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Composition, nutritional and therapeutic values of goat milk: A review

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ABSTRACT

Goat is one of the main contributors of milk and meat products. Goat milk is different from cow and human milk in composition, nutritional and therapeutic attributes. The compositional differences are of significance in indicating the technological suitability for goat milk processing and its products. The differences in composition of cow milk and goat milk may result into the products with different sensory characteristics, nutritional and therapeutic values. Goat milk contains higher amount of Ca, Mg and P than cow and human milk but vitamin D, vitamin B_{12} and folate contents are less. Goat milk is recommended for infants, old and convalescent people. Three fatty acids *viz*., caproic, caprylic and capric have great medicinal values for patients suffering from a variety of ailments. Further, it is worthwhile to compare the milk of goats with that of cows and note benefits or limitations which may result from differences found. Goat milk products other than cheese and pasteurized milk are considered to be the diary products with greatest marketing potential. Therefore, several characteristic of goat milk are currently the focus of increased research interest. Fermented goat milk incorporating live probiotic cells represent a group of products with great prospects in the future with regard to their nutritive and therapeutic properties.

Key words: Goat milk composition, Nutritional value, Therapeutic properties, Medicinal properties.

INTRODUCTION

Goat husbandry has been a part of agriculture since almost the first use of domestic animals and presently its popularity is increasing throughout the world, this increase is reflected to a greater degree by the rise in the number of small herds maintained by individuals either as a source of income or as an avocation. Goats form an important component of livestock industry and play a vital role in the socio-economic structure of rural poor (Park and Haenlein, 2006). Goats are particularly suited to this role because they have minimal land use and attention requirements yet still allow an individual to become actively involved in dairying. The goat's milk produced by such enterprise is typically sold as whole milk or processed in to cheese, evaporated milk or dried milk products. Because of this increased interest, it is valuable to be aware of the factors affecting the composition and nutritional value of caprine milk. Further, it is worthwhile to compare the milk of goats with that of cows and note benefits or limitations which may result from differences found. Cow milk is what comes to mind for most people when thinking about what to put on their cereal and for making cheese, yogurt, kefir, ice cream, and many other types of dairy products. Some may be surprised to learn that goat milk is very prevalent and commonly found on kitchen tables in many cultures around the world. Goat milk is as versatile as cow milk in just about every area. There are several factors that influence people in their personal preference of goat or cow milk for drinking, cheese-making, culturing, baking, or cooking (Haenlein and Wendorff, 2006). Goat milk has a great demand in the present market although its cost is very high. Hence, considering these, it is of interest and necessary to review the available literature regarding composition of goat milk, its nutritional and therapeutic value.

Composition of goat milk: Compositions of goat, cow and human milks are different and are given in Table-1(Park *et al*., 2007) but vary with diet, breed, individuals, parity, season, feeding, management, environmental conditions, locality, stage of lactation, and health status of the udder (Park *et al*., 2007; Park, 2006). Goats' milk has some particular properties that confer technological advantages in comparison to cow's milk, such as a smaller size of fat globules, which provides a smoother texture in derived products, lower amounts of alpha1-casein, resulting in softer gel products, a higher water holding capacity and a lower viscosity (Haenlein, 2004; Kondyli *et al*., 2007; Kucukcetin *et al*., 2011; Gomes *et al*., 2013). However, the flavour of goat's milk is more intense in comparison to cow's milk, which can restrict the acceptance of its derivatives by consumers (Gomes *et al*., 2013). However, essential differences are present with regards to the structure, composition and size of the casein micelles, the proportion of individual protein fractions and higher content of non

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protein nitrogen and mineral compounds in goats' milk (Kucukcetin *et al.*, 2011; Domagala, 2009). The basic nutrient composition of goat milk resembles cow milk, where both milks contain substantially higher protein and ash, but lower lactose content than human milk. Goat milk reportedly has higher fat and ash contents in the tropics than cow counterparts although Holstein cow milk fat is similar to that in milk of Swiss goats. Mineral contents of goat milk from French-Alpine and Anglo-Nubian breeds showed higher Ca, P, K, Mg, and Cl, and lower Na and S levels than bovine milk.

Goat milk is an excellent alternative to cow milk. The composition of any type of milk can vary depending on the animal's breed, diet, environment and point in the lactation period, but on an average, composition of basic nutrients in goat, cow and human milk compare in Table 1. Variation in the chemical composition of goat milk is, however, highly seasonal. The major constituents of goat milk are high in early lactation, decline rapidly, then remain low for a variable length of time, and increase again towards the end of lactation (Guo *et al.*,2001) However, lactose content is independent of stage of lactation. It is well known that the composition of goats' milk changes throughout lactation (Keskin *et al.*, 2004). Any changes in milk composition will be reflected in the nutritional, technological and economic values of goats' milk as well as of other dairy products.

