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Therapeutic properties of milk from goats (*Capra hircus*)

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Abstract

The goat (Capra aegagrus hircus) is an economically accessible animal and was the first animal to be domesticated. The ample nutritional and health benefits of goat milk are the paramount factors that drew consumers to use goat milk and milk products as functional foods. The superior digestibility of goat milk is the key factor that led to the extensive usage of goat milk as an alternative to cow milk for infants who suffer from the shortage of mother's milk. Goat milk demonstrated positive health effects, viz., immunomodulating, immunity boosting, anti-allergic, antiatherogenic, anti-carcinogenic, antimicrobial, anti-inflammatory and anti-mucousal, lactose intolerance, dengue viral fever overcoming, heart health, nutrient uptake enhancing, prebiotic supplementing and ultra-nourishing.

Keywords: Anti-allergy, Dengue viral, Goat milk, Immunity, Medicinal value, Therapeutic properties.

Introduction

The goat (*Capra aegagrus hircus*) is an economically accessible animal and was the first animal to be domesticated. Their extensive adaptability to unfavourable climatic or geographical conditions and low cost of maintenance have made them a flexible species of livestock for marginalized and landless farmers. Hence, goat milk has been suggested as an alternative source of milk for infants due to its similar composition to human milk and its improved nutraceutical properties (Kumar et al., 2016). Furthermore, factors such as amino acid composition, protein secondary structures, and the chemical properties of goat's milk significantly reduced the potential for allergic reactions compared to cow's milk (Clark and García, 2017).

Data Collection Methods

A thorough search of the existing literature was conducted using a range of scientific databases, including Biological Abstracts, CABI, Cochrane Library, Google Scholar, PubMed, Research Gate, Science Direct, Science Hub, and Scopus. The search terms used included Anti-allergy, Dengue viral, Goat milk, Immunity, Medicinal value, Therapeutic properties and others. The author also gathered relevant data from primary and secondary sources. Consequently, this review focuses on the collection on the latest information related to the therapeutic properties of milk from goats (*Capra hircus*).

Therapeutic properties of goat milk

Immunomodulating properties

The immunomodulatory properties of goat milk can be attributed to the compounds like peptides and oligosaccharides that were reported to modulate host inflammatory cytokines (Daddaoua et al., 2006). Milk can trigger innate and adaptive immune responses in the human body that can help fight inflammation (Jirillo and Magrone, 2014). Lara-Villoslada et al. (2006) stated that oligosaccharides from goat's milk reduce inflammation in the intestines of rats and aid in the healing of damaged colonic mucosa. In a live mouse model, goat milk protein blocked the NF-κB p65 and p38 MAPK signaling pathways which subsequently reduced the gene expression of different pro-inflammatory indicators. Also, goat whey increased the expression of proteins such as mucins and occludin proteins that increase gut barrier properties (Araujo et al., 2017).

Immunity boosting properties

Selenium is one of the key components of the immune system's functionality. A small amount of selenium is found in cow's milk, but a significant amount of the same is found in goat's milk. Hence, goat milk and its products act as immunity boosters and are able to protect an individual from illness.

Many types of cells are involved in the innate and adaptive immune responses, with T-lymphocytes (T-cells), Natural Killer (NK) cells, and B-lymphocytes (B-cells) as the main players. Even though immunoglobulins (Ig) have a comparable structure, slight variations within the primary immunological categories (IgG, IgM, IgA, IgD, and IgE) are linked to a range of biological characteristics, and IgG and IgA make up the bulk of serum immunoglobulins. A number of factors influence our immune health, and nutrition in particular is the main determinant of the body's immune response.

Even if goat milk might not be a perfect alternative for people with cow milk allergies, very recent studies have shown immunomodulatory effects from goat milk in both *in vitro* and human studies. Recently, researchers investigated the effects of goat milk on human blood cells in terms of nitric oxide (NO) and cytokine release. The results demonstrated that goat milk was able to activate NO release from blood cells as well as trigger cytokine production (IL-10, TNF-a, and IL-6). The release of NO may potentially have protective effects on the milk consumer's cardiovascular system and also exhibit antibacterial properties, thereby reducing the risk of infections.

