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Beneficial impacts of goat milk on the nutritional status and general well-being of human beings: Anecdotal evidence

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ABSTRACT

Goats provide an essential food supply in the form of milk and meat. Goat milk has distinct qualities, but it shares many similarities with human and bovine milk regarding its nutritional and therapeutic benefits. Because of their different compositions, goat and cow milk products could have different tastes, nutrients, and medicinal effects. Modification in composition aid of goat milk determining the viability of goat milk processing methods. Comparatively, goat's milk has higher calcium, magnesium, and phosphorus levels than cow's or human milk but lower vitamin D, B12, and folate levels. Goat milk is safe and healthy for infants, the old, and healing ailments. Capric, caprylic, and capric acid are three fatty acids that have shown promise as potential treatments for various medical issues. Considering the benefits and drawbacks of goat milk over cow milk is essential; goat milk is more digestible, has unique alkalinity,

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Casein

Human health

has a better buffering capacity, and has certain medicinal benefits. Acidifying goat milk shrinks fat globules and makes protein friable (with less αs1-casein and more αs2-casein). Goat milk treats malabsorption illnesses because it has more short- and medium-chain triglycerides that give developing children energy. In wealthy countries, goat milk and its products—yoghurt, cheeses, and powdered goods—are popular with connoisseurs and persons with allergies and gastrointestinal issues who need alternative dairy products. A food product category containing fermented goat milk with live probiotic microbes appears promising nutritionally and medicinally. This article presents anecdotal evidence of the therapeutic effects of consuming goat milk for human health and its nutritional value.

1 Introduction

Milk has always played an important role in the human diet, which has not changed over history. It has been used for decades by individuals of all ages. In addition, milk is regarded as a great food due to its balanced composition of proteins, vitamins, lipids, and minerals. Most of the milk consumed presently ought to be cow milk (Chandran et al. 2021a; Prakash et al. 2021a;). Cow's milk provides the full spectrum of nutrients, including proteins, calcium, vitamin B12, and iodine, essential for healthy human growth and development. The good news comes with a catch, though. Some people have sensitivities to the proteins found in cow's milk (Chandran et al. 2019; Chandran 2021b). Cow milk consumption is also related to lactose intolerance and other health problems. The answer to this predicament lies with the goat, the rich man's substitute for the cow. India has many high-return, low-risk industries, including goat husbandry (Khan et al. 2019; Gallier et al. 2020; Chandran 2021a). Farmers on tight budgets and with restricted land can still make a living by raising goats due to this endeavor's minimal risk and cheap cost (Prakash et al. 2021b). Investment returns from goats are higher than those from cows. Hence the adage that goats are the poor man's cow is correct. Goat farming appeals to many subsistence farmers because of its low input costs and relatively low grazing space requirements (Martemucci and D'Alessandro 2013; Li et al. 2020). Two indicators may show how the worldwide popularity of goat farming is developing. A growing number of people are keeping goats for two reasons: either as a means of subsistence or as a hobby (Chandran and Athulya 2021; Manuvanthra et al. 2022). The goat industry is crucial to the economic well-being of rural communities because of the income generated from the sale of goat meat. Anyone can raise goats without access to land by simply giving them leftovers and herbs from the kitchen. Their mild demeanor and diminutive stature make them a breeze to house and handle (Lejaniya et al. 2021a).

The market for dairy goats around the world is expanding quickly. Keeping dairy goats provides smallholders with a sustainable source of income and assets in the form of healthy milk products and helps them maintain a more self-sufficient lifestyle. Estimates put the global goat population at 1 billion, with 94 percent residing in Africa and Asia's poorest nations (Chandran and Arabi 2019; FAOSTAT 2019; Prakash et al. 2021b). The 20th Livestock Census of India found 535.78 million cattle in the country in 2019, with 148.88 million goats making up 10.14 percent of the total (GOI 2019). Goats are valuable and necessary livestock for many reasons. Their adaptability to many environments, dietary requirements, and climate extremes is a bonus to their already helpful versatility and moderate output. Dairy, meat, fleece, and manure are just a few products that may be derived from goats. Milk production from goats begins at around 16 to 17 months of age, and the animals reproduce quickly. Goats are helpful to rural areas since they are inexpensive to raise, have a rapid reproduction rate, require little food, and consistently yield only a tiny amount of milk that is perfectly adequate for the needs of a single family (Clark and Mora García 2017; Chandran et al. 2021c).

Unlike cows and sheep, goats spend most of their time browsing rather than grazing on the grass to cover more ground on their way to a water source. Goat milk, in comparison to the other two kinds of milk from the same species, can have a substantial effect on human nutrition due to the presence or lack of specific proteins, vitamins, carnitine, lipids, minerals, glycerol ethers, enzymes, fat globule size, orotic acid, and casein polymorphisms. This is because goat milk has a distinct flavor compared to sheep and cow milk (Deepak et al. 2020a; Chandran et al. 2021a). Due to species-specific metabolic, nutritional, physiological, and anatomical distinctions, goat milk and its derivatives may command a premium over cow's milk. Goat milk has been recognized as a functional beverage. Its smooth consistency and high mineral and vitamin content make it an appealing substitute for various common dietary supplements (Roy et al. 2021). Goat milk's improved digestion makes it a better option than cow's milk; its medicinal advantages, buffering ability, and alkalinity are also significantly higher. Goat milk fat has more incredible physical qualities than cow milk fat, including increased surface tension, viscosity, and specific gravity (Turck 2013; Patange et al. 2022a; Patange et al. 2022b). The global goat milk production profile and top-producing countries are depicted in Figure 1.

The principal carbohydrate in goat milk, lactose, is beneficial because it increases the body's absorption of calcium, magnesium,