Table 1: Basic composition of various milks (mean values per 100 g)

Gross	Goat	Cow	Human
Composition			
Total solids (g)	12.2	12.3	12.3
Fat %	4.0-4.5	3.8	4.1
Protein %	3.2	3.3	1.3
Lactose %	4.6	4.7	7.2
Ash (g)	0.8	0.7	0.2
Water %	87.5	87.7	86.7
Energy(K.cal)	70	69	68
Minerals (mg/100g)			
Na	34.0	50.0	14.0
K	180.0	150.0	58.0
Ca	129.0	120.0	34.0
Mg	20.0	12.0	3.0
P	106.0	95.0	14.0
Fe	0.04-0.1	0.05	0,07
Cl	130.00	95.0	42.0
Vitamins(per 100g)			
Vitamin A(IU)	185.0	126.0	241.0
Thiamin (mg)	0.05	0.04	0.014
Riboflavin(mg)	0.14	0.16	0.04
Pantothenic acid (mg)	0.31	0.314	-
Niacin(mg)	0.28	0.08	0.18
Vitamin B(mg)	0.05	0.04	0.01
Folic acid (mg/ L)	6.0	50.0	56.0
Vitamin B_{12} (mg)	0.05	0.14	0.14
Biotin (mg)	2.00	2.00	0.70
Vitamin C (mg)	1.50	1.50	1.00
Vitamin D (mg)	0.06	0.03	0.025

Source: Chandan *et al.* (1992)

Like cow milk, goat milk caseins have the same four species of α_{S1}, α_{S2}, beta and kappa but in different proportions (Table 2). It has been reported that beta casein is the major component of goat milk casein, whereas, α_{S1} is the major component of cow milk casein. Level of α_{S2} casein is relatively higher in goat milk but total of α_{S1} and α_{S2} casein fractions together are lower than α_{S1} fraction alone of cow milk. Such differences might contribute to soft curd forming properties, better digestibility and least allergic to children.

The variability in milk composition, among individual animals of the same breed, is attributed to an extensive and complex genetic polymorphism of the goat milk caseins (Haenlein, 2004; Albenzo, *et al*., 2006). A particular characteristic of goat milk is the minor solvation and heat stability of caseinate micelles and the higher content in β-CN with respect to α_{s1}-CN than in bovine milk (Haenlein, 2004; Albenzo *et al*., 2006; Park, 2011). It is well known that plasmin (PL) is the principal indigenous proteinase in milk and that the increase in plasmin activity can lead to casein degradation in milk and reduction in cheese yield. Caprine milk contains the entire PL system: PL, plasminogen (PG), PL inhibitors, PG activators and inhibitors of PG activators (Haenlein, 2004; Albenzo, *et al*., 2006) and recently the specificity of PL on goat β-caseins has been investigated (Haenlein, 2004; Albenzo *et al*., 2006). A much overlooked component in goat milk is its fat or lipid content. Average goat milk fat differs in contents of its fatty acids significantly from average cow milk fat being much higher in butyric ($C_{4:0}$), caproic ($C_{6:0}$), caprylic ($C_{8:0}$), capric ($C_{10:0}$), lauric ($C_{12:0}$), myristic ($C_{14:0}$), palmitic ($C_{16:0}$), linoleic ($C_{18:2}$), but lower in stearic ($C_{18:0}$), and oleic acid ($C_{18:1}$).

Nutritional and therapeutic values of goat milk

Digestibility: Goat milk differs from cow or human milk in having better digestibility, alkalinity, buffering capacity and certain therapeutic values in medicine and human nutrition.

Table 2: Comparison of proteins of goat and cow milk

Protein	Concentration (%)	
	Goat milk	Cow milk
Total Casein	2.33-4.63	2.4-2.8
α_{S1} Casien	0-28.0	50.0-53.6
α_{S2} Casien	10.0-25.0	12.5-14.3
β-Casien	06-64.0	37.5-39.3
κ-Casein	15.0-29.0	8.3-14.3
Whey proteins	0.37-0.70	0.5-0.7
β-Lactoglobulin	39.2-72.1	40.0-57.1
α-Lactalbumin	17.8-33.3	12.0-24.3
Serum albumin / Lactoferrin	5.1-21.5	4.0-5.71
Immunoglobulins	4.6-21.4	10.0-25.7

Source: Tziboula-Clarke (2003)

The digestibility of goat milk can be attributed to its casein curd which is both softer and smaller than that produced by cow milk. This makes it more easily digestible and accepted by the human digestive system (Park *et al*., 2007). The size of the fat globules also affects the digestibility since it provides a better dispersion and a more homogenous mixture of fat. The large total surface area of the globules makes it easier for enzymes to reach and get in contact with the lipids (Attaie and Richter, 2000).