Anti-allergic properties

Anti-allergic and improved digestibility characteristics Allergy to milk proteins, particularly cow's milk, is an unfavourable reaction to milk consumption that is

inherently immunomodulatory and categorized as IgE-mediated, non-IgE-mediated, or mixed (Fiocchi et al., 2010; Koletzko et al., 2012). Cow milk allergies are commonly observed during the first 3 years of human life. This is because the presence of α-S1-casein, β-casein, and β-lactoglobulin in milk leads to allergic reactions (Ruiter et al., 2006). The N and C-terminal peptides of cow's α-S1-casein (16–35 aa and 136–155 aa) have a greater affinity for IgE, while the epitopes 17–36, 39–48, 69–78, 93–102, 109–120, 123–132, 139–154, 159–174, and 173–194 were identified as IgE ligands in children (Vila et al., 2001). In contrast, studies have indicated that the utilization of goat milk has resolved between 30 and 40% of the cases (Haenlein, 2004). Haenlein (2004) reported that 40–100% of allergic patients were sensitive to cow's milk proteins and were able to tolerate goat's milk proteins. The genetic variation that exists in the proteins between the different species supports the potential usage of goat milk as a substitute for cow's milk during allergic conditions. Moreover, the consumption of goat's milk has been demonstrated to trigger natural and acquired immune reactions in the human body, while simultaneously preventing the activation of monocytes in the host caused by endotoxins (Jirillo and Magrone, 2014).

The better digestibility of goat's milk in comparison with cow's milk is related to the differences in the fatty acid (FA) composition. The smaller size of the fat globules in goat milk is one of the factors that increases its digestibility. In addition, the proportion of small-sized casein micelles is higher in goat's milk than that of cow's milk, which explains the better digestibility of goat's milk and its dairy products (Park et al., 2007). Goat milk contains a relatively lower amount of α-s casein and often has more αs2 than αs1-casein. Furthermore, the β-casein and kappa-casein are present in higher quantities in goat milk compared to cow milk, resulting in the formation of a less firm gel. This characteristic is advantageous for improved digestibility (Lad et al., 2017).

An allergy is defined as an altered or abnormal tissue reaction following exposure to a foreign antigen (McCullough, 2003). It is well known that proteins are essential for body functions like growth, development, and repair. They are the most common antigens. Infants are most commonly sensitive to proteins, with about 2–6% incidence (Lara-Villoslada et al., 2004). Some research shows that cow milk intolerance is often due to alpha-s-1 casein. It is interesting that the level of alpha-s-1 casein in goat milk is 89% lower than that of cow milk. As a result, it causes fewer allergies; goat milk has demonstrated advancements in colic, minor gastrointestinal issues, bronchial asthma, and dermatitis compared to cow milk, particularly for individuals with sensitivities to cow milk (McCullough, 2003).

Goat milk provides more immunological advantages by decreasing specific markers linked to allergic responses (Lara-Villoslada et al., 2004) in mice compared to cow milk, like the cytokine interleukin-4 (IL-4) and antigen-specific immunoglobulin G1 (IgG1), essential markers in hypersensitivity reactions. IgG1 attaches to mast cells and stimulates degranulation (the initiation of an allergic response), leading to an increase in histamine levels and subsequent allergic symptoms. This response to cow milk differed from goat milk, which did not elicit an allergic reaction. It is demonstrated that there are disparities in IgG1 (A) and

histamine (B) production when cow milk is administered compared to goat milk.