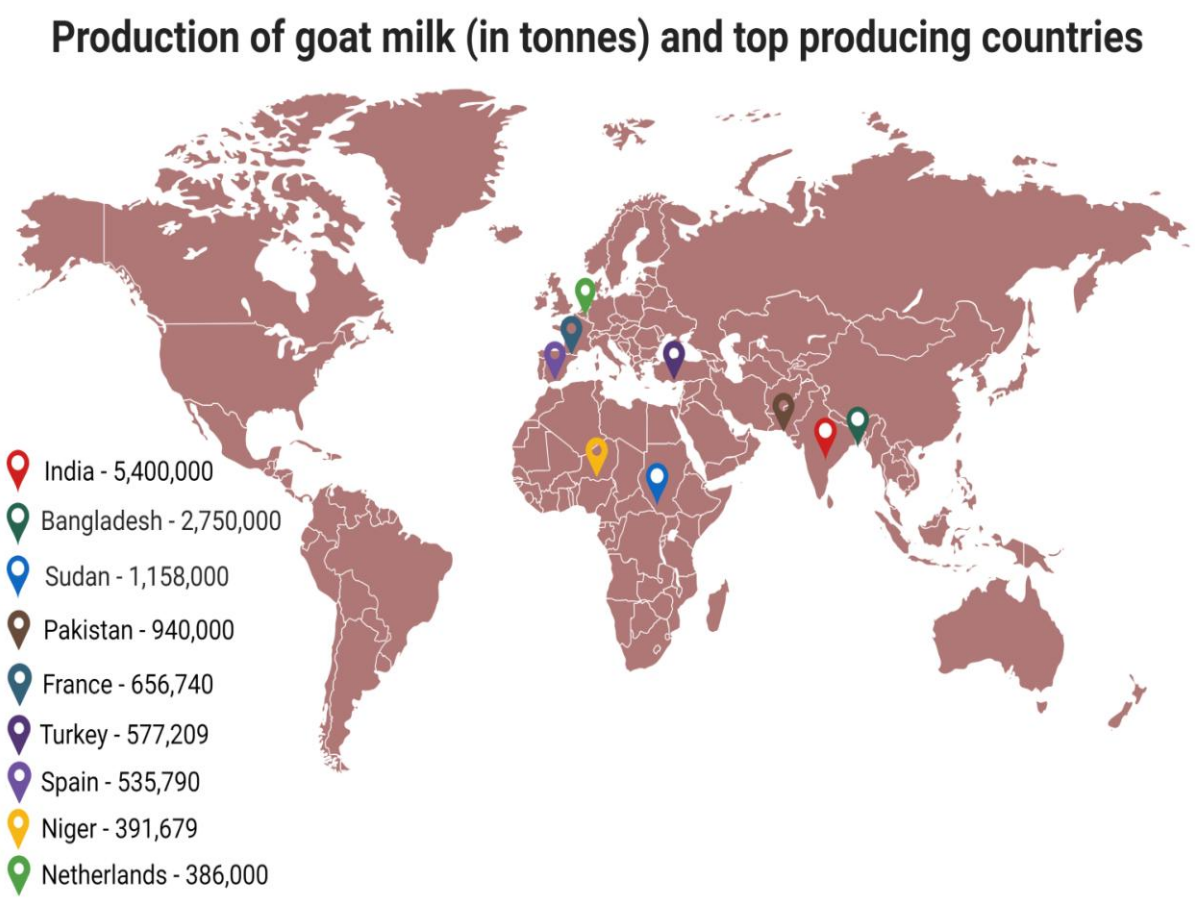

Figure 1 Analyzing the state of goat milk production throughout the world
(Designed with Biorender premium software; https://app.biorender.com/)

phosphorus, and vitamin D. Because goats convert all of the beta-carotene in their food into vitamin A, goat milk naturally contains higher vitamin A than cow milk. Goat milk outshines cow milk in many minerals, including potassium, selenium, zinc, calcium, chloride, phosphorus, and copper. Goat milk is a better alternative for persons who cannot tolerate lactose. The popularity of goat milk may be linked to the fact that it is digested more easily than cow's milk (Stergiadis et al. 2019). Cheese and yoghurt made from goat's milk can soothe stomachs that have problems digesting cow's milk. Given its composition, human breast milk represents a biologically typical diet for babies. Its chemical makeup helps prevent inflammation and infection while providing nutrients, easing digestion, promoting healthy organ development, and protecting against food poisoning. Yet, issues of time, health, and living in an urban environment can all contribute to the premature end of breastfeeding. During the COVID-19 pandemic, even India's government guidelines warned that nursing was unsafe under the current circumstances and should be avoided if possible (Chawla et al. 2020; Chauhan et al. 2021; Kaur and Pareek 2022). Hence, it is vital to find a way to provide an alternative to breast milk for babies who cannot get enough of it.

Dairy products, especially milk, have undeniable health and practical benefits. Several people undoubtedly consume goat milk or goat cheese. Goat's milk is processed into various dairy products, including ice cream, paneer, channa, srikhand, condensed milk, dried whole milk, butter oil, and flavored milk (Martemucci and D'Alessandro 2013). The nutritional and therapeutic benefits of goat milk for illnesses like lactose intolerance, inflammatory bowel disease, antibiotic resistance, cardiovascular disease, and lactose malabsorption should not be overlooked (Collard et al. 2021). Goat milk is known for its health benefits. Goat milk helps cow milk-allergic or digestively challenged infants (Jirillo et al. 2010). Figure 2 shows how goat milk benefits health. Individuals' awareness of the problems with conventional medical treatments for certain ailments also contributes to this rising demand. Goat milk has gained popularity as a functional food in recent years since it is easily absorbed and causes fewer allergic reactions than bovine milk. Goat milk is a promising alternative to traditional dairy products that can help those with lactose intolerance and other digestive issues (Lejaniya et al. 2021a). Milk has very high nutritional benefits and has recently been a popular part of the diet in industrialized countries. Milk is drunk either on its own or as

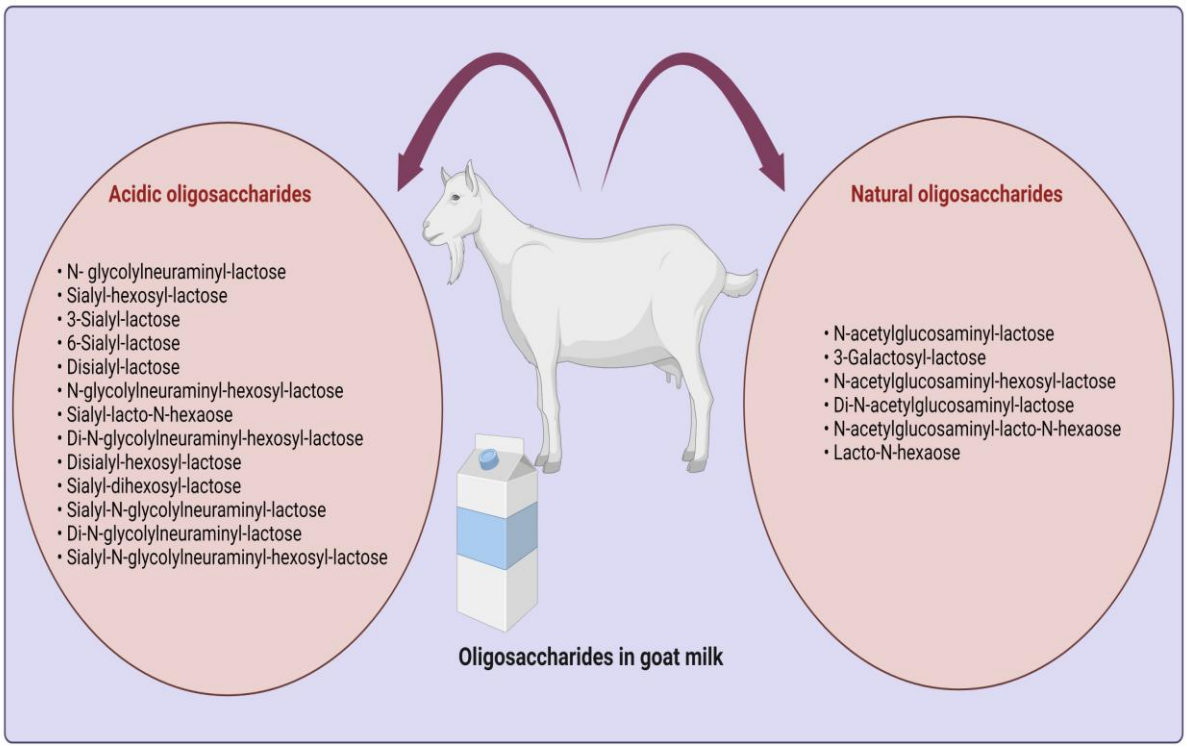

Figure 2 Oligosaccharides in goat milk (Designed with Biorender premium software; https://app.biorender.com/)

part of a new category of functional dairy goods in industrialized countries. Physiologically active metabolites and probiotic bacterial strains are common ingredients in these products (Kumar et al. 2016; Rai et al. 2022). The article below looks at anecdotal evidence supporting the nutritional and physiological advantages of consuming goat milk by humans.

