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The Significance of Goat Milk and its Products

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Abstract

Research in the past few decades has extended knowledge of composition of goat milk and of properties of its constituents. Goats of several European breeds produce milk of lower fat content in the tropics than in temperate zones. Fat, protein, lactose and Mineral contents of milk of dwarf goats are higher than those of other breeds. Fat globules of goat milk resemble those of cow milk in lipid composition and properties of the globule membrane, but goat milk lacks "agglutinin" which causes fat globules of cow milk to cluster when cooled. Five principal proteins of goat milk, α-lactalbumin, β-lactoglobulin, κ-casein, β-casein, and α_{s2}-casein, closely resemble their homologs in cow milk. Goat milk lacks a homolog of bovine β_{s1}-casein, the most abundant protein in cow milk. Caseinate micelles of goat milk contain more calcium and inorganic phosphorus, are less solvated and less heat stable, and lose β-casein more readily than bovine micelles. Activities of ribonuclease, lipase, and xanthine oxidase are less in goat than in cow milk. Goat milk contains more potassium and chloride but less orotic acid, N-acetyl neuraminic acid, folate, vitamin B_6, and vitamin B_{12} than cow milk. Little work in the past decade has been on nutritive value of goat milk for humans except to describe cases of folate deficiency in infants. Goat Milk and its Dairy Products have alwyes identified as an important part of human diet bothin developing as well as developed nations of the world.

Keywords- Fat, protein, lactose, protein , α-lactalbumin, β-lactoglobulin , Fatty Acids and, Dairy Products.

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INTRODUCTION

Milk is considered as nearly complete human food and considered as the first food for the newly born off-spring. Goats (*Capra aegagrushircus*) were the first species to be domesticated as livestock about 8000 BC in Mesopotamia, part of today's Middle East. Goat milk production in India increased from 3.6 to 4.7 million tons during the year 2015-16 with an annual growth rate of 2.6%. The country stands first in goat milk production in the world by sharing 29%(CIRG, 2015-2016). Different varieties of cheese, yoghurt, ice cream, fluid milk and milk powder are produced from goat milk. Goat milk has traditionally been known for its medicinal properties and has recently gained importance in human health due to easy digestibility and it's all round health promoting traits. Goat milk has advantages over cow or human milk in having higher digestibility of protein and fat, alkalinity, buffering capacity, and certain therapeutic values in medicine and human nutrition. Due to lack of availability of cow milk, goat milk and its products provide important daily food sources of protein, phosphate and calcium in developing countries. Goat milk is considered as "self-homogenized" milk. Goat milk contains, water, protein, fat, sugar, minerals, and vitamins, which are essential for the maintenance of good health. Goat milk and its processed products are useful as functional foods, maintaining nourishment and health of young and elders.

CHEMICAL COMPOSITIONS OF GOAT MILK

Composition of goat milk are vary according to changes in diet, individuals, season, breed, species, feeding managements, environmental conditions, stage of the lactation, locality and condition of the udder. Goat milk is similar to cow milk in its basic composition. Caprine milk contains 12.2% total solids, 3.8% fat, 3.5% protein, 4.1% lactose, and 0.8% ash. It has more fat, protein, and ash and less lactose than cow milk. Goat milk contains slightly less total casein, but higher non-protein nitrogen than the cow counterpart. Goat milk and cow milk have 3 to 4 times greater levels of protein and ash than human milk. Total solids and caloric values of goat, cow, and human milks are similar (Jenness, 1980; Chandan*et al*., 1992).Goat milk differs from cow milk in having better digestibility, buffer capacity, alkalinity and therapeutic values. Fat of goat milk have higher physical properties i.e. surface tension, viscosity and specific gravity as compared to cow milk (Park *et al.*, 2007).