Goat milk proved its anti-allergy benefits upon drinking when a similar trial in children with cow milk protein allergies was conducted. Drinking cow milk had significantly higher levels of the inflammatory marker tumour necrosis factor-α (TNF-α) than those who consumed goat milk. TNF-α is a primary mediator of adverse reactions to cow milk protein, including gastrointestinal distress, respiratory distress, and cutaneous symptoms such as eczema. Furthermore, apart from the absence of inflammatory reactions linked to the intake of goat milk, individuals who consumed goat milk also exhibited elevated levels of the anti-inflammatory cytokine IL-10. This cytokine hinders the production of pro-inflammatory cytokines like TNF-α and is believed to play a role in immune suppression, thereby preventing responses to cow milk antigens. The findings highlight the contrasting impact of cow's milk and goat's milk on these markers of allergenicity.

Antiatherogenic properties

Goat's milk is abundant in medium-chain triglycerides (MCT), which encompass fatty acid esters of caproic, caprylic, and capric fatty acids. These MCT have demonstrated a cholesterol-lowering impact in rat models (Alferez et al., 2001) and also hinder the accumulation of cholesterol in tissues (Babayan, 2009). Consumption of goat's milk stimulates the release of nitric oxide (NO) by blood cells, which subsequently enter the bloodstream through the lymphatic pathway. This prompts vasodilation and exerts a protective effect on the heart and arteries. Additionally, goat's milk contains lower levels of xanthine oxidase, an enzyme that serves as an indicator of inflammation and contributes to heart disease (Alférez et al., 2001). Moreover, several studies have also suggested the ACE inhibitory potentiality, anti-oxidative property, and cholesterol-lowering ability of goat milk-derived peptides and fats (Ibrahim et al., 2017; Moreno-Montoro et al., 2017), therefore indicating their possible role in controlling coronary artery diseases (CVD).

Anti-carcinogenic properties

The anti-carcinogenic properties of goat milk have been studied against mammary and colon cancer in animal models as well as *in vitro* in human melanoma, colorectal, and breast cancer cells (Ceballos et al., 2009; Johansson, 2011). The mechanism by which conjugated linoleic acid (CLA) inhibits tumour development is not fully understood. Additionally, several lactic acid bacteria that are isolated from goat milk have also been reported to demonstrate anticancer effects (Mittu and Girdhar, 2015), therefore suggesting the use of goat milk-derived LAB for the preparation of fermented milk products that impart the same therapeutic properties that the bacterial strains possess.

Goat milk has a high content of conjugated linoleic acid (CLA) (Jirillo et al., 2010). Anticarcinogenic properties of CLA have been reported against mammary and colon cancer (Liew et al., 1995) in animal models, as well as *in vitro* models of human melanoma (Shultz et al., 1992), colorectal, and breast cancer. The mechanism by which CLA inhibits tumour development is not fully understood, although perturbation of the eicosanoid-dependent cell signalling systems, anti-oxidative effects, and disturbance of the receptor-mediated actions of oestrogen have all been suggested by fermented goat milk (Jirillo et al., 2010).

Antimicrobial properties

The overall inhibitory impact of milk is generally higher than the combined antimicrobial effects of immunoglobulin and other defense proteins, such as lactoferrin, lactoperoxidase, lysozyme, and other peptides. Therefore, the cooperative effect of naturally occurring proteins and peptides provides the antimicrobial effect. In this context, lactoperoxidase has been discovered to possess inhibitory activity against a wide range of pathogens, including Vibrio cholera, Salmonella typhi, Klebsiella pneumoniae, Shigella dysenteriae, and Staphylococcus aureus (Moreno-Montoro et al., 2017). Similarly, several antimicrobial peptides like isracidin and lactoferricin from goat milk have been isolated and have been effective against several disease-causing and spoilage organisms (Atanasova and Ivanova, 2010).

Anti-inflammatory and anti-mucousal properties

Cow milk may be responsible for the allergens because of its protein fractions, while goat milk is not. On the other hand, along with these, cow milk contains a higher content of fat than goat milk, which may increase mucous buildup. Goat milk does not provoke discomfort in the digestive tract because the magnitude of the fat droplets in goat milk is one-ninth the magnitude of cow milk fat droplets.

