Journal of Animal Feed Science and Technology 5 (2017) 65-72
DOI: http://dx.doi.org/10.21088/jafst.2321.1628.5217.5

Implication of functional ingredients of goat milk to develop functional foods

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Abstract

Growing understanding of the relationship between diet, specific food ingredients and health is leading to new insights into the effect of food components on physiological function and health. This awareness has moved consumers to become more health-conscious, driving a trend towards healthy and nutritious foods with additional health promoting functions, such as functional foods. Goats are important component of livestock industry having adaptability to harsh climates which make them suitable for landless and marginal farmers. The importance of goats as providers around the world of essential food in meat and dairy products has been discussed and documented. The milk is affordable, available and nutritious hence a wide variation of knowledge on the nutrition and hypollergic characteristics of goat milk could promote the direct use of the milk in the nutrition of orphans and vulnerable children.

Keywords:

Goat Milk
Functional Foods
Fatty Acid Composition
Nutrition
Technological Quality.

Introduction

The sociological, economic and nutritional values have significantly impact on the food industries and consumers for the production of functional food products with health-related required properties. A functional food may provide expanded utility beyond its nutritional benefit. Functional foods are those foods which provide health benefits beyond the normal nutritional requirements. These foods contain physiologically-active food components (Hasler, 1998). These benefits can be both physical and mental and are commonly attributed to the active components of the food. Today's animal originated functional foods are typically marketed to large groups of the total population. Goats are known as *"Wet nurse of infant"* in the United Kingdom and "Poor man`s cow" in India. Accurate statistics are required to determine the future outlook of the goat populations and their productivity (Belewu and Adewole, 2009). Goats are present in all of the continents and the world total numbers of goats are 861.9 million. The livestock population in India includes 135.17 million goats standing at first and second place in milk and meat production overall the world respectively (FAO STAT 2013). Research in 20th century has led to a substantial increase in our knowledge of the basic and unique features of the composition of goat milk.

Goat is a good source of meat (Chevon), milk, yoghurt, cheese and other by-products such as hide and skin. Goat milk production is a dynamic and growing industry that is fundamental to the wellbeing of hundreds of millions of people worldwide and is an important part of the economy in many countries (Haenlein, 2004). Goats' milk nutritional properties and lower allergencity in comparison to cow milk, especially in non sensitised children, has led to an increased interest in goat milk as a functional food, and it now forms a part of the current trend to healthy eating in developed countries like India. Goats' milk contains bioactive components such as polyamines, nucleotide sugars, free amino acids, medium chain fatty acids, polyunsaturated fatty acids and serum proteins (Rampilli et al., 2004).

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Received on 04.07.2017, **Accepted on** 24.07.2017

Goat milk shows great variability in biochemical composition, technological properties and bacteriological quality depending on genetic factors, environmental conditions, and goat farming practices. These factors are- pure breeding, crossing, age, birth season, birth type, duration of lactation and dry period, milking type, frequency and duration of milking, mating season, first pregnancy age, survival rate of kids, nutrition and diseases (Alferez *et al.* 2004).

Average composition of basic nutrients in goat, sheep, cow and human milk (Narangel et al., 2016)

Composition	Goat	Sheep	Cow	Human
Fat (%)	3.8	7.9	3.6	4.0
Solid-not-fat (%)	8.9	12.0	9.0	8.9
Lactose (%)	4.1	4.9	4.7	6.9
Protein (%)	3.4	6.2	3.2	1.2
Casein (%)	2.4	4.2	2.6	0.4
Albumin, Globulin (%)	0.6	1.0	0.6	0.7
Non Protein N (%)	0.4	0.8	0.2	0.5
Ash (%)	0.8	0.9	0.7	0.3
Calories/100 ml	70	105	69	68

The popularity of dairy products from goats' milk has shown a gradual increase all over the world due to those properties which differentiate it from other milks and beneficial effects on human health. In comparison with cow's milk, goats' milk has a higher concentration of short and medium chain fatty acids and lipoprotein lipase associated with the fat phase. Fat is one of the most important components in the technological and nutritional quality of goat milk. Lipids are involved in the sensorial quality of caprine dairy products, as well as in cheese yield per kg of milk and firmness. In addition to their quantitative contribution to energy intake, the different lipid and fatty acid (FA) compounds (e.g., short- and medium-chain saturated, branched, mono- and polyunsaturated, *cis* and *trans*, conjugated FAs) are deemed to be positive or negative factors with respect to the health of human consumers.

