Physico-Chemical, Nutritional, Heat Treatment Effects and Dairy Products Aspects of Goat and Sheep Milks

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Abstract: Physico-chemical characteristics of milk are related to its composition for a particular animal species. Sheep milk contains higher levels of total solids and major nutrient than goat and cow milk. Lipids in sheep and goat milk have different physical characteristics than cow milk. Renneting time for goat milk is shorter than for cow milk and the weak consistency of the gel is beneficial for human digestion but decreases its cheese yield. Sheep and goat milk also have 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. The purpose of this paper was to review the several differences in physico-chemical, nutritional aspects of goat and sheep milk. It also dealt with changes in milk constituents due to heat treatments as well as dairy products produced from these species to focus international attention on the dairy products which can be produced on a large scale in many countries.

Key words: Goat milk · Goat milk · Physico-chemical characteristics · Nutrients · Nutritional and dairy products

INTRODUCTION

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 [1]. However, large-scale industrialization of the dairy goat and dairy sheep sectors in many countries is limited by low volume and seasonal cyclicity of individual milk production, around 50 kg annually [2]. Information on composition and physico-chemical characteristics of goat and sheep milk is essential for successful development of dairy goat and sheep industries as well as for the marketing the products. There are distinct differences in physico-chemical characteristics among goat, sheep and cow milks. The composition of marketed cow milk is expected to have minimal changes throughout the year, because the milk entering bulk tank from the cow herds would vary little by seasons because of year-round breeding. On the other hand, this is quite different from sheep and goat milk, which is predominantly produced by seasonal breeding of ewes and does [3]. Therefore, changes in goat and sheep milk compositions occur due to seasons, because towards the end of the lactation, the fat, protein, solids and mineral contents increase, while the lactose content decreases [4-5].

Goat milk differs from cow or human milk in having better digestibility, alkalinity, buffering capacity and certain therapeutic values in medicine and human nutrition [6-7]. Sheep milk has higher specific gravity, viscosity, refractive index, titratable acidity and lower freezing point than average cow milk [8]. Lipids in sheep and goat milk have higher physical characteristics than in cow milk, but there are variations between different reports [9].

Why goat and sheep milk? This is a critical question which should be asked and answered by all who are trying to help establish a dairy goat and sheep business and industry [10] because the milk supplied from cows is cheaper and more plentiful than goat and sheep milk. There are around 480 million goats worldwide which provide more than 5 million tons of milk [11]. A good dairy goat gives about 3-4 l milk daily [12], which is 90% 1800 kg milk in a 305-day lactation period [13]. The value of goat and sheep milk in human nutrition has so far received very little academic attention and few facts are available [14].

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Physico-Chemical Aspects: Goat and sheep milk is white in colour as compared with cow milk, which is yellowish due to the presence of carotene [15]. Goat milk has a stronger flavour than sheep milk. This might be due to the liberation of short-chain fatty acids during rough handling, which give off a goaty smell [16-17]. Unlike cow milk, which is slightly acidic, goat milk is alkaline in nature, which is very useful for people with acidity problems. This alkalinity is due to the higher protein content and a different arrangement of phosphates [18]. The gross composition of goat and sheep milk is similar, but sheep milk contains more fat, solids-non-fat, proteins, caseins, whey-proteins and total ash as compared with goat milk. These differences make the rennet coagulation time for sheep milk shorter and the curd firmer owing to the differences in the caseins [19]. Solids in goat milk can range from 12 to 18%, while in sheep the range is from 15 to 20%. Proteins within the solids are between 3% and 4.5% in goat milk and between 5% and 6% in sheep milk [20-21].