2 Nutritional composition of goat milk

Goat milk has more therapeutic characteristics than cow and human milk because it is more easily digested, has a higher buffer capacity, is more alkaline, and has a higher pH. The fat in goat's milk has a higher specific gravity, greater density, and more viscosity than cow's milk. Steroids and glycerides can make up as much as 99 percent of fat. The fat in milk emulates oil and water (Siefarth and Buettner 2014). While the fat globules in goat milk are chemically and physically comparable to cow milk, agglutinin is lacking in goat milk. Globules in goat milk range in size from 1.5 to 2 mm, whereas those in cow milk range from 2.5 to 3.5 mm, and there are 28 percent more of them in goat milk than cow milk (10 percent). Fat globules in goat milk are typically much smaller than in cow milk, with about 65 percent of fat globules being less than 3m. Goat's milk is sometimes referred to as "self-homogenized" because of its quality (Cebo et al. 2010; Toral et al. 2015), offers better values than cow milk in terms of free lipids, and has twice the C8, C10, and C12 fatty acids as cow milk (Patange et al. 2022a). Medium-chain triglycerides are a healthy fat that may be burned for fuel instead of stored as fat, and they also help lower cholesterol. Chyluria and chylothorax (lung conditions) are also treated with these. Medium-chain triglycerides are used to treat a variety of digestive disorders, including those that result from abnormal food absorption, such as diarrhea, steatorrhea (fat indigestion), celiac disease, liver illness, short bowel syndrome, and digestive problems caused by the surgical removal of a portion of the stomach (gastrectomy) or intestine (Collard et al. 2021).

Milk proteins can be separated into a stable micellar phase, made up of casein, and an insoluble whey protein phase. Compared to cow's milk, goat's milk has a little lower αs-casein concentration, a much greater β-casein concentration, and a comparable κ-casein concentration (Stergiadis et al. 2019; Chandran et al. 2021b). Goat milk has more αs1-casein than cow milk, which has more β-casein. Micelles derived from goat milk are more soluble in β-casein, have higher calcium and phosphorus concentrations, and are less heat stable than those derived from cow milk. Compared to cow's milk, less allergen αs1-casein is found in goat's milk (Ballabio et al. 2011; Dhasmana et al. 2022).

The mammary gland needs beta-lactalbumin to make milk from glucose and galactose. Lactose aids protein digestion, intestinal mineral absorption (especially calcium, magnesium, and phosphorus), and vitamin D usage. The udder's duct system secretes milk from it (He et al. 2022). Goat milk contains

monosaccharides, oligosaccharides, glycopeptides, glycoproteins, and nucleotides. Lactose-derived oligosaccharides are much more significant in goat milk than in cow's milk. Milk oligosaccharides have prebiotic and antibacterial properties, which are thought to contribute to human nutrition. Goat milk oligosaccharides inhibit colitis-induced inflammation in mice (Kiskini and Difilippo 2013). These findings may treat inflammatory bowel disease. Goat milk has fewer oligosaccharides than human milk, but more than bovine and ovine milk, and its structures are like human milk. Human milk oligosaccharides are prebiotic and anti-infective, making them advantageous for newborn feeding (Khan et al. 2019; Li et al. 2020). Goat milk oligosaccharides are illustrated in Figure 2.

Goats convert all β carotene in their food into vitamin A, so their milk has more vitamin A and is whiter than cow milk. Goat and cow milk lack the essential vitamins and minerals that infants require, including vitamins B6 and D (He et al. 2022). Vitamin A levels in the milk of goats and humans are comparable. Vitamin A is necessary for cell-mediated immunity and antibody responses, two immune system aspects crucial for fighting infection and maintaining health (Kumari et al. 2022). Goat milk has higher concentrations of the well-known water-soluble antioxidant vitamin C than cow milk (Stergiadis et al. 2019). The immune system is just one of the many things this vitamin has been shown to influence. It has antiviral and antioxidant effects, which help regulate the immune system. Goat milk contains all of the B vitamins (particularly thiamine, riboflavin, and niacin) and vitamins D and E. Folate levels are low in goat's milk (Gallier et al. 2020).

Each species' milk has a particular mineral pattern, which may indicate the element's nutritional value. Goat milk has more minerals than cow's milk, making it more mineral-rich (Stergiadis et al. 2019). Cow milk is different because it has lower sodium, phosphorus, zinc, copper, and manganese concentrations than goat and human milk. Goat milk is enriched with a higher concentration of nutrients, making it a healthier alternative to cow's milk. Goat milk, like cow milk, is not a suitable replacement for human milk, although it can be used as a supplement for newborns and toddlers (Patange et al. 2022a; Patange et al. 2022b). Goat milk's mineral richness exceeds cow and human milk, reflecting that it may be used as a supplement if more people know about it. Goats' mineral metabolism is distinctively different from that of cows and sheep, especially in molybdenum, copper, iodine, selenium, magnesium, and iron (Siefarth and Buettner 2014). Goats, as opposed to cattle or sheep, spend most of their time browsing rather than grazing in a grassland setting, meaning they may cover more ground on foot and require less frequent watering. Proteins, vitamins, carnitine, lipids, minerals, glycerol ethers, enzymes, fat globule size, orotic acid, and casein polymorphisms distinguish goat milk from cow, sheep, and human milk (Martemucci and D'Alessandro 2013; Khan et al. 2019). Differences in anatomy, physiology, metabolism, and nutrition contribute to goat milk and its derivatives having their own properties. Goat milk and other dairy products are more popular because they contain a higher concentration of nutrients (Toral et al. 2015). While goats' milk has identical amounts of protein, lipids, and lactose as cows' milk, the protein and fat structures are less digestible and nutritious. The chemical composition, secondary protein structures, and amino acid profile of goat milk differ from cow milk, making it hypoallergenic. Due to its high nutrient content and functional components, such as prebiotic chemicals and probiotic microorganisms, goat milk can be used in various products. Goat's milk can be a good alternative for lactose intolerant or suffering from gastrointestinal conditions like ulcers or colitis (Sousa et al. 2019; Rai et al. 2022).

3 Dietary and therapeutic significance of goat milk

The dietary and medicinal benefits of goat milk on human health and nutrition are summarized in Figure 3.