Technological and Nutritional Quality

Goat milk fat is more digestible (Alferez et al., 2001) and may be considered an excellent source of energy for use in various metabolic processes (Boza and Sanz Sampelayo,1997; Ceballos et al., 2009), even for combating metabolic diseases.

The percentage of total fat in goat and cow milk is quite similar, and the fatty acid composition depends to a large extent on the diet composition in both species. Two characteristics of goat milk fat have important consequences for manufacturing. One is the smaller size of the fat globules in goat milk in comparison to those in cow milk (Haenlein, 2004). In both species the fat globules range from 1 to 10 µm, but the number of fat globules less than 5 ìm is ~60% in cow milk whereas it is ~80% in goat milk which results in a softer texture of goat milk products. The second feature, is the fatty acid composition of goat milk with a higher proportion of medium chain fatty acids, i.e., caproic (C6:0), caprylic (C8:0) and 5 capric (C10:0), which are partly responsible for the characteristic "goaty" odour of goat milk (Park, 2009).

Average fatty acid composition (g/100 g milk) in lipids of goat and cow milk (Sbihi et al., 2015)

Fatty Acids	Goat Milk	Cow Milk
C4:0 butyric	0.13	0.11
C6:0 caproic	0.09	0.06
C8:0 caprylic	0.10	0.04
C10:0 capric	0.26	0.08
C12:0 lauric	0.12	0.09
C14:0 myristic	0.32	0.34
C16:0 palmitic	0.91	0.88
C18:0 stearic	0.44	0.40
C6-14 total MCT	0.89	0.61
C4-18 total SAFA	2.67	2.08
C16:1 palmitoleic	0.08	0.08
C18:1 oleic	0.98	0.84
C16:1-22:1 total MUFA	1.11	0.96
C18:2 linoleic	0.11	0.08
C18:3 linolenic	0.04	0.05
C18:2-18:3 total PUFA	0.15	0.12

Goat milk contains less lactose than cow milk (on average, 4.1% vs. 4.7%), but cannot be regarded as a dietary solution to people suffering from lactose intolerance. Cow milk and goat milk do not differ significantly as far as the protein percentage is concerned and, in contrast to milk fat, the protein content in both species is less amenable to dietary manipulation (Luara *et al.,* 2009). However, casein micelles in cow milk are small (60-80 nm) when compared to goat milk casein micelles, which range between 100-200 nm. Another key difference between species is the level of alpha$_{s1}$-casein. The level of alpha $_{s1}$-casein in goat milk ranges from 0-7 g/L. This variability is associated with polymorphisms within the alpha$_{s1}$-casein gene, which are very common in goats.

Average amino acid composition (g/100 g milk) in proteins of goat and cow milk (Yangilar, 2013)

	Goat Milk	Cow Milk
Essential amino acids		
Tryptophan	0.044	0.046
Threonine	0.163	0.149
Isoleucine	0.207	0.199
Leucine	0.314	0.322
Lysine	0.290	0.261
Methionine	0.080	0.083
Cystine	0.046	0.030
Phenylalanine	0.155	0.159
Tyrosine	0.179	0.159
Valine	0.240	0.220
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

The mineral content of goat milk varies from 0.70 to 0.85%, and compared to human and cow milk; goat milk contains more calcium, phosphorous and potassium. The vitamin content of goat milk is similar to that of cow and human milk. Goat milk differs from cow or human milk in having better digestibility, alkalinity, buffering capacity and certain therapeutic values in medicine and human nutrition(Ghada, 2005). 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 as1-casein, resulting in softer gel products, a higher water holding capacity and a lower viscosity. 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. 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 nonprotein nitrogen and mineral compounds in goats' 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. Mineral contents of commercial US goat milk yogurt have been shown to have significant differences in the levels of Ca, Mg, P, Fe, Zn, and Al between different yogurt varieties (Hernadez and Young, 2014) Mineral concentrations of 30 varieties of commercial goat milk cheeses produced in the US revealed that there were wide variations in concentrations of P, K, Ca, Na, Cl, Fe, Al and Zn among and within varieties of the cheeses.