There are many significant differences in the amino acids of goat and sheep milk proteins [22] and also in the relative proportions of the various milk proteins and their genetic polymorphism [23-25]. Sheep milk caseins differs markedly from that of goat milk [26]. K-casein has been isolated and characterized from goat milk [27] and sheep milk [28] and both were similar to cow K-casein in many respects. Sheep K-casein glycopolypeptide has polysaccharide fractions which closely resemble those of cow K-casein glycopolypeptides [29]. The casein in goat milk appears to lack an electrophoretic component with the mobility of bovine βs-1-casein. The CÎÎ-2-fraction of goat casein represents a much smaller proportion of the total casein than the CYs-1-moietiy of bovine casein, making the p-caseins quantitatively the major proteins of goat milk [30]. The very low content or absence of αs-1-casein in goat milk makes it possible to detect adulteration of goat milk with cow milk. It has been reported that as little as 1% of cow milk may be detected in goat milk by gel electrophoresis [31]. P-âcactoglobulin (p-Lg) has been purified and characterized in milk from goats and sheep [32,33]. Several workers have reported the amino acid composition of the sheep p-Lg variants (Mc-Kenzie, 1971) and the goat p-Lg variants. Amino acid analysis of sheep p-Lg A and p-Lg B indicates that p-Lg A has one His less and one Tyr more than p-Lg B [34]. Further studies carried out on the p-Lg of goat and sheep milk confirmed that these proteins are generally formed of two identical polypeptide chains with a molecular weight of 18000 + 500 daltons [35]. These differences may explain the significant advantages of sheep milk for infants and other patients with digestive problems [36]. The lipids of sheep milk are somewhat similar to those of goat milk. The most significant difference between goat and sheep milk is the presence of low-chain fatty acids such as caproic, caprylic and capric acids in higher proportions in goat milk than in sheep milk. The presence of relatively high levels of medium-chain fatty acids in goat milk could be responsible for its inferior flavor [37]. A comparison of the straight-chain fatty acids in goat milk fat with those in cow milk fat shows slightly higher levels of C6:0, C8:0, C10:0 and C14:0 and a considerably higher level of C12:0 in goat milk [38]. Goat milk is also different from cow and sheep milk in several other ways. It has a greater proportion of medium- and short-chain fatty acids and lacks the agglutinating protein that causes the clustering of fat globules and the rapid separation of cream [39]. The carbohydrate fraction of goat and sheep milk is lactose [40]. The level of lactose in goat milk is usually slightly higher than that in sheep milk (IDF, 1986). The total ash content of goat milk is lower than that of sheep milk. Goat milk contains approximately 194 mg calcium, 270 mg phosphorus, 154 mg chloride, 50 mg sodium and 204 mg potassium per 100 g [41] as compared with 160 mg calcium and 145 mg phosphorus per 100 g for sheep milk. The total ash level in goat milk is slightly higher than that in cow milk, usually ranging from 0.70 to 0.85%. Some workers [42,43] have reported that the iron content in goat milk is between 1.50 and 2.20 p.p.m. Lipase activity has been found in the milk of both goats and sheep, but little or no lysozyme activity has been found. Xanthine oxidase has been reported in sheep and goat milk [43] and it has also been reported to contain more rhodanase than cow milk. One study reported that raw goat milk contains less alkaline phosphatase than raw cow milk (Milk Industry Foundation, 1959). Goat and sheep milk supplies adequate amounts of vitamin A, thiamine, riboflavin and pantothenic acid, but it is deficient in vitamins C and D, cyanocobalamin and folic acid and may be deficient in pyridoxine [44]. Several cases of anaemia attributed to goat milk diets were reported to have been cured by the patients being given folic acid [45]. Goat and sheep milk contains phospholipids at a level of 30-50 mg per 100 ml depending on the species, type of feed and season. These phospholipids account for 0.2-1.0% of the total lipids. The phospholipids of goat and sheep milk consist of about six fractions, the main ones being phosphatidyl choline, phosphatidyl ethanolamine and sphingomyelin, while phosphatidyl serine, phosphatidyl inositol and lysophospholipid constitute only a small fraction [46]. The purpose of this review paper is to review the specific characteristics of physico-chemical and dairy products properties of goat and sheep milks.
DISCUSSION

Nutritional Aspects: The nutritional advantage of goat milk over sheep milk actually comes not from its protein, mineral or vitamin differences, but from the lipids, or more specifically the fatty acids within the lipids [47]. The fat of goat milk is more digestible than that of cow milk because the fat globules of goat milk are smaller and have a greater surface area and lipases in the gut are supposedly able to attack the lipids more rapidly. However, almost 20% of the fatty acids of goat milk fall into the short-chain fatty acids category (C4:0 to C12:0) compared with less than 20% for cow milk. Lipases attack the ester linkages of the shorter-chain fatty acids more readily, so these differences may contribute to more rapid digestion of goat milk fat [48]. The proteins in goat milk are digested more readily and their constituent amino acids absorbed more efficiently than those of cow milk [49]. Caproic, caprylic, capric and other medium-chain 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 [50]. Goat milk is recognised for its superior nutritional quality and is an important source of milk constituents for individuals suffering from an allergy to cow milk [51].

Minerals: Trace mineral contents of goat milk are also affected by diet, breed, individual animal and stages of lactation [52]. Mean levels of Mn, Cu, Fe and Zn in goat milk were 0.032, 0.05, 0.07, 0.56 mg/100 g, while Anglo-Nubian goat milk contained significantly higher levels of Cu and Zn than French-Alpine goat milk. Among trace minerals, Zn was in greater amounts, but goat and cow milk had more Zn than human milk. Levels of Fe in goat and cow milk are significantly lower than in human milk, 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 [52].