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Table 1: Average composition of milk from goat, cow, buffalo and human

Component (Per cent)	Goat	Cow	Buffalo	Human
Water	87.5	87.7	83.2	86.7
Protein	3.4	3.2	4.5	1.2
Fat	3.8	3.6	6.7	4.0
Solid-not-fat	8.9	9.0	10.1	8.9
Lactose	4.1	4.7	4.5	6.9
Casein	2.4	2.6	-	0.4
Total ash	0.8	0.7	0.8	0.3

(Source: Park *et al.*, 2007

Milk lipid

Major differences between goat and cow milk is physicochemical structure and composition of milk fats. The fat globules range between 1 and 10 μm in both goat and cow milk (Silanikove*et al.*, 2010).In respect to free lipids, goat milk has higher values than that of cow milk. Goat milk contains 97–99% of free lipids and 1–3% bound lipids of total milk fat (Cerbulis*et al.*, 1982). Goat milk contained 96.8% triglycerides, 2.2% diglycerides and 0.9% monoglycerides. Goat milk is rich in short- and medium-chain fatty acids (FAs) compared to the cow milk (Luke and Keith, 1992; Silanikove*et al.*, 2010; Amigo and Fontecha, 2011).

Table 2:Fatty acid composition (Per cent of total fatty acids) of goat milk (n=30) from Granadina goats and cow milk (n=30)

Fatty Acids	Goat milk	Cow Milk
Butyric acid	1.27	3.84
Caproic acid	3.28	2.28
Caprylic acid	3.68	1.69
Capric acid	11.07	3.36
Lauric acid	4.45	3.83

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Myristic acid	9.92	11.24
Palmitic acid	25.64	32.24
Stearic acid	9.92	11.06
Oleic acid	23.8	21.72
Linoleic acid	2.72	2.41
CLA tot	0.68	0.4
α- linolenic acid	0.53	0.25
PUFA n-6	2.81	2.53
PUFA n-3	0.51	0.25
PUFA tot	4.08	10.49

(**Source:**Ceballos*et al.,* 2009**)**

The short-chain FAs represent 15-18%. The short- and medium-chain FAs are partly responsible for the characteristic "goaty" odor (Silanikove*et al.,* 2010; Amigo and Fontecha, 2011).The medium-chain triglycerides were found to be 30.83% and 25.16% in goat and cow milk, respectively, whereas the long-chain triglyceride were 53.95% and 64.01% in the same order (Ruiz-Sala *et al*., 1996). Cholesterol contents of goat, cow and human milk were reported as 11, 14, and 14 mg/100 g milk, respectively (Posati and Orr, 1976). Goat milk consists more of the linoleic and arachidonic acids and CLAs (Luke and Keith, 1992; Amigo and Fontecha, 2011). Total CLA content of goat milk is 35.75 mg/100 g while it is only 15.62 mg/100 g in cow milk (Ceballos *et al*., 2009).

Amino acids andProtein

The amounts of free amino acids are different between goat and cow milk. The higher content of cysteine (derived from cystine) has been shown to improve intestinal absorption of copper and iron in a rat model of malabsorption syndrome (Barrionuevo*et al*. 2002; Haenlein, 2004).

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Table 3: Average amino acid composition (g/l00 g milk) in proteins of goat and cow milk

Amino acids	Goat milk	Cow milk	Difference (per cent) for Goat milk
Essential amino acids			
Tryptophan	0.044	0.046	
Threonine	0.163	0.149	+9
Isoleucine	0.207	0.199	+4
Leucine	0.314	0.322	
Lysine	0.290	0.261	+11
Methionine	0.080	0.083	
Cystine	0.046	0.030	+53
Phenylalanine	0.155	0.159	
Tyrosine	0.179	0.159	+13
Valine	0.240	0.220	+9
Non-essential amino acids			
Arginine	0.119	0.119	
Histidine	0.089	0.089	
Alanine	0.118	0.113	
Aspartic acid	0.210	0.250	
Glutamic acid	0.626	0.689	
Glycine	0.050	0.070	
Proline	0.368	0.319	
Serine	0.181	0.179	