Goat milk plays a pivotal role in nearly all physiological responses and exerts antioxidant and anti-inflammatory impacts in the organism. This is significant as inflammation is the organism's main reaction to infection, and oxidation has been associated with the emergence of numerous ailments, including cancer. Furthermore, other factors, such as the maintenance of a healthy intestinal microflora with the help of probiotics and prebiotics (Also contained in goat milk), are essential for protecting against the negative effects of pathogenic infections and allergies (Shea et al., 2004).

Lactose intolerance properties

Goat milk contains a slightly lower lactose content than cow milk. Lactose intolerance is caused by a deficiency of lactase, which digests the milk sugar Lactose. In patients suffering from lactose intolerance, unhydrolyzed lactose passes to the large intestine. In the large intestine, this unhydrolyzed lactose is fermented by microbes, leading to gas formation and the release of free fatty acids, which cause gastrointestinal disturbances such as diarrhoea, abdominal pain, and flatulence (Russell et al., 2011). Anecdotal report indicates that goat milk is simple to process due to its gentler coagulation. The casein profile of goat milk allows lactose to pass through the large intestine more quickly and prevents the symptoms of lactose intolerance (Robinson, 2001). However, goat milk is not recommended for patients suffering from lactose intolerance. Along with its digestibility, it explains why patients with lactose intolerance can enjoy goat milk without any repercussions.

Haenlein (2004) stated that therapy with goat milk generally resolves 30–40% of difficult instances of childhood cow milk hypersensitivity, which may be greater in certain circumstances (One study demonstrates enhancements in 89 per cent of 55 children treated with goat milk).

The inability to metabolize lactose (essential milk sugar) leads to lactose intolerance, which is a gastrointestinal disorder. Goat milk is an alternative source for people with lactose intolerance. Although goat milk has lactose, it has been

hypothesized that the superior digestibility of goat milk relatively masks its intolerance effect (Johansson, 2011); however, it needs to be further studied. Goat milk is more thoroughly and readily assimilated than cow milk, resulting in a smaller amount of undigested waste in the colon to ferment and trigger the unpleasant symptoms of lactose intolerance (Haenlein, 2004; Aliaga, 2010).

Dengue viral fever Overcoming properties

Dengue fever is the most prevalent major health issue (viral illness) in India. *Aedes aegypti* transmits the virus to humans (Neuberger et al., 2016). Treatment of dengue fever typically involves the consumption of goat's milk and dairy products as they are abundant in selenium (Se) (13.7 ng/mL). However, the selenium (Se) content in the milk is influenced by various factors such as diet, climate, and breed (Singh and Sharma, 2016; Zhang et al., 2018). A deficiency of selenium has been linked to a decrease in platelet count, which is a crucial indicator of the onset of dengue fever. Selenium has an anticoagulant effect, while a deficiency of selenium is primarily associated with thrombotic or pro-clotting effects (Mahendru et al., 2011).

Heart health properties

Low-density lipoprotein (LDL) is an atherogenic lipoprotein that transports cholesterol from the liver to the blood vessels and is often called "The bad cholesterol". The "good" cholesterol is the high-density lipoprotein (HDL), which transports cholesterol from the vessels to the oxidative modification of LDL (ox-LDL), which plays a pivotal role in atherosclerosis progression. This implies that antioxidants, which could inhibit LDL oxidation, should be effective in suppressing atherosclerosis (Lindqvist, 2008).

Proteins in goat milk are important sources of the angiotensin-converting enzyme (ACE), antihypertensive peptides, and inhibitory peptides. They are able to control microbial infections and also provide disease defense.

Minor milk proteins include immunoglobulins, lactoferrin, transferrin, proteose peptone, ferritin, calmodulin (a calcium-binding protein), prolactin, and folate-binding proteins. Non-protein nitrogen (NPN) in human and goat milk is higher than that in cow milk. Taurine in goat milk, which is obtained from the sulfur-containing amino acid, has significant metabolic roles, just like carnitine, a vital nutrient for newborns. The mineral and vitamin content of goat milk is mostly higher than that of cow milk (Park et al., 2007).

