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## Review Article

**Goat Milk: A Rich and Unique Source of Nutraceuticals****Krishanu Samanta<sup>a\*</sup>, Amrita Jain<sup>b</sup>**<sup>a\*</sup> School of Pharmaceutical Sciences, Lovely Professional University, Phagwara, India<sup>b</sup> Delhi Transport Corporation, New Delhi, India**Article Info***Article history:*

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**ABSTRACT**

Goat milk is one of the major contributors of dairy products as 2% of the total world demand for milk depends upon goats. The presence of proteins, vitamins, minerals, amino acids, fatty acids, potentiates the nutritional value of goat milk. Goat milk is an alternative source of milk for the people who are intolerant and allergic to cow milk. Nowadays, both goat milk and its isolated derivatives like probiotic lactic acid bacteria, casein, fatty acids (taurine, glycine and glutamic acid) are being used to treat various health conditions. Clinical and preclinical studies on goat milk provide evidence that it is useful in the treatment of different diseases like dengue fever, cancer, iron deficiency anemia, infertility in males, atopic dermatitis, and hypertension. Goat milk has significant antioxidant, anti-inflammatory and antimicrobial activities due to which it has wide therapeutic applications. Considering the wide therapeutic benefits of goat milk and its constituents, awareness regarding these should be enhanced.

**INTRODUCTION**

Milk is secreted by the mammary glands of mammals. Primarily, it is a liquid food which provides nutrients to infant mammals. But due to its nutrient rich composition, it is also consumed by humans worldwide as a food product. For human consumption, generally milk is extracted from farm animals like buffaloes and cows. Alternatively, other livestock like goats, sheep, camels, donkeys, horses, reindeers and yaks are also used by humans for dairy milk production. Cows' milk dominates commercial production and approximately 85% of all milk worldwide is produced from cows<sup>[1]</sup>. On the other hand, only 2% of the total world demand for milk depends upon the goats.

Goat-milk is obtained from female goats (*Capra aegagrus hirus*) belonging to family Bovidae. It contains proteins, vitamins, lipids, carbohydrates and minerals. Its nutritional composition is almost similar to cow-milk. It is easily available and digestible also. It is less allergenic and is better tolerated by people who are allergic or intolerant to cow-milk. So, it is considered as an alternative to cow milk for the allergic persons<sup>[2]</sup>. Goat milk has acid neutralizing properties as well as therapeutic importance in different ailments which makes it different from human and cow milk. Another important property of goat milk is its low-fat content, its higher buffering capacity and ability to neutralize toxins

present in the body. In comparison to the cow and human milk, goat milk has more levels of calcium, potassium, phosphorous, non-protein nitrogen and has simple (diacylglycerols, monoacylglycerols, cholesterol) and complex (phospholipids) lipids, liposoluble (sterols, hydrocarbons) compounds [3]. Because of all these properties it can be regarded as a natural nutritional food or an alternative meal. This review article focuses on the nutritional as well as therapeutic benefits of goat milk consumption.

#### NUTRITIONAL COMPOSITION OF GOAT MILK

Goat milk is considered a nourishing food due to its significant nutritional value. It is a rich source of calcium and phosphate. It contains proteins, lipids, carbohydrates, vitamins and minerals. However, the composition of milk varies according to various factors like age, breed, species, stage of the lactation, changes in diet, disease or environmental conditions etc. Goat milk is used as a substitute for a number of the supplements and regarded as a health drink [4]. Table 1 compares the nutritional composition of goat, cow, human and camel milk.

**Table 1:** Average composition (%) of milk from different species.

S. No.	Average composition per 100 g	Species			
		Goat	Cow	Human	Camel
1	Water	87	87.20	87.43	81.4-87
2	Fat	4.25	3.70	3.75	3.5
3	Proteins	3.52	3.50	1.63	3.1
4	Vitamins				
	Vitamin A (IU)	185	126	190	26.7
	Vitamin D (IU)	2.3	2	1.4	0.3
	Thiamine (mg)	0.068	0.045	0.017	0.048
	Riboflavin (mg)	0.21	0.16	0.02	0.168
	Niacin (mg)	0.27	0.08	0.17	0.77
	Pantothenic acid (mg)	0.31	0.32	0.20	0.368
	Vitamin B6 (mg)	0.046	0.042	0.011	0.55
	Folic acid (µg)	1	5	5.5	87
	Biotin (µg)	1.5	2	0.4	-
	Vitamin B12 (µg)	0.065	0.357	0.03	85
	Vitamin C (mg)	1.29	0.94	5	33
5	Lactose	4.27	4.90	6.98	4.4
6	Ash	0.86	0.70	0.21	0.79
7	Solid non-fat (SNF)	8.75	9.10	8.82	11.9
8	Total solids	13.00	12.80	8.82	11-16
9	Moisture	87.38	86.7	86.47	87.05
10	Total Carbohydrates	4.44	4.98	8.04	4.67
11	Total Energy	67.36	71.06	74.13	70.1

#### GOAT MILK AND MILK PRODUCTS

Goat milk is available as whole raw milk, homogenized milk, pasteurized milk, skimmed milk [5]. Nowadays, availability of

pasteurized goat milk which is free from any flavour and odour has increased its acceptance amongst consumers. Apart from this, special goat milk beverage fortified with vitamins is

also available. Infant food and dairy products derived from goat milk like cheese, yoghurt and ice cream are also getting popular among consumers [6].

