Nutritional Features of Goat Milk — A Review

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The goat is one of the main contributors of dairy and it produces about 2% of the world’s total annual milk supply. Goat’s milk is the most highly consumed milk in many other parts of the world and it is delicious as well as extremely nutritious. It has vitamins, minerals, trace elements, electrolytes, enzymes, proteins, and fatty acids that are easily assimilated by the body. Goat’s milk has a similarity to human milk that is unmatched in bovine (cow) milk and also has several medicinal values. Therefore, awareness about advantage of consumption of goat milk should be popularized so that production and utilization of goat milk could be enhanced.

Keywords: Goat’s milk, Nutritional value, Protein, Fat profile, Minerals, Vitamins

INTRODUCTION

Goat is truly known as the poor man’s cow. Dairy goat and dairy sheep farming are a vital part of the national economy in many countries, especially in the Mediterranean and Middle-East region and are particularly well organized in France, Italy, Spain and Greece (Chiofalo et al., 2004). Presently, India possesses 126 million goats which constitute 14.5% of the world (FAO, 2009). The goat is one of the main contributors of dairy and meat products for rural people, more than any other mammalian farm animal, particularly in developing country. One of the prominent aspects of demand of goat milk is its home consumption. This demand is increasing because of the growing populations of people. The second important aspect of demand for goat milk is the connoisseur interest in goat milk products especially, cheeses and yoghurt in several developed and developing countries. This demand is growing because of the increasing levels of per capita incomes. In addition to that, another important aspect of demand for goat milk derives from the affliction of persons with cow milk allergies and other gastro-intestinal ailments. This demand is also growing because of a greater awareness of problems with traditional medical treatments to such afflictions among the people. Goat milk is wanted or even needed by people of all income groups. Despite the much larger volume available of cow milk, it’s much cheaper production usually and therefore, lower market price, the production and marketing of goat milk and its products is therefore, an essential niche in the total dairy industry sector. Goat milk differs from cow or human milk in having better digestibility, alkalinity, buffering capacity and certain therapeutic values in medicine and human nutrition (Coni et al., 1999).

The specific gravity of cow and goat milk is almost similar and generally found in the range of 1.023 to 1.030. Titratable acidity (expressed as percentage of lactic acid) is also nearer to that

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of cow's milk and generally observed from 0.11 to 0.18. Viscosity at 27°C is marginally lower than that of cow's milk. In addition to that, the refractive index of goat milk is also almost close to cow milk. The electrical conductivity of goat milk is found in the range of 0.0101 to 0.0188 ohm$^{-1}$ cm$^{-1}$, whereas, pH value of goat milk found in the ranges of 6.5 to 6.9 as against 6.6 to 6.8 in case of cow milk. However, curd tension is below than the cow milk, which is responsible for better digestibility in goat milk as compared to cow milk. Goat milk has more Ca, P and K in comparison to cow and human milk (Bihaqi and Jalal, 2010). Goat milk also has simple lipids (diacylglycerols, monoacylglycerols, cholesterol esters), complex lipids (phospholipids) and liposoluble compounds (sterols, cholesterol esters, hydrocarbons). Non-protein nitrogen (NPN) contents of goat and human milks are higher than in cow milk (Jooyandeh and Aberoumand, 2010). Especially, one of the important aspects of demand for goat milk is mainly due to its medicinal value. Still, more research for its nutritional and medicinal value is essential for utilization of goat milk in human consumption as well as in medicinal use in developing as well as in developed countries.