(Source: Posati and Orr, 1976**)**

Taurine is the most representative free amino acid in goat milk and the concentration is much higher than in cow milk (Huxtable, 1992;Sarwar*et al.,* 1998; Tripaldi*et al.,* 1998; BelewuandAiyegbusi, 2009). There are two distinct phases of milk proteins; micellar phase composed of casein and a soluble composed of whey proteins. The caseins constitute about 80% of the proteins and are classified as αs_1, αs_2, β and κ-caseins, while the major whey proteins are β-lactoglubulin and α- lactalbumin (Slacanac*et al.,* 2010). Goat milk contains

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lower amounts of the αs-casein, higher amounts of the β-casein fractions and equal amounts of the κ-casein fractions compared to cow milk (Park *et al.*, 2007). The casein micelles in goat milk differ from those in cow milk in having greater β-casein, more calcium & phosphorus and lower heat stability (Jenness, 1980). Two types of β-lactoglobulin have been identified in goat milk and three variants of α- lactalbumin (Moatsou*et al.*, 2005).

Lactose

Lactose is a major carbohydrate present in goat milk but content slightly low as compared to cow milk (Slacanac*et al.*, 2010). Other carbohydrates found in goat milk are oligosaccharides, glycopeptides, glycoproteins and nucleotides in small amounts. Goat milk is significantly rich in lactose-derived oligosaccharides compared to cow milk (Slacanac*et al.*, 2010). Milk oligosaccharides are thought to be beneficial to human nutrition because of their prebiotic and anti-infective properties (Kunz *et al.*, 2000).

Mineral and Vitamins

Goat milk is reported to have higher content of potassium, calcium, chloride, phosphorus, selenium, zinc and copper than cow milk (Slacanac*et al.*, 2010).Goat milk has a higher vitamin A content than cow milk because goats convert all β-carotene from foods into vitamin A (Geissler and Powers, 2011).

Table 4: Proximate vitamins (per 100 g) content in milk of various species

Component	Goat milk	Cow milk	Buffalo milk	Human milk
Vitamin A (IU)	185	126	177	190
Vitamin D (IU)	2.3	2.0	-	1.4
Thiamin (mg)	0.07	10.05	0.04	0.02
Riboflavin (mg)	0.21	0.16	0.13	0.02
Pantothenic acid (mg)	0.31	0.32	0.20	0.20
Niacin (mg)	0.27	0.08	0.09	0.17
Vitamin B_6 (mg)	0.05	0.04	0.02	0.01

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Folic acid (µg)	1.0	5.0	3.3	5.5
Vitamin B_{12} (µg)	0.07	0.36	0.14	0.03
Biotin (µg)	1.5	2.0	-	0.40
Vitamin C (mg)	1.29	0.94	1.00	5.00
Energy (kcal/100 ml)	70.0	69.0	117.0	68.0

(Source: Park *et al.*, 2007**)**

Both goat and cow milk have low concentrations of vitamin B6 and vitamin D, which are both important during infancy (Park *et al*., 2007). Goat milk is deficient in folic acid and vitamin B12, which cause 'goat milk anemia' (Jenness, 1980; Park *et al.* 2007). Vitamin C is a well-known water-soluble antioxidant that is found in greater amounts in goat milk than in cow milk (Geissler and Powers, 2011).