Vitamins: Goat and sheep milk have higher amounts of Vitamin A than cow milk. Because goats convert all 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 [41]. 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. Vitamin B levels in goat and cow milk are a result of rumen synthesis and are somewhat independent of diet [42]. Compared to cow milk, goat milk has significant deficiencies in folic acid and Vitamin B12, which cause “goat milk anemia” [43]. Levels of folic acid and Vitamin B12 in cow milk are five times higher than those of goat milk and folate is necessary for the synthesis of hemoglobin. Vitamin B12 deficiency can cause a megaloblastic anemia in infants, but the anemia has been attributed mainly to folate deficiency in goat milk. 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. In heat treatment of goat milk, Haenlein [44] 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. Vitamin contents in sheep milk are mostly higher than in cow and goat milk, except for carotene, however, research data on vitamins in sheep milk are sparse.

Heat Treatment Effect: Guo[??] reported that alkaline phosphatase activity is reduced to minimal levels when goat milk is heated to 62°C for 30 min. Lipase activity has been found in the milk of goats and sheep. Storage of raw goat milk at 4°C resulted in an eight-fold increase in the folic acid content during the first 7 days of storage [44]. When sheep and goat milk were subjected to heating, pasteurization at 63°C for 30 min and boiling, all the treatments caused an increase in the size and a decrease in the number of fat globules due to coalescence, but sheep milk was the most strongly affected. Pasteurization of goat milk did not result in any change in the proteose-peptone level. The average acetaldehyde content in yoghurt from sheep and goat milk was 13.8 and 4.7 p.p.m., respectively. The corresponding average values for the acetone contents were 12.5 and 14.5 p.p.m., respectively. There was an average of 82.8 and 22.1 p.p.m. ethanol in yoghurt from sheep and goats, respectively [45]. The average contents of conjugated and free forms of biliverdin were 1.98 and 0.73 ps per 100 ml in sheep milk and 3.73 and 11.16 pg per 100 ml in goat milk, respectively. Boiling the milk caused a decrease in the conjugated form and an increase in the free form of biliverdin. Milk stored for 3 and 6 days showed a decrease in the conjugated form of biliverdin and an increase in free form [46].
Lipase activity in goat milk can be enhanced by agitation when the milk is slightly alkaline, or reduced by heating (20° and 50°C), cooling (5°C), pasteurization (71°C for 15 s) or boiling when the milk is slightly acidic, as well as by the addition of chemicals such as copper sulphate, lead and silver nitrates and sodium chloride.

**Dairy Products:** There are few available data on the manufacture of fluid goat and sheep milk products such as low-fat, fortified or flavoured milks, cultured products such as buttermilk or yoghurt, frozen products such as ice cream, condensed milk, dried milk products and cheeses [52,53]. Goat and sheep milk and their products have been produced and consumed over many centuries in certain regions of the world, apart from some well-known products as Roquefort cheese [54]. Goat milk is not considered suitable for the manufacture of ghee (Atora and Singh, 1986), the main reason being its relatively small fat globules which present problems during cream separation and its typical odour and flavour.

**Frozen Sheep Milk for Cheese:** Some researchers reported on the influence of freezing sheep milk on coagulation of the milk for cheese making. They found that freezing and thawing sheep milk did not change rennet coagulation properties compared to fresh, unfrozen sheep milk. He froze the sheep milk for 1 month in a blast freezer, so the study was of a short duration. Eric also looked at the activity of five different coagulants on sheep milk. The two *Mucor* enzymes did not coagulate sheep milk as rapidly as calf rennet, chymosin, or the *Endothia* enzyme. No explanation was given for the difference in coagulating activity [55].

**Sheep Milk Flavors:** Dr. Bob Lindsay of the Food Science Department has been working on unique flavor compounds of both goat and sheep milk. In 1991, he reported on some of the branch-chained fatty acids that were unique to mutton and sheep milk [56]. More recently, he has been working on a new group of flavor compounds found in sheep milk and sheep milk cheeses. These alkyl phenols are responsible for the cowy flavor of cow’s milk and the sheepy flavor of sheep’s milk. These flavors, at lower levels of intensity, give a slight dairy note to milk, butter and cheeses. They are also involved in what Dr. Lindsay describes as the “bake-through” flavor of butter. At the current time, Dr. Lindsay and his research group are looking at the use of enzymes to hydrolyze the precursors of these flavor compounds to release these flavor compounds in desirable levels in blended sheep milk cheeses.