**NUTRITIONAL VALUE OF GOAT MILK**

The overall average composition of goat, cow and human milk is presented in Table 1. The nutritional and health benefits of goat milk are related to a number of medical problems of people, foremost being food allergies with cow milk proteins the dominant food cause (Walker, 1964). The $\alpha$-Lactoglobulin is not present in human milk and has therefore been assumed to be the most offending protein in cow milk, however comparative studies showed no difference between the allergenicity of $\alpha$-lactoglobulin and caseins (Buergin-Wolff et al., 1980; Taylor, 1986). Cow milk allergy is considered a common disease with a prevalence of 2.5% in children during the first 3 years of life (Businco and Bellanti, 1993), occurring in 12-30% of infants less than 3 months old (Lothe et al., 1982), with an overall frequency in Scandinavia of 7-8% (Host et al., 1988), even as high as 20% in some areas (Nestle, 1987), and reported in Italy in 3% of children under 2 years of age (Bevilacqua et al., 2000). Treatment with goat milk resolved between 30 and 40% of the problem cases, and in one particular study 49 of 55 treated children benefited. There are wide varieties of genetic polymorphisms (Grosclaude, 1995) of the different caseins and whey proteins which add to the complexity of the cow milk allergy situation and difficulty to determine which protein is mainly responsible for an allergic reaction. However, it has now been noticed that this genetic protein diversity may actually help identify which protein is the allergen, if genetic polymorphisms of milk proteins are specifically used for clinical tests (Bevilacqua et al., 2000). Goat milk with the genetic trait of low or no $\alpha_s$-casein, but instead with $\alpha_s$-casein, has less curd yield, longer rennet coagulation time, more heat stability, and weaker curd firmness, which also may explain the benefits in digestibility in the human digestive tract (Ambrosoli et al., 1988). Goat milk as a substitute for cow milk was studied in 38 children during a 5 months period (Mack, 1952). The children on goat milk surpassed those on cow milk in weight gain, height, skeletal mineralization, and blood serum contents of Vitamin A, calcium, thiamin, riboflavin, niacin and hemoglobin. Similar findings were obtained in studies with rats (Park et al., 1986). In other extensive clinical studies with children allergic to cow milk, the treatment with goat milk produced positive results in 93% of the children and was recommended as a valuable aid in child nutrition because of less allergenicity and better digestibility than cow milk (Reinert and Fabre, 1997; Fabre, 1997; Grzesiaj, 1997). In further studies with rats, which had 50% of their distal small intestine removed by resection, simulating the pathological condition of malabsorption syndrome, the feeding of goat milk instead of cow milk as part of the diet resulted in significantly higher digestibility and absorption of iron and copper, thus preventing anemia (Barrionuevo et al., 2002). Due to predominance of smaller fat globules in goat milk, it is easier to digest than cow milk and this may be attributed to faster lipase activity on smaller fat globules due to greater surface area. Due to this, fatty acids like caproic, caprylic and capric are reported to have great medicinal values for patients suffering from a variety of malabsorption, childhood epilepsy, cystic fibrosis and gallstones (Haenlein, 1992). Hence, goat milk is recommended for infants, old and convalescent people. In addition to this, fatty acids like caproic, caprylic and capric are reported to have great medicinal values for patients suffering from a variety of malabsorption, childhood epilepsy, cystic fibrosis and gallstones (Haenlein, 1992). Also in these further studies, the utilization of fat and
weight gain was improved with goat milk in the diet, compared to cow milk, and levels of cholesterol were reduced, while triglyceride, HDL values remained normal (Alferez et al., 2001). It was concluded that the consumption of goat milk reduces total cholesterol levels and the LDL fraction because of the higher presence of medium chain triglycerides (MCT) (36% in goat milk versus 21% in cow milk), which decreases the synthesis of endogenous cholesterol. Thus goat milk is recommended as a "useful alternative to cow milk for all age groups especially to children."

**PROTEIN PROFILE OF GOAT MILK**

The comparative composition of proteins and their components in the milk of goats and cows have been reviewed by Jenness (1980) and Haenlein (2001), identifying many unique differences between the two species, and showing a wide diversity due to genetics of different breeds within each species, influences of stage of lactation, feeding, climate, and subclinical mastitis. It has been found that goat milk has a significantly higher dye-binding capacity per unit protein (1% more than cow milk) and a lower infra-red absorption (4% less than cow milk) (Grappin et al., 1979), making it necessary to use different calibration curves for each species to measure milk protein content. These studies have been supported by Zeng (1996), when testing with cow milk standards resulted in 0.04% less fat and 0.27% less protein in goat milk. Goat milk proteins are similar to the major cow milk proteins in their general classifications of \( \alpha \), \( \beta \), \( \kappa \)-caseins, \( \beta \)-lactoglobulin, \( \alpha \)-lactalbumin, but they differ widely in genetic polymorphisms and their frequencies in goat populations (Grosclaude, 1995). The presence of the \( \alpha_s \)-casein 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, \( \alpha_s \)-casein is the major \( \alpha \)-casein. The "null" type or absence in some goat milk means that in different goats the major (\( \alpha_s \)-casein is the \( \alpha_{s2} \)-casein variant, but which has different digestibility and cheese making properties (Remeuf, 1993). The differences in genetic types are because of amino acid substitutions in the protein chains, which are responsible for the differences in digestibility, cheese making properties and flavors of goat milk products (Rystad et al., 1990), but the amino acid substitutions also enable the detection of even small amounts of adulteration with cow milk (Aschaffenburg and Dance, 1968; Amigo et al., 1989). Peptides formed from goat milk casein by proteases tasted much less bitter than those from cow milk casein (Pelissier and Manchon, 1976). Casein micelles, the form of casein molecule suspended in goat milk, also differ markedly from cow milk in less complete sedimentation rate, greater \( \beta \)-casein solubilization, smaller size of micelle, more calcium and phosphorus, less solvation, and low heat stability (Jenness, 1980). Average amino acid composition of goat and cow milk (Table 2), shows higher levels of 6 of the 10 essential amino acids: threonine, isoleucine, lysine, cystine, tyrosine, valine in goat milk (Posati and Orr, 1976). Their comparative metabolic effects have not been studied much in goat milk, but this could assist in the interpretation of some of the empirical beneficial effects of goat milk in human nutrition. In studies with rats, which had malabsorption syndromes, it was found that goat milk improved the intestinal absorption of copper, which was attributed to the higher contents of cysteine (derived from cystine) in goat milk (83 mg/100 g) than in cow milk (28 mg/100 g) (Barrionuevo et al., 2002). Overall, the adult daily dietary nutrient recommendations for essential amino acids would be met equally or exceeded by a 0.5 litre goat milk consumption compared to same quantity of cow milk (NRC, 1968).