Composition of minerals and vitamins in human and goat milk

Composition	Human	Goat
Ca, mg/L	280	1304
P	140	1080
Mg	35	136
Na	180	488

K	525	1996
Cl	420	1566
Fe	0.3	0.5
Zn	1.2	2.9
Cu	0.25	0.23
Vitamin A (RE)	670	548
Vitamin D microg/L	0.55	0.6
Vitamin E	2.3	--
Vitamin K	2.1	12
Thiamin	0.21	0.5
Riboflavin	0.35	1.4
Niacin	1.5	2.7
Ascorbic acid	40	12.6
Panthothenic acid	1.8	3.0
Vitamin B6	0.093	0.5
Vitamin B12	0.97	0.64

Bioavailability of Nutrients

The nutrients are contained in fairly good proportions, well balanced and readily available to meet human body requirements. Availability of proteins is higher than in milk from other animals. Provides 8.7 grams of protein (17.4% of the daily value for protein) per 100 gm. While same amount of cow milk provides 8.1 grams (16.3% of the daily value for protein). Although the mineral content of goat's milk is generally similar to the cows, goat's milk contains 13 percent more calcium, 25 percent more vitamin B-6, 47 percent more vitamin A, 134 percent more potassium. It has three times more niacin. It contains four times more copper and 27 percent more selenium (Peter, 2015).

Goat dairy products have interesting characteristics in their levels of flavour, taste, aromas and leanness as well as the specific composition of fats, proteins, amino and fatty acids. The quality of goat milk may be defined as its potential to undergo technological treatment and result in a Product which lives up to the consumer's expectations in terms of nutritional value, safety, and sensory attributes (Boyazoglu et al., 2001)Their quality is very much linked to historical and cultural uniqueness right through the production, marketing and consumption chains. It is a source of proteins of excellent quality, thanks to the proportion of essential amino acids they provide. Goat milk is also highly digestible and the biological value of its proteins is superior to that of cow milk proteins. Goat milk proteins are similar to the major cow milk proteins in their general classifications of α-, β-, κ-caseins, β-lactoglobulin, α-lactalbumin, but they differ in genetic polymorphisms and their frequencies in goat populations. The presence of the αs1casein trait has been studied much in recent years, when it was discovered that it has six different types, A, B, C, E, F and "null" in goat milk. In cow milk, αs1-casein is the major αs-casein. The "null" type or absence in some goat milk means that in different goats the major (αs-casein is the αs2-casein variant, but which has different digestibility and cheese making properties.

Properties of Functional Ingredients in Goat Milk

The differences in genetic types are due to amino acid substitutions in the protein chains, which in turn are responsible for the differences in digestibility, cheese making properties and flavors of goat milk products, but the amino acid substitutions also enable the detection of even small amounts of adulteration with cow milk.

Furthermore, caproic, caprylic, capric and other mediumchain fatty acids have been used for the treatment of malabsorption syndromes, intestinal disorders, coronary diseases, premature infant nutrition, cystic fibrosis and gallstone problems because of their unique metabolic ability to provide energy while at the same time lowering, inhibiting and dissolving cholesterol deposits (Ariane *et al.*, 2014).

The production of cheese from goats' milk has a very long history and is an important source of protein for people in several countries. In the last decade, there has been an increased interest substitute to cow milk for those who suffer from cow milk allergy or goat milk production and its conversion to value added products as well as a renewed interest in goat milk as an alternative milk source for people with cow milk intolerance. In some developing countries, goat milk provides a principal source of animal protein, calcium and phosphorus to human nutrition. Goat milk contains much taurine, the substance added to health drink and revitalizers and there are reports that goat milk contributed to the treatment of diabetics.

The drug called Aimspro made from goat blood offers hope to multiple sclerosis patients by improving their vision. It is the first time that any treatment has been shown to reduce an aspect of disability in the chronic phase of the disease (Anaeto *et al.,* 2010). These nutritional, health and therapeutic benefits enlighten the potentials and values of goat milk and its specialty products. The chemical characteristics of goat milk can be used to manufacture a wide variety of products, including fluid beverage products (low fat, fortified, or flavored) and UHT (ultra high temperature) milk, fermented products such as cheese, buttermilk or yogurt, frozen products such as ice cream or frozen yogurt, butter, condensed/dried products, sweets and candies (Riberio and Riberio, 2010). In addition, other specialty products such as hair, skin care and cosmetic products made from goat milk recently have gained a further attention. Nevertheless, high quality products can only be produced from good quality goat milk. The quality milk should have the potential to tolerate technological treatment and be transformed into a product that satisfies the expectations of consumers, in terms of nutritional, hygienic and sensory attributes. Taste is the main criteria used by consumers to make decisions to purchase and consume goat milk and its products. Typical goat taste is considered as a quality component in certain goat cheese products. Farmers can produce more value-added products for the economic sustainability of their business and the dairy goat industry in general (Yalinger, 2013).