The high proportion of short and medium chain fatty acids in goat milk contributes to easier and faster digestion. Medium chain triacylglycerols in goat milk are absorbed intact in the intestine and do not undergo degradation and reestrefication processs. Micelle formation is not required for absorption, since the molecules are taken up directly into the portal vein (Lopez-Aliaga *et al*., 2010). The levels of α_{S1}-ceasein also affect digestibility. The more α_{S1}-ceasein in milk the longer the digestion, which depends on that alpha S_1-ceasein is not totally hydrolyzed until it reaches duodenal enzymes (Almaas *et al*., 2006). Finally goat milk does not contain the protein agglutinin that promotes clustering of fat globules.

Antimicrobial property: Lactoperoxidase (LP), a protein present in goat milk was found to be effective against a battery of bacteria causing cholera (*Vibrio cholerae*), typhoid (*Salmonella typhi*), pneumonia (*Klebsiella pneumoniae*), dysentery (*Shigella dysenteriae*) and food poisoning (*Staphylococcus aureus*). Similar studies using bovine LP showed that goat milk alone is antibacterial (Anonymous, 1998).

Malabsorption disorders: Malabsorption disorders are states arising from abnormality in absorption of food nutrients across the gastrointestinal tract. It can be caused as side effects or symptoms of several different forms of cancer. Malabsorption causes deficiency of various nutrients, especially anemia's of vitamin B_{12}, folic acid and iron but also other minerals, vitamins and macronutrients.

Malabsorption syndrome is often studied in rat models where the condition is provoked by reaction of about 50% of their small intestine. When comparing diets of goat and cow milk respectively, studies showed improved digestive utilization of fat and protein, and higher apparent digestibility coefficient and absorption of calcium, phosphorus, magnesium, iron, copper, zinc and selenium (Barrionuevo *et al*., 2002; Lopez-Aliaga *et al*., 2010). The good metabolic utilization of several minerals in goat milk is suggested to be due to higher protein content, cysteine levels and amount of vitamin C and D compared to cow milk (Alferez *et al*., 2003).

Prevention of inflammatory bowel disease (IBD): Inflammatory bowel disease comprises two different but closely conditions, ulcerative colitis and Crohn's disease. The hallmark of IBD is chronic and relapsing inflammation of the intestine, but there are important differences from Crohn's disease with regard to path physiology and treatment. Thus, ulcerative colitis affects the large intestine at the mucosal level, whereas Crohn's disease is characterized by transmural inflammation and may involve any segment of the gastrointestinal tract, although the majority of cases show ileocolonic involvement (Daddaoua *et al.*, 2006). IBD is an important health problem because of its effect on the patient's quality of life and because of its high prevalence, which has increased in the past few years. Despite intensive investigative efforts, the cause of IBD is essentially unknown (Ekbom, 2004)

IBD can often be treated pharmacologically, and sometimes also with prebiotics and or probiotics. But additional treatments are much warranted. Two studies in Spain have evaluated the effects of oligosaccharides isolated from goat milk in rat models of induced colitis (Lara Villoslada *et al*., 2006; Daddaoua *et al*., 2006). Oligosaccharides from goat milk are shown to have an anti-inflammatory effect. The expected decrease in body weight, increased colon size and extension of necrotic lesions are prevented by the oligosaccharides. They also decreased clinical symptoms (diarrhea and bloody stools) and caused a weaker immune response with less neutrophil infiltration (Lara Villoslada *et al*., 2006). The control group received regular rat chow without the efficient oligosaccharides.

Cardiovascular diseases: Cardiovascular disease (CVD) is the most common cause of death in industrialized countries. It includes many diseases that involve heart and blood vessels; coronary heart disease, high blood pressure, arrhythmia and atherosclerosis. The main cause of CVD is atherosclerotic plaque development in blood vessels that eventually leads to cardiovascular incident. The risk factors influencing atherosclerosis are lifestyle (smoking, diet and exercise) high blood pressure, dyslipidemia, diabetes and obesity (Lindqvist, 2008). The initiation of the process is unknown, but a major mechanism seems to be retention of atherogenic lipoproteins in the arterial walls. Low-density lipoprotein (LDL) is atherogenic lipoprotein which 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 liver where it is degraded. The oxidative modification of LDL (ox-LDL) plays a pivotal role in atherosclerosis progression. This implies that antioxidants, which could inhibit LDL oxidation, should be effective in suppressing atherosclerosis (Lindqvist, 2008). Goat milk is rich in medium chain triglycerides (MCT) including fatty acid esters of caproic, caprylic and capric fatty acids. These MCT have been shown to have a lowering effect on plasma cholesterol in rat models and also to inhibit and or limit

cholesterol deposition in the tissues. Altogether, MCT found in goat milk act as anti atherogenic.