<table>
<thead>
<tr>
<th>Species</th>
<th>Water</th>
<th>Fat</th>
<th>Protein</th>
<th>Lactose</th>
<th>Ash</th>
<th>Solid-not-fat (SNF)</th>
<th>Total Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat</td>
<td>87.00</td>
<td>4.25</td>
<td>3.52</td>
<td>4.27</td>
<td>0.86</td>
<td>8.75</td>
<td>13.00</td>
</tr>
<tr>
<td>Cow</td>
<td>87.20</td>
<td>3.70</td>
<td>3.50</td>
<td>4.90</td>
<td>0.70</td>
<td>9.10</td>
<td>12.80</td>
</tr>
<tr>
<td>Human</td>
<td>87.43</td>
<td>3.75</td>
<td>1.63</td>
<td>6.98</td>
<td>0.21</td>
<td>8.82</td>
<td>12.75</td>
</tr>
</tbody>
</table>

Source: Webb and Johnson, 1965
FAT PROFILE OF GOAT MILK

An important component in goat milk is its fat or lipid content. The size of fat globules in milk range from 1-10 micron in both cow and goat. But, in goat milk the globule size less than 5 microns is 83%, as compared to 62% in cow’s milk (Bihaqi and Jalal, 2010). Average goat milk fat differs in contents of its fatty acids profile significantly from average cow milk fat (Jenness, 1980), being much higher in butyric (C4:0), caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0), linoleic (C18:2), but lower in stearic (C18:0), and oleic acid (C18:1) (Table 3). Capric, caprylic acids and medium chain triglycerides (MCT) have become established medical treatments for an array of clinical disorders, including malabsorption syndromes, chyluria, steatorrhea, hyperlipoproteinemia, intestinal resection, premature infant feeding, non-thriftiness of children, infant malnutrition, epilepsy, cystic fibrosis, coronary by-pass, and gallstones, because of their unique metabolic ability to provide direct energy instead of being deposited in adipose tissues, and because of their actions of lowering serum cholesterol, inhibiting and limiting cholesterol deposition (Alferez et al., 2001). Goat milk has higher content of monounsaturated (MUFA), polyunsaturated fatty acids (PUFA), and medium chain triglycerides (MCT) than cow milk, which all are proven to be beneficial for human health, especially for cardiovascular conditions (Table 3). This biomedical superiority has not been promoted much in marketing goat milk, goat yoghurt and goat cheese, but has great potential in justifying the uniqueness of goat milk in human nutrition and medicine (Haenlein, 1992) for treating the various gastro-intestinal disorders and diseases, besides its value in alleviating cow milk allergies. The fatty acid composition of goat milk fat can also be changed towards even more of the beneficial fatty acids by different regimes of feed supplementation to goats (LeDoux et al., 2002; Sanz Sampelayo et al., 2002).

Manipulations of goat feeding towards higher contents of beneficial unsaturated fatty acids in goat milk fat by feeding special feed supplements like protected fats can be used to “tailor make” “functional foods” and even further improve the nutritional value of goat milk (Sanz Sampelayo et al., 2002). Recently more “beneficial fat”, conjugated linoleic acid (CLA), has been identified as a potent anticarcinogen and is primarily provided to the human diet by dairy products (Pfeuffer, 2000; Kansal, 2003). Mono ethyl-branched substitutions on C4 and C6 fatty acids are present only in goat milk and not in...
cow milk. A comparatively high number of minor branched-chain fatty acids is found in goat milk and the content of trans-C18:1 fatty acids is significantly lower in goat milk than in cow milk, also a benefit for coronary heart disease risks.