Besides, certain therapeutic properties in human nutrition, such as a better utilization of fat and mineral salts in individuals suffering from malabsorption syndrome, are attributed to goats' milk. Goats' milk contains also free taurine, one of the final metabolic products of sulphur containing amino acids, which may have several biological functions: modulator of growth and of neuronal activity; conjugation of bile salts; regulation of osteoblast metabolism ; protection of cells against various types of injury and prevention of cardiovascular damage; treatment of fatty liver of children . Thus, due to the unavailability of cow milk products, goat milk and its products are important daily food sources of protein, phosphate and calcium in underdeveloped countries.

Functional Dairy Products with Goat Milk

The use of milk with particular nutritional properties (e.g., goats', mares' and donkeys' milk), alone or in combination with bacterial strains having probiotic properties and/or producing physiologically active metabolites, represents one of the technology options for manufacturing new dairy functional beverages. The functional value of goats' milk may be further exploited through fermentation by selected microorganisms possessing specific features. A mixed starter comprising *Lactobacillus acidophilus, Bifidobacterium lactis* and *Streptococcus thermophilus* has been successfully used for fermentation of goats' milk, and a high viability of probiotic strains in a fermented goats' milk stored at 4^0C for 10 days has been reported (Kongo *et al.,* 2006). Furthermore, the synthesis of folate from some Lactic acid bacteria has been shown to occur during fermentation of goats' milk, and the antiatherogenic effects of a goats' milk fermented with the probiotic *Lactobacillus fermentum ME-3* have been reported (Sanna *et al.,* 2005). The anti-atherogenic effects of a goats' milk fermented with the probiotic Lactobacillus fermentum ME-3 have been reported in 16 healthy subjects (Kullisaar et al., 2003). Sheep and goat cheeses are very well recognized by connoisseurs as gastronomic and festive products.

Goats' milk products, especially cheeses and yogurt are very popular in the Mediterranean peninsula, the Middle East, southern Russia and the Indian subcontinent. Goat cheese was originated in Mesopotamia. The milk was probably made into soft cheese, and then hard, ripened goat cheeses were later developed in the Mediterranean basin countries (Jenness, 1980). There are goat cheeses made from raw and pasteurized milk. In many countries the manufacture of goat cheese from raw milk is prohibited due to food safety issues (e.g. brucellosis). The type of milk used significantly influences the finished cheese. oup of dairy products, made by a process involving lactic acid fermen fermentation, which is popular in Bedouin areas of Saudi Arabia and Arabian Gulf countries.

Oggtt is basically a hard cheese like product that is considered stable and safe dried fermented milk. It is mainly produced by Bedouins during the spring season when milk is produced in excess amount (Badriah *et al.,* 2013). Chakka is a concentrated product obtained after draining the whey from dahi (fermented milk product). Mixing Chakka obtained from goat milk with sugar and other condiments results in Shrikhand, a very popular and traditional dessert in Western India (Prajapati *et al.,* 2003).

Goat Milk: Development of Functional Foods and Neutraceuticals

Traditionally, goat and cow milk has been considered as a fundamental food in the diets of many cultures. Milk provides an easily accessible matrix, rich in a large variety of essential nutrients like minerals, vitamins and easy digestible proteins with balanced amino acid profiles, important in supporting most body functions. Together with grains, meats, vegetables and fruits, dairy products are categorized as nutrient-dense foods, i.e., foods that deliver many nutrients with relatively low energy content, and are relevant to health throughout the life cycle. Consumption of dairy products and goat milk in particular, is also associated with beneficial health effects beyond its pure nutritional value. 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 (Minervini *et al.*, 2009). Goat milk lacks a homolog of bovine β_{s1}-casein, the most abundant protein in cow milk. Goat dairy products also serve as vehicles for other functional ingredients, such as phytosterols (as cholesterol replacement), fish fatty acids (as omega-3 acids) and various kinds of probiotic bacteria. Goat milk makes an excellent matrix for developing a large variety of innovative health promoting products or functional foods.