3.1 Alleviation of lactose intolerance

Sugar lactose is present in goat milk, just as in human and cow milk. Due to its lower lactose content, goat's milk is more easily absorbed by the human digestive system than cow's milk. Lack of lactase, the enzyme responsible for digesting lactose, is the root cause of lactose intolerance (milk sugar). Lactose is the primary carbohydrate in milk (Turck 2013). Lactose is formed when two molecules of D-glucose and D-galactose are joined together. Goat milk is a better choice for lactose intolerant people since it has lesser (22 to 27 %) lactose content as compared to cow milk (33 to 40 %) (Martemucci and D'Alessandro 2013; Lund and Ahmad 2021). High lactose content in milk gives it a pleasant flavor and facilitates calcium absorption in the small intestine. It has a critical role in establishing healthy bone structure in infants.

However, many lactose-intolerant persons find that goat's milk suits their tastes. It is hypothesized that this is due to the better digestion of goat's milk (Gallier et al. 2020). Because goat's milk has a more remarkable lactose absorption ability than cow's milk, fewer people experience the discomfort of lactose intolerance when drinking it. Some people may be allergic to cow's milk despite not being lactose intolerant because of the protein as1-casein, which is uncommon in goat's milk or non-existent in some cases. Similar symptoms accompany lactose intolerance and milk protein allergy (Arasi et al. 2022; Liu and Zhang 2022). Patients with lactose intolerance have difficulty digesting lactose because the sugar is absorbed by the large intestine undigested. Microbes fermenting this unhydrolyzed lactose in the large intestine produce gas and free fatty acids, which in turn cause bloating, cramping, and other gastrointestinal symptoms (Lund and Ahmad 2021). Due to its softer curd, goat milk is often advised as an alternative to cow's

milk. Higher casein content in goat's milk facilitates lactose digestion and reduces the chance of lactose intolerance by hastening the process by which the sugar is absorbed by the large intestine (Quigley et al. 2013; Rai et al. 2022).

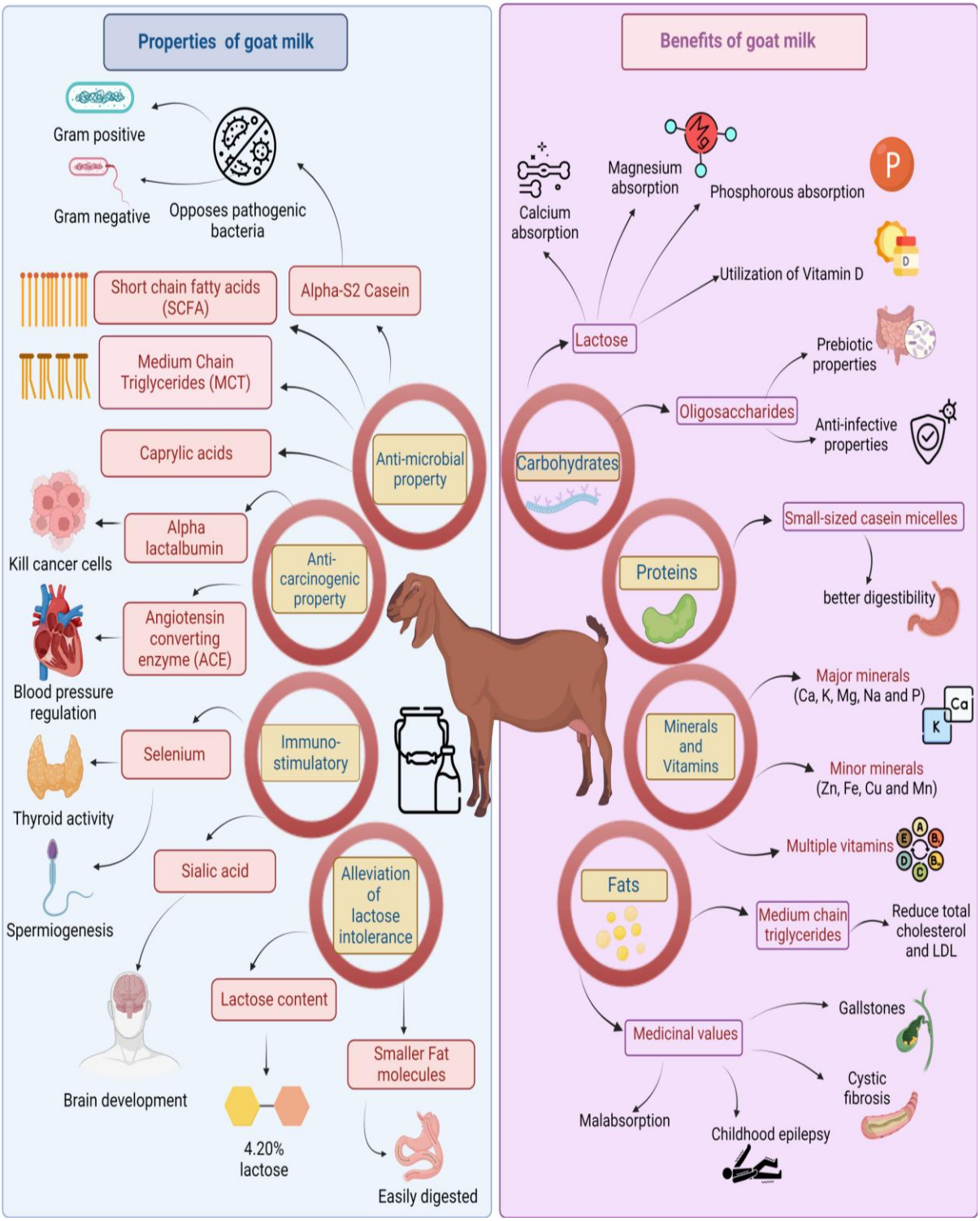

Figure 3 Dietary and therapeutic implications of goat milk on the human health and nutrition (Designed with Biorender premium software; https://app.biorender.com/)

3.2 Digestibility, gastrointestinal function, and prevention of malabsorptive disorders

Goat milk fat contains more short- and medium-chain (C4:0-C12:0) fatty acids than cow milk. Goat's milk absorbs more easily since it has fewer fat globules. Goat milk's unique protein profile allows for forming of a milder curd, which is easier on the digestive system and more comfortable to eat (Roy et al. 2021). Compared to bovine casein micelles, goat casein micelles are less heat stable, less soluble, and lose β-casein faster due to their higher inorganic phosphorus and calcium content (Chandran et al. 2021b). Less αs-casein can be found in goat's milk, and sometimes αs2-casein is more prevalent than αs1-casein. Proteins in goat milk are absorbed more effectively because they are easier to digest. The decreased αs1-casein level in goat milk results in a more tender and crumbly curd when acidified (Clark and Mora García 2017; Dhasmana et al. 2022).