Goat butter, ghee and related products with their even higher contents of MCT, unsaturated fatty acids and CLA than the original milk has not been studied much nor produced commercially. Here is the potential to provide a goat milk product with specially beneficial and proven properties for human nutrition and health, besides its general food value to starving people and to connoisseurs. This supports the idea that goat butter would have new and not yet promoted for human health benefits so far. So, there is a need to further studies the beneficial health aspects of goat milk and milk products.

There are a number of unique physiological and anatomical differences between goats and cows which translate into differences in composition of goat milk and its products (Haenlein, 1992, 1996, 2001). This was already recognized by the Goat Milk Task Force of the National Conference on Interstate Milk Shipments (NCIMS, USA) (Atherton, 1983). US dairy industry had set up separate standards for goat milk from cow milk for butter fat content minimum, solids-not-fat content, somatic cell count maximum, method for only nucleated cells in milk, lower freezing point level, different natural inhibitor test, different milk pasteurization test, validity of brucellosis ring test, detection of cow milk in goat milk, all of which had to insure fair market quality control regulations and practices for goat milk producers.

**MINERAL PROFILE OF GOAT MILK**

Mineral contents of goat milk are much higher than cow and human milk. Goat milk contains about 134 mg Ca and 121 mg P/100 g (Table 4), while human milk has only one-fourth to one-sixth of these two major minerals. The concentrations of macro-minerals may not fluctuate much, but they vary depending on the breed, diet, individual animal, stage of lactation, and status of udder health (Park and Chukwu, 1988). Overall, goat milk has more Ca, P, K, Mg and Cl, and less Na and S contents than cow milk (Park and Chukwu, 1988; Chandan et al., 1992). Among trace minerals, Zn was in greater amounts, but goat and cow milk had more Zn than human milk (Park and Chukwu, 1989). Levels of Fe in goat and cow milk are significantly lower than in human milk (Table 4), whereas goat and cow milk contain significantly greater iodine contents than human milk, which would be important for human nutrition, since iodine and thyroid hormones are involved in the metabolic rate of physiological body functions (Underwood, 1977). Goat and human milk contain

| Table 3: Average fatty acid composition (g/100 g milk) in lipids of goat and cow milk |
|--------------------------------------|--------------------------------------|--------------------------------------|
| Goat milk                           | Cow milk                             | Difference (%) for goat 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                                 |

(Source: Posati and Orr, 1976)  
MCT: medium chain triglycerides; SAFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids

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higher levels of Se than cow milk (Table 4). Small amounts of Se (<3%) are associated with the lipid fraction of milk. Glutathione peroxidase is higher in goat than in human and cow milk. Total peroxidase activity (associated with glutathione peroxidase) was 65% in goat milk as opposed to 29% for human and 27% for cow milk (Debski et al. 1987).

**VITAMIN PROFILE OF GOAT MILK**

Goat milk has higher amounts of Vitamin A than cow milk (Table 5). Because goats convert all β-carotene into Vitamin A in the milk, caprine milk is whiter than bovine milk. Goat milk supplies adequate amounts of Vitamin A and niacin, and excesses of thiamin, riboflavin and pantothenate for a human infant (Ford et al., 1972; Parkash and Jenness, 1968). If a human infant fed solely on goat milk, the infant is oversupplied with protein, Ca, P, Vitamin A, thiamin, riboflavin, niacin and pantothenate in relation to the FAO-WHO requirements (Jenness, 1980). Compared to cow milk, goat milk has significant deficiencies in folic acid and Vitamin B₁₂, which cause "goat milk anemia" (Jenness, 1980). Levels of folate and Vitamin B₁₂ in cow milk are five times higher than those of goat milk, and folate is necessary for the synthesis of hemoglobin (Davidson and Townley, 1977). Goat and cow milk are both deficient in pyridoxine (B₆), Vitamins C and D, and all these deficient vitamins must be supplemented to baby nutrition from other sources (Mc Clenathan and Walker, 1982). In heat treatment of goat milk, Lavigne et al. (1989), reported that high temperature short time pasteurization (HTST)
of goat milk was the best processing method to preserve vitamins as well as to extend shelf-life of the milk, although some losses of thiamine, riboflavin and Vitamin C occurred.

CONCLUSIONS
It is evident from this paper that goat milk is superior with respect to cow milk in terms of nutritional value of milk. Awareness about advantage of consumption of goat milk should be popularized so that production and utilization of goat milk could be enhanced. More research are 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.

REFERENCES


Features of Goat Milk