In addition to contributing to the specific "goaty" flavor, the higher proportion of medium chain fatty acids in goat milk, are known to:

i. Anti-bacterial

ii. Anti-viral

iii. Inhibit development and to dissolve cholesterol deposits

iv. Absorbed rapidly from the intestine

Thus, these characteristic undoubtedly contribute to the specific health promoting properties of goat milk. However, further research is needed to exploit these interesting characteristics of goat milk in full. As human milk lacks α_{s1}-casein, the low levels of α_{s1}-casein in some goat milks and higher proportion of β-casein means that goat milk casein profile is closer to human milk.

Goat milk is reported to form a finer curd than cow milk following acidification, which mimics the conditions in the stomach, suggesting it would be more readily digested. In vitro studies confirm a different pattern of digestion of goat milk proteins compared to cow milk proteins.

In goat milk, taurine, glycine and glutamic acid are the major free amino acids.

Taurine is particularly high in goat milk, being 20-40-fold higher than cow milk. Taurine is involved in bile salt formation, osmoregulation, antioxidation, calcium transport and in the central nervous system. Premature infants who lack the enzymes needed to convert cystathionine to cysteine may become deficient in taurine. Thus, taurine is a dietary essential nutrient in these individuals and is often added to many infant formulas as a measure of prudence (Perk *et al.*, 2007). Taurine is also beneficial for adults, helping to regulate blood pressure and possibly to alleviate other cardiovascular ailments.

Goat milk also contains a complex array of Nucleotides which are assumed to facilitate immune maturation of the milk-fed offspring and are often added to infant formulas. Nucleotides are major components of RNA and DNA, and participate in the mediation of energy metabolism, signal transduction and general regulation of cell growth. They also participate in lipoprotein metabolism, enhanced high-density lipoprotein (HDL) plasma concentration, as well as enhanced synthesis of apolipoprotein (Apo) A1 and Apo A1V in preterm infants, and in upregulation of long-chain polyunsaturated fatty acid synthesis in human neonates.

Ribonucleotides (RNu) are considered 'conditionally essential' for the proper development of human neonates, because the supply of RNu through *de novo* synthesis and endogenous salvage pathways is thought to be insufficient for optimal functioning of rapidly growing intestinal and lymphoid tissues, even though their low levels might not result in an overt clinical deficiency.

Plants produce an enormous array of secondary metabolites, which serves diverse functions, such as protection against microbial pathogens, as a natural deterrent to grazing animals, or as inhibitors of pre-harvest seed germination. Tannins are the prevailing secondary metabolites when considering the diets of ruminants. Detoxification of tannins by goats is based on enzymatic hydrolysis and depolymerization of the ingested tannins.

The physical, chemical and organoleptic features of milk and cheese are greatly affected by the diet of the grazing animals, due to accumulation of phytochemicals in the lipid and water-soluble fraction of mil). In particular, monoterpens are identified as compounds that greatly influence the aroma of milk. High content of phenols in goat milk has shown to improve the quality of milk, such as its oxidative stability and the processing efficiency and quality of dairy products. Goat milk is also rich in phenolic compounds derived from the diet represents a 'treasure trove' of potential opportunities for developing functional foods.

Conclusion

The production of quality goat milk through professional breeding programs can be rewarding, profitable, pleasant and successful. Although goats have been the most defamed domesticated animal in many countries, it has played an important role in human nutrition, wellbeing and survival around the world. Human had to give more importance to their health and nutritional situation with increasing environmental pollution and stress in their life. So, recently it is watched that there has been increasing demand to foods that has functional foods. Functional foods can be defined as foods that have positive effects on the health. The nutritional value of goat meat and milk is becoming recognized because of the medicinal values for treating many human diseases. Therefore, awareness about advantage of consumption of goat milk should be popularized so that production and utilization of goat milk could be enhanced. The research is still required to exploit the use of liquid goat milk as well as its application licensing in manufacture of several milk products especially various types of cheese and fermented milk food throughout the world.

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