Table 5: Proximate minerals (g/100 g) content in milk of various species

Component	Goat milk	Cow milk	Buffalo milk	Human milk
Sodium	41	44	35	15
Potassium	181	152	92	55
Calcium	134	122	112	33
Magnesium	16	12	8	4
Phosphorus	121	119	99	43
Sulphur	28	32	-	14
Iron	0.07	0.08	0.16	0.20
Chloride	150	100	-	60
Se (µg)	1.33	0.96	-	1.52
Copper (mg)	0.05	0.06	0.04	0.06
Manganese (mg)	0.03	0.02	0.02	0.07
Zinc (mg)	0.56	0.53	0.41	0.38
Iodine (mg)	0.02	0.02	-	0.01

(Source: Park *et al.*, 2007**)**

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NUTRITIONAL AND THERAPEUTIC VALUES OF GOAT MILK

Digestibility and Micronutrient absorption

The most appearing property of goat milk is superior digestibility and absorption of micronutrients. Digestibility of goat milk is highly enhanced by nature of the proteins and the fat molecules (Park *et al.*, 2007). Goat milk does not contain the protein agglutinin that promotes clustering of fat globules. The absence of clustering facilitates rapid digestion and absorption (Farah, 1991).

Antimicrobial activity

Goat milk contains high levels of medium chain fatty acids, such as caprylic and capric acids. These fatty acids are highly antimicrobial. Capric and caprylic acids are used in dietary supplements to inhibit the growth of *Candida albicans*and other yeast species (Mwenze, 2015).

Alkalinizes the blood and the intestine

Goat milk helps to increase the pH of the blood stream. It is the only dairy product with the highest amount of the L-glutamine. Acidic blood and low intestinal pH levels have been associated with fatigue, headaches, muscle aches and blood sugar imbalances (Mwenze, 2015).

Less allergenic and brain development

In the USA and Canada the department of pediatrics has recommended that cow's milk be avoided for children between 0-6 months due incidences of allergy (Playford*et al.* 2000).Sialic acid profile of goat colostrums milk is similar to human milk (Kumar*et al.*, 2016) and helps in brain development.

Dengue fever

Dengue fever is mainly transmitted to humans by *Aedesaegypti*mosquito. So, for treating this disease goat milk and milk products are mostly preferred. Deficiency of selenium and decrease in platelet count are the main complications of dengue fever. Goat milk as well as its products is richest source of selenium (Kumar *et al.*, 2016).

Growth factors for infants

Goat milk contains high levels of growth factors similar to those found in human milk making it an essential diet for the infants. The Transforming Growth Factors (TGF) has a physiological role in maintaining regular functionality of the infant (Playford*et al*., 2000).

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Prevention of inflammatory bowel disease

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 (Lara Villosladaet *al*., 2006).

Cardiovascular diseases (CVD)

Goat milk is rich in medium chain triglycerides (MCT) including caproic, caprylic and capric acids. These MCT have a lowering effect on plasma cholesterol in rat models and act as anti-atherogenic(Davenport, 2002).

Prevention of milk allergy

The proteins αs_1 casein and β-lactoglobulinare important allergens in cow milk allergy. Since the content of αs_1casein 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 (Tomotake*et al*., 2006).

Immunomodulatory activity and immunity booster

Jirillo*et al*. (2010) showed immune modulatory effects from goat milk both in *in vitro* and human studies. 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.Selenium is one of the key component for the immune system functionality.

Anti-carcinogenic 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 and breast cancer (Palombo*et al*., 2002).

Effect on infancy intake

Basnet *et al*. (2010) reported 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 but when it gave malnourished children (1-5 years) goat or cow milk, weight gain and fat absorption were similar in both groups.

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Therapeutic value of goat milk

Kullisaar*et al*. (2003) showed antioxidative and anti-atherogenic effects from fermented goat milk. Minervini*et al*. (2009) developed fermented goat milk with a mixed starter culture which resulted in production of GABA and provoked an in vitro ACE-inhibitory activity, which counteract high blood pressure. Sanna*et al*. 2(005) 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. IgA account for the majority of serum immunoglobulins.