**Food Uses for Goat and Sheep Whey:** In the 1980's, there was a significant growth in the dairy goat industry [57]. In 1995, there were 6 cheese plants in Wisconsin processing about 11-12 million pounds of goat milk from the upper Midwest. Three of the cheese plants wanted to expand to meet the demand of new markets for their cheeses. However, due to the environmental constraints on land spreading their whey, these plants were hesitant to increase their production at the current sites. In 1995, we initiated a research project on finding potential food uses for goat whey. At the same time, we included sheep whey in the study to provide for a comparison between the two species.

In the first phase of the study, we looked at the seasonal changes in protein composition of whey from commercial manufacture of goat and sheep cheeses [58]. We wanted to know what patterns in composition to expect as we looked at potential whey products for the food industry. We then took a closer look at the individual whey proteins in each source of whey to determine potential food use for each source of whey. Each whey protein has slightly different functional properties that may be useful in various food systems. When we looked at the seasonal changes in individual proteins of sheep whey, we observed some minor changes. However, when we took into account other parameters impacting whey composition, we felt that the seasonal variation would not significantly impact processing of whey for specific food uses. Results of this first phase of the study showed that goat and sheep wheys have uniquely different whey protein compositions from cow whey. These differences might be useful to provide food-grade whey products for specific uses in the food industry. For example, the high proportions of b-lactoglobulin in sheep whey may offer the potential for whey products with enhanced foaming, gelation and emulsification. In the second phase of our study, we separated the whey proteins from the whey in the form of whey protein concentrates (WPCs). Here again, we ran the trials with goat and cow WPC for comparison. The sheep WPC contained slightly higher levels of minor proteins, such as serum albumin and immunoglobulins than cow or goat WPC and lower levels of b-lactoglobulin. The solubility of the three species of WPC were very soluble at pH 3.0 and 7.0. The foaming properties of sheep WPC were significantly better the goat and cow WPC. Overall, sheep WPC showed some improved functionality over that of 58 goat and cow WPC. Further studies will have to be conducted in specific food systems to confirm these anticipated functional properties.
that we observed in sheep whey proteins. The other question would be what is the value of sheep WPC with these improved functional properties[59,60].

**Storage Stability of Frozen Raw Sheep Milk:** Samples of raw sheep milk were frozen at two different temperatures, 5°F and-18°F, last July. Samples were thawed at 1, 2, 3, 6, 9 and 12 months and analyzed for total bacteria, coliform bacteria, acid degree value (ADV) and intact protein [61]. Results indicate that milk frozen in a standard home freezer at 5°F was not as stable as that frozen in a commercial hardening room at-18°F. After 6 months of storage at 5°F, about one third of the casein was destabilized and precipitated out upon thawing. The raw milk stored at the lower temperature was stable up to the 9th month sampling period. Final analyses after 12 months of storage should give us some feeling for how long we can maintain quality in frozen raw sheep milk. Additional studies may be necessary to determine the cause for the destabilization of casein in frozen milk. Casein precipitation was experienced in frozen concentrated milks that were produced in the 1970’s. This destabilization was due to the concentrated milk salts in the frozen 3:1 concentrates [61].

**Future Sheep Milk Studies:** Further studies will be required to address milk quality problems experienced in frozen raw sheep milk. Some work may involve the use of a preheat treatment of the milk before freezing to inactivate some of the native milk lipases and proteases. Additional studies may look at the adjustment of salts in sheep milk to stabilize the proteins during frozen storage.

In September 1998, we will be initiating a study on the impact of frozen storage of milk on quality of yogurt. The second phase of this study will address the potential production of a dried sheep milk product that would allow the storage of excess sheep milk solids in a stable form. This dried sheep milk could then be used for fortification of cheese milk or addition to other processed sheep milk products like yogurt or ice cream.

In conclusion, the nutritional value of goat milk over sheep milk actually comes from the lipids, or more specifically the fatty acids within the lipids and therefore organoleptic properties of dairy products obtained from goat and sheep milk depends on the milks lipids. We will support the sheep milk processing industry as best we can with available research funds. Up to the present, much of our research funding has come from the specialty cheese program and has been directed toward blended milk cheeses. We will continue to seek additional funding to attempt to address problems and potentials in full sheep milk products. Our ultimate goal is to assist the dairy sheep industry, as best we can, to develop potential markets for dairy sheep milk products.

**REFERENCES**