## THERAPEUTIC SIGNIFICANCE OF GOAT MILK

### Antioxidant And Anti-Inflammatory Properties

Excessive production of reactive oxygen species leads to oxidative stress which is a major mechanism underlying the pathogenesis of various diseases initiate such as atherosclerosis, diabetes, rheumatoid arthritis, and cancer [7]. It has been reported that goat milk possesses antioxidant, anti-inflammatory and immunomodulatory properties. Therefore, goat milk is considered beneficial in various acute and chronic diseases. Food-derived peptides and food protein hydrolysates have been investigated as natural and safe antioxidants [8]. Oligopeptides derived from goat milk casein hydrolysates (GMCH) have shown significant antioxidant activity. In another study Araujo et al. examined the anti inflammatory effect of goat whey on DNBS-induced colitis. Colitis inflammation was induced by 2,4-dinitrobenzenesulfonic acid in experimental mice . The outcomes of the study revealed that goat whey at the dose of 4g/kg/day inhibit the level of various proinflammatory markers such as IL-1 $\beta$ , IL-6, IL-17, TNF- $\alpha$ , iNOS, MMP-9, ICAM-1 with increased the expression of proteins such as mucins, occludin proteins and cytokine signalling suppressors. In addition murine macrophage cell line Raw 264 and CMT-93 cells were also used for the study of immunomodulatory properties of goat whey [9].

Some researchers also reported that oligosaccharides derived from goat-milk are also anti-inflammatory in nature. They prevent the growth and translocation of pro-inflammatory bacteria but enhance the growth of healthy bacteria [10].

### Antimicrobial Properties

Continuous rise in cases of development of resistance by various pathogenic bacteria against the available synthetic antibiotics has led to the failure of antibiotics. Due to this there is urgent need to develop some new antibiotics derived from natural sources. Caprylic and capric acids (C8 & C10) are high level medium chain fatty acids present in the goat milk. These fatty acids possess the antimicrobial activity against the *Candida albicans* and other yeast species [11]. Milk

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proteins may serve as presursors for antimicrobial peptides. Lactoferrin presents in the goat milk act as starting material for the synthesis of various antimicrobial peptides. Lactoferrin possesses various physiological functions, but it also has anti-oxidant and anti-inflammatory properties. Strains of lactic acid bacteria (LAB) present in goat milk have shown activity against various microorganisms [12].

### Treatment of Gastrointestinal Diseases

Various oligosaccharides present in the goat milk possess anti-inflammatory properties. Due to this, goat milk can be used for the treatment of inflammatory bowel disease. It not only prevents the various complications of this disease, but also reduces its clinical symptoms such as diarrhea and blood stools. Previous studies have shown that oligosaccharides derived from goat-milk produce anti-inflammatory effects in rats with experimental colitis [13]. Another study showed that goat whey reduced inflammation due to abundance of conjugated linoleic acid and oligosaccharides in it [14].

### Treatment of Dengue Fever

In dengue fever, mainly decrease in platelet counts takes place. In severe cases, platelet transfusions are required [15]. Goat milk has been reported to be beneficial in the dengue patients because of the presence of selenium (Se) in it. Se, maintains body fluid balance because transfusion of platelets is not possible from outside in all cases [16].

### Iron Deficiency Anemia

Studies have shown that dairy products interfere with the iron absorption due to the presence of calcium in it. Both calcium and iron act on the intestinal divalent metal transporter-1 for their absorption. According to a study conducted in rats, goat milk diet improves iron status and increases red blood cell count. This is due to presence of more soluble casein proteins as well as more amount of medium chain triglycerides in goat milk that undergo the metabolism, and the metabolized product enhance the synthesis of carrier protein that results in more absorption of iron. Similarly, higher concentration of vitamin D in goat milk has also been held responsible for its effectiveness in iron deficiency anemia because vitamin D favours the absorption of iron by increasing the concentration of iron binding protein known as mobilferrin [16-18].