MILK PRODUCTS

Various goat milk products, including fluid, fermented, frozen, condensed, and dehydrated milk products, are produced in many countries. Goat milk products especially cheeses and yogurt are very popular in the Mediterranean peninsula, the Middle East, Southern Russia and the Indian subcontinent (Yangilar, 2013)

Liquid Milk Products

Goat milk is white in colour and has a stronger flavour (Agnihotri and Prasad, 1993). Ahmed *et al.* (1992) used fruit Guava, Orange and Fig for fortifying skim goat milk in order to prepare low fat beverages. Pruksasri and Supee (2013) assessed the feasibility of producing goat milk containing galactooligosaccharides (GOS) by treating milk with the enzyme β-galactosidase. Milk contains GOS had higher overall acceptability compare to regular milk.

Butter and ghee

Rodriguez *et al*. (2003) optimized processing parameters for manufacture of butter from cultured cream. This cultured formulation achieved optimal sensory quality in appearance, flavour, texture, and overall quality. Bindal and Wadhwa (1993) demonstrated that goat ghee has a higher liquid fraction (69%) compared with cow ghee (30.5%) or buffaloe ghee (36%). Levels of glycerides were also higher in ghee prepared from goat milk as compared to cow and buffalo milks.The melting point and softening point of ghee prepared from goat milk were also low.

Milk Powder

The freeze, roller and spray drying techniques were used in manufacture of milk powder from goat milk (Pandya and Ghodke, 2007). Reddy *et al.* (2014) optimized the processing

conditions for manufacture of spray dried from goat milk. A mixed fruit flavour was added to the concentrated milk to avoid the goatyflavour in the final powder. The mean values of proximate composition of spray dried powder viz., moisture content, fat, protein, carbohydrates, ash and titrarable acidity were 4.08%, 26.85%, 25.48%, 36.99%, 6.60% and 0.14%, respectively.

Yoghurt and Fermented Milk Products

Fermented goat milk incorporating live probiotic cells have good nutritive and therapeutic properties (Slacanac*et al.,* 2010).A mixed starter has been successfully used for fermentation of goats milk (Yangilar, 2013). Beyond all nutritive features of goat milk, one of the major disadvantages is non-existent of folic acid content. This disadvantage could be solved by using folate producing bacteria during fermentation by use in *Streptococcus thermophilus*and*Lactobacillus delbrueckii subsp. bulgaricus*in goat milk results in yoghurt with significant quantity of folate and good sensory features (Sanna*et al.,* 2005).Ehirim and Onyeneke (2013) made yoghurt with cows and with goat milk. Patel and Roy (2016) compared the quality of yoghurt using instrument texture analyser. Paz *et al.* (2014) showed the technological potential and adequacy of using goat milk to produce potentially symbiotic yogurt. Bano*et al.* (2011) concluded that mixing 75% goat milk and 25% sheep milk in manufacture of yoghurt improved color, flavour and texture scores of the resultant yoghurt. Damunupola*et al*. (2014) suggested that the incorporation of beetroot extract could mask the goaty-flavor and goaty-odor of the yogurt made from goat milk. Gursel*et al*. (2016) made yoghurt with the fortification of 2% (w/v) each of skim goat milk powder, sodium caseinate, whey protein concentrate, whey protein isolate, or yogurt texture improver. Labneh is a delicious popular cultured dairy product which produced from yoghurt coagulates (Abbas *et al.,* 1999). Goat labneh is higher in ash, but fat and protein contents were the same as cow labneh (Rao*et al.,* 1987). Mehaia (2005) studied the chemical composition and sensory evaluation of fresh labneh made from goat milk, using ultrafiltration (UF) and traditional processes.