An *in vitro* study have shown that cells isolated from humans who had been drinking goat milk from different breeds were triggered by components in the milk to release nitric oxide (NO). In turn, the NO reaches the blood stream via lymphatic route, thus provoking vasodilation and exerts a cardioprotective and anti atherogenic affect. It is also suggested that NO protects the blood vessels from atherogenic plaque accumulation (Davenport, 2002).

Prevention of milk allergy: Cow milk allergy is a common disease in infancy and childhood and its prevalence is about 2.5% during the first three years of life (Vita *et al*., 2007). Cow milk is an important nutritive source and is often one of the first types of food proteins that infants get introduced to. After or parallel to breast feeding, the children are usually given cow milk based formula. But for children who immediately develop allergic symptoms after ingestion, a substitute is needed. Cow milk allergy is an IgE-mediated allergy which means that the body starts to produce IgE antibodies against certain protein (allergens) in cow milk for unknown reasons. When the person ingests milk repeatedly, an immune reaction including the IgE antibodies will occur and the person gets allergic symptoms as eczema, respiratory symptoms as hay fever, wheezing or asthma, gastrointestinal symptoms, or even anaphylaxis.

The proteins α_{S1} ceasein and β-lactoglobulin are important allergens in cow's milk allergy. The allergy causing properties of β-lactoglobulin can be partially eliminated by certain treatments as extended heating. But caseins maintain the capability of binding to lgEs even after a strong denaturating process (Tomotake *et al*., 2006). Since the content of α_{S1}-ceasein is very high in cow milk but relatively low in goat milk, the latter has been suggested as an alternative milk source for cow milk allergies. Some people with cow milk allergy do tolerate goat milk, probably because of low α_{S1}-ceasein levels. However, several studies reports extensive cross-reactivity between cow and goat milk, caused by cow milk specfic IgE antibodies (Pessler and Nejat, 2004). Because of the cross reactivity all scientific reports dissuade persons with cow milk allergy to ingest goat milk.

The *in vitro* study shows that cow milk proteins have higher binding capacity to lgE and lgG than goat milk protein. In animal models cow milk is shown to cause higher lymphocyte proliferation, IL-4 production, histamine secretion (Lara-Villoslada *et al*., 2004) and lgG production (Sanz Ceballos *et al*., 2009; Lara-Villoslada *et al*., 2004) which are all parameters indicating more extended allergic inflammation.

Alleviation of lactose intolerance: Goat milk, as well as cow and human milk, contains lactose. Despite that many people with lactose intolerance do tolerate to drink goat milk. It has been hypothesized that the reason is the superior digestibility of goat milk. Goat milk is more completely and easily absorbed than cow milk, leaving less undigested residue behind in the colon to ferment and cause the uncomfortable symptoms of lactose intolerance (Haenlein, 2004; Lopez-Aliaga *et al*., 2010). It may also be that the patients are not lactose intolerance, but instead are allergic to the major α_{s1}-casein proteins in cow milk, which usually is lower or absent in goat milk. The symptoms are almost identical in lactose intolerance and milk protein allergy.

Immunomodulatory activity: Even if goat milk not be a perfect alternative for people with cow milk allergy, very recent studies showed immune modulatory effects from goat milk both in *in vitro* and human studies, Jirillo (Jirillo *et al*., 2010) recently 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 triggering of cytokine production (IL-10, TNF-α and IL-6). The NO release could have cardio protective effects in the milk consumer and also expose antibacterial activity and thereby prevent infections. TNF-α is a pro-inflammatory cytokine, IL-6 is an acute phase reactant and growth factor for B cells and IL-10 is an anti inflammatory cytokine. The mix of released cytokine has been suggested to maintain the immune homeostasis by goat milk (Jirillo *et al*., 2010).

Anticarcinogenic effect: Goat milk has a high content of conjugated linoleic acid (CLA) (Jirillo *et al*., 2010). Anti-carcinogenic properties of CLA have been reported against mammary and colon cancer in animal models, as well as in vitro models of human melanoma, colorectal (Palombo *et al*., 2002) and breast cancer. The mechanism by which CLA inhibit tumor development is not fully understood, although perturbation of the eicosanoid dependent cell signaling systems, antioxidative effects, and disturbance of the receptor mediated actions of oestrogen have all been suggested (Williams, 2000).