### Cardiovascular Diseases

Deposition of atherosclerotic plaque in the walls of coronary arteries is leading cause of various cardiovascular diseases. Pathophysiological mechanism behind the formation of atherosclerotic plaque is the accumulation of low-density lipoproteins (LDL) on the arterial walls. High density lipoprotein is known as good cholesterol as it decreases the formation of atherosclerotic plaque by enhancing the oxidative modification of LDL. Goat milk very effectively decreases the levels of LDL and stimulates the oxidative modification of LDL as it is rich source of antioxidants such as flavonoids and carotenoids. Goat milk is rich source of fatty acid esters of caproic, caprylic and capric and medium chain triglycerides. These fatty acids esters and medium chain triglycerides decrease the deposition of cholesterol in the tissues [18]. Another study has reported that various constituents of goat milk enhance the production of nitric oxide which causes vasodilation and thus exerts a cardio protective effect. Thus it can be concluded that goat milk is can be useful in the treatment and prevention of cardiovascular diseases [19].

### Hepatoprotective Effect

Goat milk is rich source of various antioxidant substances such as vitamin E and C, flavonoids and carotenoids. These physiological antioxidant substances present in goat milk has the potential capability to carry out the detoxification of various free radicals and to reduce the toxic effects to the liver induced by them. A recent study has reported that consumption of goat milk improves biliary-composition as well as hepatic-antioxidant defense mechanism. A study investigating the effect of goat milk and soybean milk in hepatocarcinogenesis in rats reported that activities of enzymes gamma-glutamyl Transpeptidases (GGT) and alkaline Phosphatase (ALP) got decreased in hepatocarcinogenic rats after administration of after administration of soybean and goat milk. The study indicated that both types of milk may be beneficial in hepatocarcinogenesis as anti-cancer agents. Due to potential anti-oxidant activity, goat milk has been investigated as hepatoprotective agent against the antitubercular drug-induced hepatotoxicity [20].

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### Anticarcinogenic Activity

*In vivo* and *in vitro* studies have been carried out to detect the pharmacological action of goat milk against cancer. *In vivo* studies have concluded that *Caseous Lymphadenitis* (CLA) present in the goat milk exhibits anti-carcinogenic activity against the mammary and colon cancer. The complete pharmacological mechanism by which the CLA present in the goat milk shows anti-cancer activity is still unclear. However, it has been suggested that CLA exhibits the anti-cancer activity by its antioxidant properties and by disturbing the eicosanoids cell-dependent signaling system. Lactic acid bacteria (LAB) present in the goat milk also has significant role in the cancer prevention [21].

### CLINICAL SIGNIFICANCE OF GOAT MILK

#### Hypertensive Activity

Inadequate level of calcium in the body due to insufficient intake of calcium in the diet or due to severe alterations in the metabolism of calcium may be a pathogenic factor for hypertension (Table 2). [22-24]. Abundance of calcium in the goat milk is supposed to decrease the level of increased blood pressure but there was no scientific evidence for it. In 2016, a randomized clinical trial was conducted to evaluate the potential of goat milk for the prevention of hypertension in sedentary women. The main aim of this study was to evaluate the effect of goat milk on hypertension and to analyze the efficacy of goat milk as an anti-hypertensive agent. Results demonstrated that administration of goat milk significantly reduced the level of systolic blood pressure in the trial group as comparison to the control group [25-26]. Average value of level of calcium in patients treated with goat milk also get significantly increased as comparison to the patients left untreated which gives evidence to the hypothesis that goat milk reduces the blood pressure in patients by increasing the level of calcium [27].

#### Nutritional Adequacy of Goat Milk

For the proper growth and development, it is very essential to give the appropriate nutritional diet to infants. Essential nutrients supplied by the mother milk are best source for the growth of infants [28]. But in certain situations when breast

feeding is not possible or breast milk supplied is not adequate for the growth of infants, then infant formula is used in such situation for the supplementation of the breast milk. First line of choice to supplement the breast milk is cow milk infant formula [29]. But the major problem associated with the cow milk is that majority of children are allergic to the cow milk. So, to overcome this allergy problem good alternative choice is the goat milk infant formula [30]. In 2013, Zhou et al. conducted double blind randomized clinical study to evaluate the nutritional adequacy of goat milk by comparing the growth in infants consuming the goat milk to the growth and development in infants who consumed cow milk. This study concluded that goat produces significant effect on the growth of infants; therefore, it can be used as a substitute to cow milk [31].

#### Treatment of Atopic Dermatitis

In 2008, Kaur et al. conducted randomized double blinded study to evaluate the effect of goat milk for the prevention of atopic dermatitis. Results of this clinical study indicated that level of diene conjugate got decreased in patients who

received goat milk and also there was significant decrease in the GSSG/GSH ratio in the skin and blood of patients. So, this clinical trial study suggested that goat milk may be effective in the treatment of atopic dermatitis [32].

#### Treatment of Rheumatoid Arthritis

A clinical trial conducted in patients of rheumatoid arthritis reported that goat milk plays preventive role in the treatment of rheumatoid arthritis by increasing the level of calcium and vitamin D [33].

