bio-available amino acids, essential micronutrients, and easily digestible food for the human diet. Yaks provide significant economic advantages to pastoralists residing in high altitudes and have been utilized for farming and threshing, as well as for fur, meat, and high-quality milk. Yak milk and dairy products such as butter (Mar), ghee, curd, wet cheese (chhurpi), and hard cheese (Churkham) provide pastoral nomads with a crucial source of vitamins and nutrients. Additionally, yak milk plays an important role in health maintenance. Recently, yak milk has gained considerable attention because of its distinctive properties, highlighting the urgent need to increase its production capacity.

Geographical distribution of Yaks: Habitat and range

Yaks are highly adapted to the severe climate and low oxygen levels found at high altitude grazing locations in the Himalayan Mountains. According to the 19th Livestock census, the count of yaks in India stands at 0. 077 million [1]. Indian yaks are categorized into Arunachali yak, Himachali yak, Ladakhi yak, and Sikkimi yak based on their geographical habitat, with only the Arunachali yak so far recognized as a breed in India. Various ethnic pastoral nomads' rear yaks under transhumance in high altitude pastures characterized by cold and low-oxygen climates for their livelihood and nutritional security. These pastoral nomads are referred to as Changpas in Ladakh, Brokpas in Arunachal Pradesh, and Dokpas in Sikkim. Yaks are crucial for human survival in high-altitude regions, as they supply vital products such as yak milk, meat, hides, and fuel (dried yak dung) to the local population [2]. Additionally, yaks are often utilized as a means of power for transportation in elevated areas.

Yak milk characteristics and its potential benefits

Yak milk is creamy white, has a sweetish, fragrant taste, and is thick in consistency. The water content in Chinese yak milk ranges from 84.37% to 80.37%, with total solids comprising of 15.63% to 19.63%, protein making up 3. 45% to 4.27%, fat between 5.29% to 8.73%, and ash at 0. 6% to 0.8%. The protein makeup of yak milk is different from bovine milk regarding higher levels of κ-casein, β-casein, and β-lactoglobulin [3]. The milk fat from yaks at extremely high altitudes is richer in PUFA and CLA. Additionally, there are high levels of colloidal and soluble calcium and phosphorus, among other benefits [4]. Recently, there has been a growing interest in research focused on yak milk. Not only does yak milk have high nutritional value, but it also offers potential health benefits for humans. Local herdsmen can use yak milk directly or process it into various traditional foods such as butter, cheese, yogurt, and Tibetan tea. When compared to other types of milk, yak milk seems to possess a richer and more varied array of nutrients. During its main lactation phase, yak milk has elevated amounts of fat (5. 5%–7. 5%), protein (4. 0%–5. 9%), and lactose (4. 0%–5. 9%). It is referred to as naturally concentrated milk [3]. The distinctive amino acids, fatty acids, elevated vitamin levels, specific enzymes, and beneficial microorganisms present in yak milk positively affect the health of nomadic groups in high-altitude areas [5].

Studies have found that the bioactive components in yak milk offer various bioactive

functionalities, including antioxidant, anticancer, antimicrobial, blood pressure-lowering, anti-fatigue and constipation treatment properties (Figure). The milk obtained from *Arunachali* yak has significantly ($p < 0.05$) higher fat, solids-not-fat and protein content compared to Yak-Cow hybrid and cow [7]. Similarly, the probiotic potential of 17 lactic acid bacteria isolated from Yak milk in a series of in vitro tests has been identified and their health benefits, i.e., cholesterol degradation, lactose digestion, antimicrobial activity, antioxidant and anticancer activities have also been demonstrated [8]. *Limosilactobacillus fermentumis* recognised as a potential probiotic strain with attributes such as antimicrobial, antioxidative and cholesterol reduction properties. The *L. fermentum NKN-51* strain has been extracted from fermented butter derived from Yak milk (known locally as churpi) in Nubra valley, and its genome sequence has been documented [9]. Similarly, lactic acid bacteria (LAB) were isolated and identified from chhurpi, a cheese product traditionally made in the Sikkim Himalaya. *Enterococcus durans* was the predominant LAB, constituting 34% of the identified LAB, followed closely by *Lactobacillus delbrueckii* at 25%. Chhurpi was created using milk-curdling LAB strains followed by a simulated in vitro gastrointestinal digestion of chhurpi. The assessment of protein hydrolysis and antioxidant properties was conducted. Chhurpi that was generated using *Lactobacillus delbrueckii WS4* exhibited a relatively higher yield (10. 4%), protein hydrolysis, and antioxidant activity when compared to other starter strains ($P < 0.05$).