Effect on infancy intake: Feeding goat milk to infants has been and still is popular in many parts of the world. The scientific thoughts about goat milk in infant nutrition are contradictory. But all agree on that unpasteurized goat milk should not be given to infants and children, since this is directly vital. Unpasteurized milk could contain bacteria or viruses leading to life threatening infections as Q fever, toxoplasmosis, tuberculosis or brucellosis (Baur and Allen, 2005). Pasteurized goat milk or formula based on goat milk could however be an option to cow milk. Through primarily commercially produced formulae are recommended, since these usually are fortified with folic acid, vitamin B_{12} and iron, that are too low in regular goat milk. Case reports have been published on infants who were fed homemade goat milk formulas and then were diagnosed with megaloblastic anemia caused by folate and or vitamin B_{12} deficiency (Ziegler *et*

al., 2005). Basnet *et al*. (2010) reported a case where an infant was exclusively fed goat milk, which led to azotemia (abnormally high levels of nitrogen compounds in the blood), hypernatremia (electrolyte imbalance caused by elevated sodium levels) and hemorrhages in the brain. This was caused by the high levels of sodium in goat milk compared to human milk. The kidneys of infants are immature and cannot handle high sodium concentrations Despite the insufficient content of certain vitamins and minerals, goat milk formulae with adjusted nutrients could be an alternative to cow milk. Two studies have investigated effects of goat milk and cow milk on weight gain and fat absorption in healthy and undernourished infants and children respectively (Grant *et al*., 2005). When giving malnourished children (1-5 years) goat or cow milk, weight gain and fat absorption were similar in both groups. The milk used in the study was modified to be as identical as possible concerning nutrients, by adding vitamins and minerals. The other study compared growth of healthy infants fed goat milk formula or cow milk formula (with comparable nutrient content). There were no differences in growth between the two groups (Grant *et al*., 2005).

Therapeutic value of goat milk: Lactic acid bacteria are often used as probiotic starter culture and health effects from these associated with increased lactose intolerance, a well balanced intestinal micro flora, antimicrobial activity, stimulation of the immune system and anti-tumoural, anti-cholesterolaemic and anti-oxidative properties in human subjects (Slacanac *et al*., 2010).

The increasing interest in healthy diets is stimulating innovative development of novel scientific products in the food industry. In particular, many studies have been conducted on fermented milk (Jirillo *et al.*, 2010). Because of several reported health benefits from goat milk, this could be a future trend in the field of probiotic fermented milk products. Kullisaar *et al*. (2003) where they showed antioxidative and anti-atherogenic effects from fermented goat milk (*Lactobacillus fermentus* ME-3) in healthy subjects. Both reduce the risk for cardiovascular disease. Minervini *et al*. (2009), developed fermented goat milk with a mixed starter culture (*Streptococcus thermophilus* CR12, *Lactobacillus Helveticas* PR4 and *Lactobaillus plantarum* 1288) which resulted in production of GABA, an inhibiting signal substance in the central nervous system, and provoked an in vitro ACE-inhibitory activity, which counteract high blood pressure. Recently, fermented goat milk (*Lactobacillus rhamnosus* CRL1505) was demonstrated to stimulate the mucosal immune system and improve the defense against intestinal and respiratory infections in a mouse immunosuppressant model (Salva *et al*., 2011). As mentioned above, one disadvantage with goat milk is the almost nonexistent content of folic acid. In a fermented product this problem could be solved by using folate-producing bacteria during fermentation. Sanna (Sanna *et al*., 2005) used a mix of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* when fermenting goat milk which resulted in to a yogurt with a significant quantity of folate and good sensory attributes.

CONCLUSION

The unique characteristic of goat milk has been fairly surveyed regarding nutritional value and some health effects. The average composition of goat milk does not differ remarkably from that of cow milk. Studies are required in the direction to reduce the 'goaty flavor' of goat milk (genetic modification /chemical modification) which makes it less acceptable. The superior digestibility of goat milk, the proper composition of fatty acids and its content of bioactive compounds seem to give properties suitable for treating or preventing certain medical conditions. Studies in animal models indicate that goat milk might have beneficial effects on malabsorption disorders and inflammatory bowel diseases. Fermented goat milk may reduce the risk of cardiovascular disease by ant oxidative anti-atherogenic effects. Concerning goat milk ingestion among cow milk allergic, it is not recommended because of extensive cross reactivity. Most studies are performed in animal models which give indications of effects. But more human studies are required to claim the health effects from goat milk products.

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