Several studies have linked goat milk to fewer cases of diarrhea, constipation, and other gastrointestinal issues. The weaker goat milk acid-induced coagulation and faster stomach emptying may affect abdominal pain perception; however, this has not been proven (Carneiro et al. 2018). Recent animal research suggests that goat milk may help prevent some of the harm that heat stress and intestinal inflammation may cause to the digestive tract. In animal models of colitis, goat milk reduces inflammation and alters short-chain fatty acid fermentation markers in mice. Goat milk had a higher impact on mice's metabolism and intestinal flora than cow milk. Goat milk inhibited even the most stubborn bacteria from attaching to Caco-2 cells, including *Escherichia coli* and a *Salmonella typhimurium* strain. Goat milk oligosaccharides increased *Bifidobacteria longum* subsp. *infantis* adherence to HT-29 intestinal cells eight-fold (Kiskini and Difilippo 2013; Khan et al. 2019; Liu and Zhang 2022). Further study, including clinical trials involving human participants, is needed to determine whether or not goat milk influences the gastrointestinal environment and metabolism in a way distinct from cow milk (Li et al. 2020).

Diseases such as malabsorption disorders stem from problems with nutrient and food digestion and absorption. Many forms of cancer can produce this, often as a side effect or symptom. Inadequate absorption of nutrients such as vitamin B12, folic acid, iron, and other minerals, vitamins, and macronutrients can lead to anemia (Liu and Zhang 2022). The rat model of malabsorption syndrome is widely used because it can be induced by a reaction in roughly half of the rodent's small intestine (Carneiro et al. 2018). Protein and fat are digested and absorbed better from goat milk diets, while calcium, phosphorus, magnesium, iron, copper, zinc, and selenium are also better absorbed. Goat milk may require more minerals for metabolism because it contains more protein, cysteine, and vitamins C and D than cow milk (Khan et al. 2019; Chauhan et al. 2021; Saikia et al. 2022).

3.3 Hypoallergenic property

Many infants have a cow milk allergy (CMA); however, its reasons remain unknown. CMA has been related to beta-lactoglobulin, the most prevalent whey protein in cow milk but missing in human breast milk. Many proteins in cow's milk, including caseins, beta-lactoglobulin, and beta-lactalbumin, have been identified as potential allergens (Ballabio et al. 2011). Although nearly all newborns younger than three years old have circulating milk antibodies, roughly 7 percent of children in the United States and possibly all western countries have signs of CMA. CMA symptoms usually appear between 2 and 4 weeks and never after six months. The immune system reacts to milk in the gastrointestinal tract, the respiratory system, the skin, and occasionally the rest of the body (He et al. 2022). CMA symptoms include vomiting, epigastric discomfort, malabsorption, bronchitis, erythraemia, hyperactivity, migraines diarrhea, colitis, eczema, urticaria, rhinitis, asthma, anaphylaxis, and many others (Carneiro et al. 2018). Rhinitis, abdominal discomfort, diarrhoea, anaphylaxis, and urticaria were the most common CMA symptoms that resurfaced. Mothers who cannot breastfeed their babies need to find a suitable substitute (Novac and Andrei 2020; Rai et al. 2022). Infants and food allergy sufferers can switch to goat milk. Goat's milk is safe for cow-milk allergy sufferers since its proteins are different. Goat milk is vital for CMA patients, milk consumers and producers, and human nutrition in general because of its therapeutic and hypoallergenic effects on newborns and CMA patients (Chauhan et al. 2021; He et al. 2022). Despite this, most research has demonstrated that goat milk therapy can help children with cow milk allergies or chronic enteropathy. However, some caprine milk proteins are immunologically cross-reactive with cow milk proteins (Hirsiger et al. 2022).

Further clinical feeding experiments are needed, but governments, corporations, and universities focusing on goat milk have not received funding from cow-milk-centric communities (Manuvanthra et al. 2022). Genetic variations in caseins and whey proteins can complicate CMA cases, making identifying the protein most likely to produce an allergic reaction more challenging. Nevertheless, milk protein genetic polymorphisms could be used in clinical studies to detect allergens (Pastuszka et al. 2016; Lund and Ahmad 2021). Cross-immune reactivity between cow and goat milk is common. Goat milk containing αs1- casein, a protein polymorph found solely in cow milk, produced allergic reactions in guinea pigs. However, guinea pigs given αs2-casein, which lacks the αs1-casein polymorph, had just a 40 percent allergic reaction, concluding that αs2-casein-lacking goat milk is less allergenic than regular goat milk (Ballabio et al. 2011). Due to differences in cheese manufacturing and renneting, several countries are selecting goats for or against αs1-casein, which could benefit or hurt goat breeding programs. Breeding techniques that aim to increase protein and casein content in milk for use in cheese

production could take advantage of the isoelectrofocussing gene (Sousa et al. 2019; Chauhan et al. 2021). Goat milk with low αs1-casein and high αs2-casein has lower curd yield, longer rennet coagulation time, higher heat lability, and lower curd stiffness. Because of significant mutation rates at each locus encoding the four casein genes, goat casein polymorphism research is arduous (Novac and Andrei 2020). Protein and DNA analyses have examined the polymorphisms. Protein synthesis rates are related to 16 alleles. The CSN1S1, CSN2, and CSN2S2 genes encode three calcium-sensitive caseins: αs1-casein, β-casein, and αs2-casein. The casein micelle requires κ-CN (Dhasmana et al. 2022). Ulcers can be treated with goat milk because it has a higher buffering capacity than cow milk. The casein and phosphate systems in milk are two protein components that contribute to the beverage's buffering ability (Chilliard et al. 2003; Khan et al. 2019). Buffering capacity is higher in goat milk than in cow milk because goat milk, regardless of breed, contains more nitrogen phosphate nitrogen (NPN) and more nitrogen moieties and phosphate. Infant formulas made from soy contain lower levels of total nitrogen and NPN than goat and cow milk, suggesting that the enhanced buffering capacity of goat milk may have therapeutic benefits for people (Hirsiger et al. 2022). The higher concentration of short- and medium-chain fatty acids in goat milk makes it helpful in treating various malabsorption disorders. Diseases and conditions that are treated by removing the gallbladder include hyperlipoproteinemia, coronary bypass, pediatric epilepsy, steatorrhea, intestinal resection, chyluria, cystic fibrosis, gallstones, and feeding a premature baby (Pastuszka et al. 2016). The therapeutic effects of these medium-chain triglycerides on cholesterol metabolism include hypocholesterolaemia action, cholesterol deposition inhibition, and gallstone dissolving. Goat's milk products, like regular milk products, can help humans in need of healing as well (Kumar et al. 2016; Pastuszka et al. 2016; Saikia et al. 2022). People in many different countries worldwide enjoy several indigenous cultured goat milk products. The nutritional value of these foods is enhanced because lactic starter cultures pre-hydrolyze the primary milk constituents, allowing for a better synthesis or availability of certain minerals. Several examples of yoghurt and other cultured foods are used in medicine. Typical uses include treating diarrhea, infantile gastroenteritis, and constipation (Li et al. 2020; Saleena et al. 2022a; Tiwari et al. 2022). Studies have indicated that yoghurt has a more significant effect on lowering cholesterol than milk, perhaps due to the presence of hydroxymethyl glutarate in yoghurt, which blocks the formation of cholesterol from acetate (Chilliard et al. 2003). Orotic acid, lactose, calcium, and casein are only a few of the many dietary components suggested as possible contributors to hypocholesterolaemia. Goat milk producers and consumers, especially in industrialized nations, have shown a consistent interest in this hypothesis because of the hypoallergenic and medicinal benefits of goat milk and products (Saleena et al. 2022a; Saleena et al. 2022b).