Gastrointestinal digestion of chhurpi increased the antioxidant activity, with the highest activity observed for gastrointestinal digests of chhurpi produced by using *Lb. delbrueckii* WS4. The EC50 for DPPH radical scavenging activity of chhurpi produced by using *Lb. delbrueckii* WS4 was observed to decrease significantly (from 239.16 to 48.87 mg sample/ml) after digestion with pepsin and pancreatin ($P < 0.05$). Protein hydrolysis and antioxidant activity in whey were comparable to that of *chhurpi,* indicating the potential of using the *chhurpi* whey to be developed as nutraceuticals [10]. These findings open up possibilities for the high-value utilization of yak milk [11]. However, more evidence is needed to confirm these functions in the human body as only a few studies have investigated milk metabolite profiles from minor dairy animals such as yak, camel and horse.

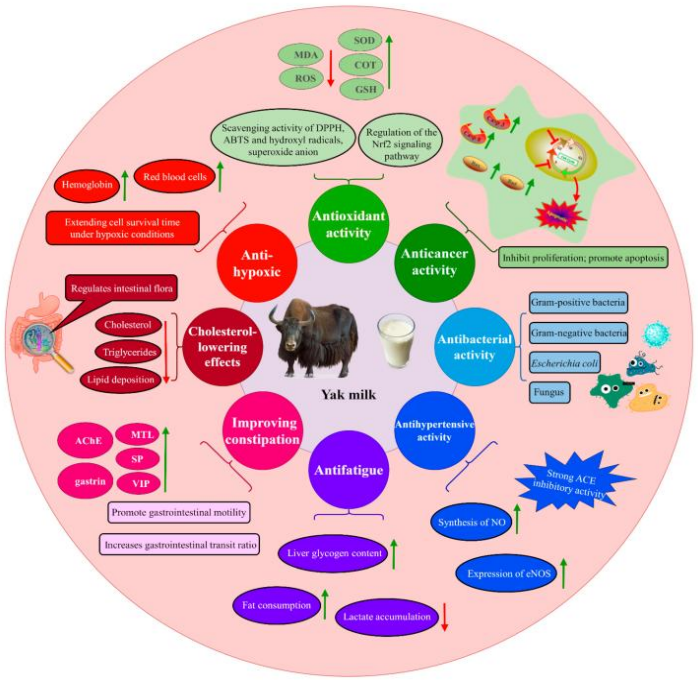

Fig 1. The potential mechanisms and impacts of yak milk components on improving human health conditions [6].

Role of metabolomics in exploring therapeutic potential of milk samples

Metabolomics, an "omics" field in systems biology and functional genomics, involves the comprehensive evaluation of small endogenous metabolites in a biological sample utilizing rapid and high-throughput methodologies. Various techniques have been established and employed in metabolomic research, including nuclear magnetic resonance (NMR) spectroscopy, liquid chromatography tandem–mass spectrometry (LC-MS) and gas chromatography–mass spectrometry (GC-MS). Key attributes of food, including taste and nutritional value, are directly linked to the existence or lack of certain combinations of metabolites. Consequently, the identification of milk metabolites that relate to milk composition, milk characteristics, and therapeutic properties must be examined from a metabolic viewpoint. In the past ten years, numerous studies have been carried out on the microbial diversity of yak milk, primarily conducted in China and the probiotic potential of the microflora in yak milk has yet to be thoroughly investigated.

Conclusion

Yak milk is being fortified with various metabolites and peptides that may offer beneficial effects, particularly in relation to human chronic

illnesses. These peptides can be obtained through the enzymatic hydrolysis of the milk's parent proteins and can be harvested for incorporation into nutraceuticals and functional foods designed to promote health and reduce dependency on pharmaceuticals in disease management. While yak milk has attracted interest as a novel type of milk and considerable advancements have been achieved in its nutritional value and functional effects research, several critical issues remain to be further investigated and addressed. Consequently, the initial selection of important strains may yield significant probiotic candidates for future study and may grant recognition to yak-rearing communities by providing substantial economic advantages and other intellectual property rights in the near future.

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