#### Type 2 Diabetes Mellitus

In 2010, Luoto et al. carried out a double blinded placebo-controlled study in pregnant women with the probiotics fermented goat milk so as to determine their efficacy in preventing the occurrence of type 2 diabetes during their pregnancy. The results of this study provided evidence that administration of goat milk to the pregnant women during their first trimester of pregnancy can decrease the risk of frequency of gestational diabetes [34].

**Table 2:** Summary of preclinical and clinical studies conducted on goat milk

Area of investigation	Outcome of the study	Reference
<b>Preclinical studies</b>		
Antimicrobial activity	Alpha-S2 Casein (CSN1S2) protein derived from goat milk and yoghurt demonstrated anti-microbial activity against pathogenic bacteria involved in gastrointestinal infections.	[35]
	Lactic Acid Bacteria (LAB) from goat milk showed their antimicrobial activity through their antagonistic properties by inhibiting the spoilage and pathogenic microorganisms in food and carry out the stimulation of immune system and colonization through the process of adhesion.	[36]
	Antimicrobial activity of lactic acid bacteria (LAB) isolated from goat milk was evident. These isolates have a great potential as probiotics that can help in resisting pathogenic bacteria.	[37]
Antihypertensive activity	Goat milk yoghurt supplemented by probiotic and roselle extract inhibited the angiotensin converting enzyme (ACE) activity indicating its antihypertensive potential.	[38]
	Fermented goat milk demonstrated ACE inhibitory activity indicating its antihypertensive potential.	[39]
Iron deficiency anemia	Goat milk consumption enhanced the synthesis of carrier protein which increases the absorption of iron. This indicates effectiveness of goat milk in iron deficiency anaemia.	[40]
Anticancer activity	Anticancer effect of goat milk fermented by <i>Lactobacillus plantarum</i> and <i>Lactobacillus paracasei</i> .	[41]
Antioxidant activity	Oligopeptides derived from goat milk casein hydrolysates (GMCH) showed significant	[42]

	antioxidant activity thereby suggesting their potential as functional food ingredients.	
Hepatoprotective activity	Goat milk prevented hepatotoxicity induced by antitubercular drugs in rats thereby highlighting its hepatoprotective potential.	[43]
Gastrointestinal tract disorders	Oligosaccharides derived from goat milk reduced inflammation in experimental colitis.	[44]
Infertility	Goat milk provided protection against toxic effects of nicotine and improved sperm quality rats. Results suggested the possibility of using goat milk as a supplement to improve infertility among male smokers.	[45]
Rheumatoid arthritis	Protein isolated from goat milk attenuated the inflammation in rheumatoid arthritis.	[46]

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### Clinical studies

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Antihypertensive activity	Administration of goat milk significantly reduced the level of systolic blood pressure in the patients treated with the goat milk as compared to the control group patients who were left untreated.	[47]
Analysis of nutritional adequacy of goat milk	Goat milk produced significant effect on growth and development of infants as compared to the cow milk. This emphasizes the role of goat milk as a substitute to the cow milk for the growth and development of infants.	[30]
Atopic dermatitis	Results suggested that goat milk can be used for the prevention of atopic dermatitis as it is a rich source of various anti-oxidants which decrease the level of oxidizing species involved in the pathogenesis of the atopic dermatitis.	[32]
Malnutrition in infants	Results of this study indicated that nutritional value of goat milk is almost similar to the cow milk, so it can be used as an alternative to cow milk for the treatment of malnutrition in infants.	[48]
Osteoporosis in rheumatoid arthritis	Inclusion of goat milk in the diet produced a positive effect on bone metabolism and prevented osteoporosis in patients with rheumatoid arthritis	[33]
Type 2 Diabetes Mellitus	Results of a study conducted on pregnant women gave evidence that administration of goat milk to the pregnant women during their first trimester of pregnancy can decrease the incidence of gestational diabetes.	[34]

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### CONCLUSION

Goat milk is one of the valuable dairy products with wide commercial applications. Goat milk contains adequate amount of nutrients, bioactive peptides as well as lactic acid bacteria which provides a therapeutic potential to it. It is easily digestible and less allergenic also. It has significant antimicrobial, antioxidant and anti-inflammatory properties. Consumption of goat milk is useful in the treatment of dengue fever due to Selenium present in it. Fermented goat milk and bioactive peptides present in it are useful in the treatment of cardiovascular/gastrointestinal/hepatic disorders, rheumatoid arthritis, iron deficiency anemia and cancer. Preclinical as well as clinical trials conducted on whole goat milk and its

derivatives support the positive potential of goat milk in the treatment of various pathological conditions. Due to all these wide applications and therapeutic benefits, goat milk is recommended as a good nutritional supplement without any adverse health effects.

### CONFLICT OF INTEREST

None

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