3.4 Prevention against inflammatory bowel disease (IBD)

While Crohn's disease and ulcerative colitis are each unique, they are classified as inflammatory bowel diseases (IBDs). Although IBD and Crohn's disease are defined by intestinal inflammation that persists and flares, they are treated differently. In contrast, Transmural inflammation is the hallmark of Crohn's disease, which can manifest in any part of the gastrointestinal system but most commonly affects the ileocolonic region (Carneiro et al. 2018). Because of its increasing frequency and negative impact on patient well-being, IBD has become a major public health issue in recent years. Although researchers have looked into what causes IBD, they still do not know much about it. Irritable bowel syndrome (IBS) is usually treated pharmaceutically and occasionally additionally with prebiotics and/or probiotics (Chilliard et al. 2003; Selvaggi et al. 2014). Contrarily, there should unquestionably be more therapeutic options available. In Spain, two studies were conducted on induced colitis in rats using goat milk oligosaccharides. Studies have shown that oligosaccharides in goat milk have anti-inflammatory properties. Weight loss predicted colon enlargement, and necrotic lesion progression are all halted by the oligosaccharides. The clinical symptoms (diarrhea, and bloody stools) were also less severe, and the immune response was less severe (less neutrophil infiltration). The untreated rats were provided a standard diet devoid of oligosaccharides (Basnet et al. 2010; Lund and Ahmad 2021).

3.5 Antimicrobial, immunostimulatory, anti-inflammatory, and anti-carcinogenic properties

Goat milk's lactoperoxidase protein is efficient against a wide range of bacteria, including those that cause pneumonia (*Klebsiella pneumoniae*), cholera (*Vibrio cholerae*), dysentery (*Shigella dysenteriae*), typhoid (*Salmonella typhi*), and food poisoning (*Staphylococcus aureus*). Bovine lactoperoxidase has been used in trials showing that goat milk has antimicrobial effects (Quigley et al. 2013; Clark and Mora García 2017). Goat milk oligosaccharides have anti-inflammatory properties due to their ability to bind to and remove a wide variety of pathogens, as well as to inhibit the heat-stable enterotoxin produced by *Escherichia coli* and to prevent the contact between leukocytes and endothelial cells (Novac and Andrei 2020). It has been shown that medium-chain fatty acids have antimicrobial activity, particularly against gram-negative bacteria (Kumar et al. 2016). When goat milk is digested by pepsin, antimicrobial peptides are generated that are active against gram-negative bacteria. There is evidence that fermented goat milk, like fermented cow milk, can inhibit the growth of *Serratia marcesens* (Chauhan et al. 2021).

Selenium is an important mineral for maintaining a healthy immune system. Selenium levels in cow milk are low, while goat milk levels are much higher, suggesting that it and its derivatives

can help people stay healthy by boosting their immune systems. Natural killer (NK) cells, T lymphocytes (T-cells), and B lymphocytes are crucial to the immune system's innate and adaptive responses (B-cells). Despite their structural similarities, IgG and IgA comprise most serum immunoglobulins and are linked to many biological properties (Faccia et al. 2020; Poppitt 2020). Similar immunological classes include IgM, IgD, IgA, IgG, and IgE. The body's immune response can be partly predicted by nutritional status, among other variables (Ra et al. 2022). Recent *in-vitro* and human research has shown that goat milk has immunomodulatory effects; thus, it may be a good option for those with a cow milk allergy and looking for an alternative. In recent research, goat milk has been demonstrated to have a number of impacts on human blood cells, including inducing NO release and driving cytokine production (IL-10, TNF-α, and IL-6). In addition to revealing antibacterial activity that may assist milk drinkers in avoiding becoming sick, the release of nitric oxide (NO) may also safeguard the heart of milk consumers (van Leeuwen et al. 2020; Kazimierska and Kalinowska-Lis 2021).

Goat milk protein does not contain allergens. Cow milk's higher lipid content than goat milk may also cause mucus buildup. Goat milk does not promote digestive system inflammation since its fat globules are a tenth the size of cow milk (Novac and Andrei 2020; Hirsiger et al. 2022). Antioxidant and anti-inflammatory goat milk is necessary for all biological functioning. Oxidation causes numerous diseases, including cancer, and inflammation is the body's principal response to infection (Kumar et al. 2016). Goat milk protects against pathogenic infection allergies, but keeping a healthy gut microbiota with probiotics and prebiotics is also important (both of which are found in goat milk) (Faccia et al. 2020; Hirsiger et al. 2022).

Conjugated linoleic acid (CLA) concentrations are exceptionally high in goat milk. *In vitro* research on human melanoma, colorectal and breast cancer, and animal studies on mammary and colon cancer have demonstrated that CLA slows tumor growth. Fermented goat milk has been hypothesized to have antioxidative properties, interfere with the receptor-mediated actions of estrogen, and disrupt the eicosanoid-dependent cell signalling systems, all of which may be involved in CLA's tumor-inhibitory effects (Lund and Ahmad 2021; Mirzaei et al. 2022).

3.6 Functional food, food intake, and mineral absorption

The technological community is concerned about the novel structures that develop when milk's calcium and proteins react (Deepak et al. 2020a). Milk and colostrum include several beneficial bioactive components that help control weight and hypertension. Digestion and health are also affected. Goat milk can be considered a functional and neutraceutical beverage because of its high concentration of these substances. Goat milk is readily absorbed because its chemical makeup is similar to human milk. Hence, it increases the bioavailability of the nutrients inside it (Hirsiger et al. 2022). Researchers are increasingly interested in antioxidant peptides due to their potential to reduce or postpone the oxidative spoilage of foods. Hydrolysis of goat milk proteins in vitro with enzymes or fermentation with lactic acid bacteria can yield powerful antioxidant peptides. Antioxidant peptides have many beneficial properties, including the ability to scavenge free radicals, chelate iron, and stop the autooxidation of polyunsaturated fatty acids (Chen et al. 2020).

Humans get more iron and copper from goat milk. Unlike cow milk, goat milk has a similar concentration of oligosaccharides as human milk. It is widely established that they function as prebiotics in the gut and boost digestive health. Bifidobacteria, the good bacteria in the gut, are their doing. Bifidobacteria improve lactose maldigestion and have been linked to several other health benefits, such as increased immunity, protection from pathogenic infections, reduced risk of cancer, and lower cholesterol levels (Clark and Mora García 2017; van Leeuwen et al. 2020).