Cheese

Goat milk cheese was originated in Mesopotamia (Yangilar, 2013). A piquant and peppery sharp flavor observed in ripened goat milk cheese due to presence of greater proportion of short & medium chain fatty acids in goat milk (Tziboula-clarke, 2003). There are three

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categories of cheese which produced from goat milkviz traditional cheeses made at home, cheeses produced on farm scale and cheese made from mixed sheep and goat milks (Kalantzopoulos, 1993; Walstra*et al*., 2006).Loewenstein*et al*., (1980) and Park and Guo (2006a, b) described goat milk whey cheese, the process where caramelized lactose in concentrated whey is combined with fat and whey proteins to make Gjetost cheese. Mehaia (2002) made fresh soft white cheese (Domiati-type) from goat milk using ultrafiltration (UF) and conventional processes. El-Sheikh *et al.* (2011) successfully made blue cheese from goat milk. Attulla*et al.* (2014) fortified goat cheese with caramel, cocoa and cocoa with walnuts are corresponding high quality protein ingredient for sweet spreadable cheese and concluded that fortified sweet goat cheese with cocoa and walnut could be regards as Egyptian economic products and nourished for human consumption especially for children feeding.

Ice cream and Frozen Desserts

Silva *et al.* (2016) manufactured ice cream enriched with different amounts of carob powder. They reported that goat milk ice cream containing carob powder which was added @ 12% was found to be most acceptable with respect to all sensory attributes. Ranadheera*et al.* (2013) developed chocolate flavored probiotic ice cream made from goat milk using a probiotic bacterial culture. Konar and Akin (1997) and Pandya and Ghodke (2007) compared the chemical, physical and organoleptic qualities of ice cream made from cow, goat and sheep milk for their suitability for ice cream production. Goat milk produced the most acceptable ice cream followed by cow milk. Goat milk frozen yogurt was prepared using caja (*Spondiasmombim*L.) flavour. The sensory acceptance test indicated that formulations containing 20% and 30% caja pulp were the most accepted (Keily*et al.*, 2016).

Other Traditional Indian Dairy Products

Several Indian traditional products such as ghee, chakka, shrikhand, paneer, channa, etc. can be made from the goat milk (Ribeiro and Ribeiro, 2010; Yangilar, 2013; Pal, 2014). Joshi *et al.* (1991) made chhana from goat milk and have soft body and smooth texture. Bhargava *et al.* (1992) investigated influence of fat percentage on the yields and qualities of chhana and rasogolla from goat milk. Sharma *et al.* (1995) investigated the method of chhana making from Jamunapari and Barbari goat milk using different level of coagulant.Viji*et al.* (2017) prepared paneer by the admixture of goat and buffalo milk at different proportion. Agnihotri

and Pal (1996) standardize the method of shrikhand production. Bhat *et al.* (2016) made a novel goat milk bar usingrose flower extracts and natural sweeteners. Singh *et al.* (2018) made goat milk shrikhand blended with sapota pulp and betel leaf extract. Ramlingam*et al.*(2009) prepared dahi utilizing goat milk

Application in Cosmetics

High volume of cosmetic products are produced from goat milk, including soaps, creams, body lotions, shampoos, hair conditioners, after shave lotions, which are marketed in many countries such as US and Switzerland (Ribeiro *et al.,* 2007). Goat milk contains capric and caprylic acids which enhance permeability in skin, used as a carrier of other chemical compounds in lotions and creams (Wongpayapkul*et al.*, 2006).

LIMITATIONS OF GOAT MILK

Goat milk contains virtually no folic acid. To be adequate as an infant formula it has to be fortified (Mwenze, 2015).

Goat milk is an apocrine secretion. Apocrine is a type of glandular secretion where the secreting cell is released along with the milk. The milk has high levels of somatic cell counts which are not desirable (Mwenze, 2015).

CONCLUSION

Goat milk and its product is a rich source of more bioavailable proteins, fats, vitamins and minerals with great suitability for infant foods. Due to its high nutritive value and physiological properties, goat milk should be promoted in the developing countries like India, where malnutrition and diseases are more prevalent along with high poverty levels. The maintenance cost, general management and feeding of dairy goat is very low. But commercialization and utilization of goat milk is still lacking in developing countries. And scientific community has lack of information related to its use for commercialization. This area needs more research to do.

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