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Physico-chemical characteristics of goat and sheep milk☆

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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 higher physical characteristics than in cow milk, but physico-chemical indices (i.e., saponification, Reichert Meissl and Polenske values) vary between different reports. Micelle structures in goat and sheep milk differ in average diameter, hydration, and mineralization from those of cow milk. Caprine casein micelles contain more calcium and inorganic phosphorus, are less solvated, less heat stable, and lose β-casein more readily than bovine casein micelles. Renneting parameters in cheese making of sheep milk are affected by physico-chemical properties, including pH, larger casein micelle, more calcium per casein weight, and other mineral contents in milk, which cause differences in coagulation time, coagulation rate, curd firmness, and amount of rennet needed. 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. Triacylglycerols (TAG) constitute the biggest part of milk lipids (nearly 98%), including a large number of esterified fatty acids. Sheep and goat milk also have simple lipids (diacylglycerols, monoacylglycerols, cholesterol esters), complex lipids (phospholipids), and liposoluble compounds (sterols, cholesterol esters, hydrocarbons). The average fat globule size is smallest (<3.5 μm) in sheep milk followed by goat and cow milk. Five fatty acids (C10:0, C14:0, C16:0, C18:0, and C18:1) account for >75% of total fatty acids in goat and sheep milk. Levels of the metabolically valuable short and medium chain fatty acids, caproic (C6:0) (2.9%, 2.4%, 1.6%), caprylic (C8:0) (2.6%, 2.7%, 1.3%), capric (C10:0) (7.8%, 10.0%, 3.0%), and lauric (C12:0) (4.4%, 5.0%, 3.1%) are significantly higher in sheep and goat than in cow milk, respectively. Principal caseins (CN) in goat, sheep and cow milk are α_{s1}-CN, α_{s2}-CN, β-CN and κ-CN. The main forms of caprine and ovine caseino-macropeptides (CMP), which are the soluble C-terminal derivatives from the action of chymosin on κ-casein during the milk clotting process of cheesemaking, have been identified and are a good source of antithrombotic peptides. Sheep and goat milk proteins are also important sources of bioactive angiotensin converting enzyme (ACE) inhibitory peptides and antihypertensive peptides. They can provide a non-immune disease defence and control of microbial infections. Important minor milk proteins include immunoglobulins, lactoferrin, transferrin, ferritin, proteose peptone, calmodulin (calcium binding protein), prolactin, and folate-binding protein. Non-protein nitrogen (NPN) contents of goat and human milks are higher than in cow milk. Taurine in goat and sheep milk derived from sulphur-containing amino acids has important metabolic functions as does carnitine, which is a valuable nutrient for the human neonate. Mineral and vitamin contents of goat and sheep milk are mostly higher than in cow milk.

Keywords: Goat milk; Sheep milk; Physico-chemical characteristics; Lipids; Proteins; Bioactive peptides; Minerals, Vitamins

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1. 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 (FAO, 2003), and are particularly well organized in France, Italy, Spain, and Greece (Park and Haenlein, 2006). 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 (Juàrez and Ramos, 1986; FAO, 1997).

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 between goat, sheep and cow milks. The composition of market 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 (Haenlein and Wendorff, 2006). Therefore, changes in goat and sheep milk compositions occur by seasons, because towards the end of the lactation, the fat, protein, solids and mineral contents increase, while the lactose content decreases (Brozos et al., 1998; Haenlein, 2001, 2004).

Goat milk differs from cow or human milk in having better digestibility, alkalinity, buffering capacity, and certain therapeutic values in medicine and human nutrition (Haenlein and Caccese, 1984; Park and Chukwu, 1989; Park, 1994). Sheep milk has higher specific gravity, viscosity, refractive index, titratable acidity, and lower freezing point than average cow milk (Haenlein and Wendorff, 2006). Lipids in sheep and goat milk have higher physical characteristics than in cow milk, but there are variations between different reports (Anifantakis, 1986; Park, 2006a).

The purpose of this paper is to review the specific characteristics of physico-chemical properties of goat and sheep milks in comparison with those of cow milk, with emphasis on lipid and protein fractions including bioactive peptides.

2. Basic composition of goat and sheep milk

Compositions of goat, sheep, cow and human milks are different (Table 1), but vary with diet, breed, individuals, parity, season, feeding, management, environmental conditions, locality, stage of lactation, and health status of the udder (Parkash and Jenness, 1968; Schmidt, 1971; Linzell and Peaker, 1971; Larson and Smith, 1974; Posati and Orr, 1976; Underwood, 1977; Jenness, 1980; Haenlein and Caccese, 1984; Juàrez and Ramos, 1986; Park, 1991, 2006a).

Table 1
Average composition of basic nutrients in goat, sheep, cow and human milk

Composition	Goat	Sheep[a]	Cow	Human
Fat (%)	3.8	7.9	3.6	4.0
Solids-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

Data from Posati and Orr (1976), Jenness (1980), Larson and Smith (1974) and Haenlein and Caccese (1984).
[a] Anifantakis et al. (1980).

Sheep milk contains higher total solids and major nutrient contents than goat and cow milk (Table 1). Sheep colostrum in the early post-partum period is also higher in basic nutrients than cow colostrum: fat 13.0% and 5.1%, protein 11.8% and 7.1%, lactose 3.3% and 3.6%, minerals 0.9% and 0.9%, total solids 28.9% and 15.6%, respectively (Anifantakis, 1986).

3. Physico-chemical characteristics

3.1. Comparison of goat, sheep and cow milk

The differences are shown in Tables 1–3. Density of goat milk is comparable to that of cow milk, but is lower than in sheep milk, while both have higher specific gravity, viscosity, titratable acidity, but lower refractive index and freezing point than cow milk (Parkash and Jenness, 1968; Haenlein and Wendorff, 2006). Surface tension of goat milk is within the range of cow milk (Juàrez and Ramos, 1986), but viscosity of goat milk is slightly higher, while that of sheep milk is much higher than in cow milk (Table 2).

Lipids in sheep and goat milk have generally higher physical characteristics than in cow milk (Table 3; Anifantakis, 1986; Park, 2006a). Flavor constituents in sheep milk are similar between the three species, but differ quantitatively over cow milk (Moio et al., 1993).

The unsaponifiable matter of milk fat and acid values are not different between goat and cow milk (Table 3),