Goat milk is better than cow milk in monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), and medium-chain triglycerides (MCT). These are beneficial for cardiovascular conditions. Along with these, goat milk has a lower level of cholesterol than cow milk (Haenlein, 2004). Because of the balanced fatty acid profile of goat milk, it helps prevent atherosclerosis, heart attacks, strokes, and other heart complications. The high potassium content of goat milk reduces blood pressure.

Goat milk demonstrates a hypocholesterolemic impact. The consumption of goat milk decreases plasma triglycerides and therefore has a beneficial influence on lipid metabolism (Lopez-Aliaga et al., 2005). Goat milk is said to lower the overall cholesterol level and

maintain sufficient triglycerides and transaminases (glutamate oxaloacetate transaminase (GOT) and glutamate pyruvate transaminase (GPT)—markers for liver poisoning). This renders goat milk valuable in managing and preventing coronary heart diseases (CHDs).

Nutrient uptake enhancing properties

As the chemical composition of goat milk is much closer to that of human milk, it easily assimilates into the body. Therefore, it enhances the bioavailability of the nutrients present in it. The authors reported that goat milk consumption increases the uptake of Iron and Copper in the digestive tract.

Prebiotic supplementing properties

Goat milk has the same high level of oligosaccharides as human milk and cow milk. It is well known that these act as prebiotics in the gut and improve the health of the digestive tract (Raynal-Ljutovac et al., 2008). They are responsible for the beneficial bacteria, i.e., *Bifidobacteria*, in the intestine. *Bifidobacteria* exert a wide range of health benefits, including immune stimulation, prevention of pathogenic infections, anticarcinogenic activity, and cholesterol-lowering activity, in addition to improving lactose maldigestion (Russell et al., 2011).

Ultra-nourishing properties

The goats are recognized as bioorganic sodium animals, while cows are referred to as calcium animals in naturopathic medicine, Bioorganic sodium is a crucial element in maintaining mobile and flexible joints. Goat milk provides 35% of the calcium that we need in a cup. Additionally, just one cup of goat milk can fulfill up to 20% of our daily riboflavin requirements. Along with phosphorous, goat milk also contains high levels of potassium and Vitamin B_{12}.

Goat milk enhances the availability of Zn, a mineral with antioxidant capacity (Zago and Oteiza, 2001). The improved nutritive utilization of goat milk fat (Alferez et al., 2001) results in a lower substrate for lipid peroxidation, which in turn reduces the production of free radicals in this type of milk. This explains why the group of animals consuming goat milk had lower levels of TBARS. The habitual consumption of goat milk, even during Fe-overloading feeding regimes, may positively impact genomic stability, possibly due to the high availability of Mg and Zn (Diaz-Castro et al., 2009), as well as its superior fat quality (Alferez et al., 2001). Magnesium metabolism plays a role in enhancing genomic stability through the following mechanisms: DNA is constantly damaged by external mutagens and internal processes. To keep mutation frequencies low, cells have developed various DNA repair systems. Nucleotide excision repair is primarily responsible for removing DNA damage caused by external mutagens, and Mg is an essential cofactor in all steps of this repair process. Additionally, endogenous DNA damage is mainly repaired through base excision repair (BER) (Hartwig, 2001).

Conclusion

The ample nutritional and health benefits of goat milk are the paramount factors that drew consumers to use goat milk and milk products as functional foods. The composition of goat milk does not reveal greater variations as compared to cow milk, whereas it shares few similarities with human milk composition. Besides, the superior digestibility of goat milk is the key factor that led to the extensive usage of goat milk as an alternative to cow milk for

infants who suffer from the shortage of mother's milk. In addition, several studies conducted on in vitro and in vivo animal models have demonstrated positive health effects, viz., anticancer, anti-inflammatory, antiatherogenic, anti-allergenic, and so on. According to the reviewed literature, goat milk has the potential to act as nutraceuticals in combination with conventional medical treatment. However, further clinical trials are needed to explain their therapeutic benefits.

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