The goat is a bioorganic sodium animal, while the cow is a calcium animal in naturopathic medicine. Bioorganic sodium is essential to keep joints flexible and dynamic. Goat milk delivers 35% of the calcium humans require daily in one cup (Novac and Andrei 2020; Saikia et al. 2022). In addition, only one cup of goat milk supplies as much as 20 percent of the recommended daily value for riboflavin. Furthermore to phosphorus, goat milk is a superb supplier of the nutrients such as potassium and vitamin B12. Zinc (a mineral with antioxidant potential) bioavailability is enhanced by goat milk. Goat milk's lower TBARS levels may be attributable to the fact that its fat is more efficiently used for nutrition, which in turn reduces its availability as a substrate for lipid peroxidation and, in turn, its formation of free radicals (Marius et al. 2020; Kazimierska and Kalinowska-Lis 2021). Goat milk's greater bioavailability of magnesium and zinc and its improved fat quality may explain why it has a good effect on genomic integrity even when consumed regularly by animals subjected to an iron-overloading feeding regime. Genomic stability is improved through magnesium metabolism because DNA is constantly being destroyed by exogenous mutagens and the body's mechanisms (Lund and Ahmad 2021). Evolutionarily, cells have adapted various DNA repair mechanisms to limit mutation frequency. Magnesium is a cofactor essential for almost all of the stages of nucleotide excision repair, which is the primary repair mechanism for DNA damage induced by environmental mutagens. The principal tool for mending endogenous DNA damage is base excision repair (Kumar et al. 2016; Faccia et al. 2020).

After consuming goat milk for breakfast, people reported feeling less hungry and less compelled to eat, indicating that the milk had a somewhat more satiating effect than cow milk. After an

overnight fast, fortified goat or cow milk did not influence appetite, fullness, or preferences for sweet, salty, savory, or fatty meals. When given the option, mice, and rats of all ages favored goat milk over cow milk (Lund and Ahmad 2021). By studying gene expression in the brain circuit involved in feeding, scientists confirmed that this hedonic food preference for goat milk is regulated centrally. There has to be an analysis of the implications for either adult or infant feeding habits (Marius et al. 2020).

Goat milk enhanced mineral uptake more than cow milk in mouse models of poor intestinal absorption. Bone health and iron absorption were significantly improved by goat milk in iron-deficient rats (Deepak et al. 2020a; Deepak et al. 2020b; Lund and Ahmad 2021). Calcium and vitamin D absorption were similar in vitamin D-deficient rats, whether given goat or cow milk enriched with vitamin D (Costa et al. 2016; Deepak et al. 2020b). In a 3-week-old piglet digestive model, goat and cow milk had similar mineral absorption. Hence, goat milk or cow milk fortification may absorb minerals better, depending on the person. This research implies that goat milk would be as helpful as cow milk in the newborn formula, including minerals and vitamins (Kok and Hutkins 2018; Gallier et al. 2020).

3.7 Heart health and cardiovascular diseases

Heart disease and stroke are the two leading killers among the wealthy world's population. Coronary heart disease, irregular heartbeats, high blood pressure, and atherosclerosis are just a few of the many disorders included under this umbrella term. Most cardiovascular occurrences may be traced back to CVD, primarily caused by the buildup of atherosclerotic plaque in the artery walls. Atherosclerosis is exacerbated by several risk factors, including a sedentary lifestyle (smoking, poor nutrition, and lack of exercise), high blood pressure, abnormal lipid profiles, diabetes, and obesity. Although its origin is a mystery, one of its fundamental mechanisms appears to be the accumulation of atherogenic lipoproteins within the artery walls (Costa et al. 2016; Lund and Ahmad 2021). Low-density lipoprotein (LDL), an atherogenic lipoprotein that transports cholesterol from the liver to the arteries, is often called "bad cholesterol". High-density lipoprotein (HDL) transfers cholesterol away from blood vessels, transforming it into oxidized low-density lipoprotein (ox-LDL), accelerating atherosclerosis. So, it comes to reason that antioxidants, which can prevent LDL oxidation, can aid in the decrease of atherosclerosis (Clark and Mora García 2017; Lund and Ahmad 2021).

Goat milk contains the enzyme angiotensin-converting enzyme (ACE), the peptide inhibitory peptide (IP), and the peptide antihypertensive (AHP). They are effective in halting the spread of disease and stopping the spread of bacteria. Immunoglobulins, proteose peptone, lactoferrin, transferrin, calmodulin (calcium-binding protein), ferritin, prolactin, and folate-binding protein are minor milk proteins (Chandran et al. 2021b). NPN levels are higher in goat and human milk than in cow's milk. Taurine, a sulphur-containing amino acid, and carnitine, a vitamin for neonates, are found in goat milk and help the body's metabolic functions. Goat milk contains higher minerals and vitamins than cow milk (Prosser 2021).

Medium-chain triglycerides, polyunsaturated fatty acids, and omega-3 fatty acids are all present in higher concentrations in goat's milk than in cow's milk. As a bonus, these are good for the heart. Yet, unlike cow's milk, goat's milk has a lower percentage of cholesterol. Goat milk's fatty acid composition offers cardiovascular disease protection (Poppitt 2020). Due to its high potassium content, goat milk effectively lowers blood pressure and cholesterol levels. Plasma triglyceride levels were lower in goat milk drinkers, indicating a beneficial influence on lipid metabolism. Goat milk has lower and more steady levels of total cholesterol and hepatic intoxication indicators (transaminases; glutamate pyruvate transaminase and glutamate oxaloacetate transaminase) than cow's milk. Goat milk can also combat and prevent heart disease (Carr et al. 2021).

3.8 Consumption in infancy

In many areas, goat milk is still widely used as an infant formula substitute. Regarding baby nutrition, there is a conflicting scientific opinion regarding goat milk. Unpasteurized goat milk is safe for adults and older children, but experts agree that it should not be given to newborns and toddlers (Gallier et al. 2020). Infectious diseases such as brucellosis, tuberculosis, and brucellosis can be spread through drinking unpasteurized milk. Pasteurized goat milk or formula made from goat milk is another option as a cow milk substitute (Roy et al. 2021). Due to insufficient essential nutrients, including folic acid, vitamin B12, and iron, in ordinary goat milk, commercially made formulas are strongly advised. Megaloblastic anemia, brought on by a lack of folic acid or vitamin B12, has been documented in infants fed homemade goat milk formulae. Goat milk alone induced hypernatremia, brain hemorrhages, and azotemia in a newborn because goat milk has more salt than human milk (Lund and Ahmad 2021; Prosser 2021). Due to their immature kidneys, infants should avoid consuming high sodium levels. Fortified goat milk formulae may be a viable alternative to cow milk, which lacks certain nutrients (He et al. 2022). Researchers evaluated goat and cow milk on development and fat absorption in healthy newborns and underfed children (Carr et al. 2021). Malnourished youngsters (aged 1–5) who were given either goat or cow milk showed similar weight and fat absorption increases. The study milk was supplemented with the same vitamins and minerals the subjects usually took to make it nutritionally equal. Healthy infants have been studied again regarding the differences between goat and cow milk formula (with comparable nutrient contents). Neither group outgrew the

other significantly faster than the other (Lund and Ahmad 2021; Prosser 2021).

3.9 Goat milk products and their importance in human nutrition

Typically, milk from goats would be produced on smaller farms. People have been processing goat's milk and eating the resulting goods since ancient times. Allergens are absent from the fresh milk of well-cared-for, well-fed goats (Ballabio et al. 2011; Kumar et al. 2016). Roquefort cheese and Leben are both favorite goat milk products. But goat milk is incompatible with ghee-making because its fat globules are too tiny, creating issues with the separation process and the resulting aroma and flavor. Baby formulas made from goat milk are of high quality. Yoghurt, cheese, evaporated milk, ultra-high-temperature milk, ice cream, milk powder, pasteurized beverages, and traditional milk products are made from goat milk (Faccia et al. 2020; Saleena et al. 2022b). This trend toward using goat milk in product manufacturing is likely attributable to the milk's well-documented functional properties and health benefits. Yet, goat milk produces an unpleasant "goaty" or "muttony" taste. Furthermore, because goat milk is low in folic acid, it is necessary to augment replacement diets with folic acid when goat milk products are used (Sousa et al. 2019; Lund and Ahmad 2021).

Lactic acid bacteria as a probiotic starter culture increase intestinal microflora, lactose intolerance, immune system activation, antibacterial activity, anti-tumor, anti-cholesterolemic, and antioxidative capabilities (Kok and Hutkins 2018). The rising demand for nutritious foods has prompted the creation of cutting-edge scientific items in the food business. Many studies have been done on fermented milk (Quigley et al. 2013; Lejaniya et al. 2021b; Saleena et al. 2022a). Many anecdotal reports of positive health effects from consuming goat milk suggest this may become the next big thing in probiotic fermented milk. Fermented goat milk (*Lactobacillus fermentus* ME-3) has antioxidative and antiatherogenic effects in healthy people (Chauhan et al. 2021). Fermented goat milk containing a mixed starter culture (*Lactobacillus helveticas* PR4, *Streptococcus thermophilus* CR12, and *Lactobacillus plantarum* 1288) reduced hypertension by producing GABA (gamma amino-butyric acid) as an inhibitory neurotransmitter in the central nervous system (Kok and Hutkins 2018; Mirzaei et al. 2022). Recently, it has been demonstrated that consuming fermented goat milk (*Lactobacillus rhamnosus* CRL1505) can improve mucosal immunity and resistance to intestinal and respiratory infections in an immunosuppression mouse model. As previously established, goat milk has a nearly non-existent folic acid level. This issue could be addressed in fermented food by including microorganisms that produce folate during fermentation. Goat milk fermented with a combination of *Lactobacillus delbrueckii* subsp. *Bulgaricus* and *Streptococcus thermophilus*, making a yoghurt having high folate content and favorable sensory qualities (Quigley et al. 2013; Kumar et al. 2016; Saleena et al. 2022b).

Researchers conclude that goat milk can potentially serve as a neutraceutical health beverage. Those who are intolerant to or allergic to the proteins in cow's milk can get what they need from goat's milk (Lejaniya et al. 2021a). Anyone with anemia, osteoporosis or malabsorption issues might also benefit from consuming goat milk. Due to its purported health benefits, goat milk's popularity and demand have soared in recent years. Children and infants benefit more from goat milk than cow's milk; however, parents should be aware that goat milk is low in essential nutrients like folic acid (Lund and Ahmad 2021; He et al. 2022).

4 Conclusion and future perspectives

This review report suggests that goat milk's nutritional value and flavor make it a good substitute for cow and human milk. Due to its high fat, protein, mineral, and vitamin content, goat milk is healthy for all ages. Goat milk's medicinal potential, ease of digestion, and buffering capacity make it a popular ingredient in many products. To a chemical degree, goat milk is equivalent to, if not superior to, human and cow milk. Goat milk's functional and nutritive properties can help with various human health and wellness aspects, including expansion, maturation, and upkeep. Goat's milk, unlike cow's milk, is better for infants, the elderly, and anyone recovering from illness or injury because of its higher nutrient content and nutraceutical characteristics. Goat milk is highly relevant to the food sector because of its number of bioactive compounds and its multiple physiological roles. Dengue, cardiovascular disease, immunological problems, etc., are only some chronic disorders that can benefit from this therapy method. As we have seen, goat milk has many advantages over other milks, including cow and human milk. The above benefits explain why goat milk has become more popular than cow and human milk. Due to its exceptional nutritional, therapeutic, nutraceutical, and physiological benefits, goat milk should be promoted in areas with high rates of poverty and a poorly functioning health sector, where malnutrition is of the most concern.

The unique characteristics of goat milk have led to extensive study of its nutritional value and the effects it may have on health. Goat milk, on average, does not differ significantly in composition from cow milk. Research is needed to find ways to mask the "goaty flavor" of goat milk, which turns off many potential consumers. Goat milk's medicinal components, fatty acid profile, and ease of digestion all point to it being a potential treatment or preventative measure for various health problems. Researchers have found that goat milk appears to help with their animal models of malabsorption disorders and inflammatory bowel diseases. There is some evidence that drinking fermented goat milk can lower the

danger of cardiovascular disease. Goat milk is highly cross-reactive with cow milk; hence cow milk allergy sufferers should avoid it. Most studies conduct their analyses on animals to extrapolate their findings to human subjects. Although there is some evidence that consuming goat milk products is beneficial, more research is needed.

Goat milk appears to have features that make it helpful in treating or avoiding certain medical diseases due to its high digestibility, balanced fatty acid profile, and abundance of bioactive chemicals. Animal studies suggest that goat milk may help with malabsorption and inflammatory bowel diseases. Fermented goat milk's antioxidant and antiatherogenic qualities may reduce cardiovascular disease risk. Due to severe cross-reactivity, goat milk is not recommended for cow's milk allergy sufferers. Most animal research shows prospective results. Goat milk products' health advantages need human research.

Even if there is still a lot to understand about goat milk, it is evident that it provides an alternative to those looking for dairy-free options. According to compositional analysis, infant formulae made from whole goat milk that maintains milk fat and is enriched with essential fatty acids, lactose, and vitamins can meet compositional parameters without whey. Clinical trials have shown that a formula produced with whole goat milk proteins and lipids is safe and effective. Goat milk is distinct from cow milk in many important respects, including composition and function, and these differences may be significant when evaluating the biological role goat milk plays for humans. Growing evidence from animal studies, for example, suggests that goat milk may alter the gut microbiome and immunological pathways important in allergy treatment in a way distinct from that of cow's milk. These results are significant for infants because of the immaturity of their digestive and immunological systems at birth.

Further clinical trials and translational studies are needed to verify the beneficial effects of this treatment on babies' gastrointestinal health and eczema. Current knowledge originates from either in vitro or animal trials. Further human studies are needed to compare the gut microbiota profile of infants fed goat or cow milk formula and assess whether adding natural milk oligosaccharides to goat milk formula improves microbiome diversity.

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