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Goat Milk: Composition, Characteristics

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Abstract

Although dairy cows produce the highest amount of the world milk supply mostly in developed countries, more people drink the milk of goats than milk of any other species worldwide. Due to unavailability of cow milk, goat milk and its products are important daily food sources of protein, phosphate and calcium for the people of developing countries. Goat milk differs from cow or human milk in having higher digestibility of protein and fat, alkalinity, buffering capacity, and certain therapeutic values in medicine and human nutrition. Goat milk and cow milk contain substantially higher protein and ash, but lower lactose, than human milk. Goat milk has smaller fat globules and more short and medium chain fatty acids (MCT) than cow milk, which have the unique metabolic ability to provide energy in growing children and treat malabsorption patients. Interest in dairy goats and goat milk products is a part of the recent trend in health food demand and consumption in several developed countries. Goat milk is also of great importance to infants and patients who suffer from cow milk allergy. Such unique properties of goat milk contribute to the sustainability of the dairy goat industry.

Keywords: Goat milk; Composition; Chemistry; Comparative values; Nutritional significance; Therapeutic values; Physicochemical characteristics; Uniqueness

Introduction

Goats produce only about 2% of the world's total annual milk supply.1 However, their global contribution to the nutritional and economic well-being of humanity is tremendous. Worldwide, more people drink the milk of goats than the milk of any other single species. 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. In basic composition, goat milk and cow milk have substantially higher protein and ash, but lower lactose, than human milk. Specific constituents and physicochemical properties differ between goat and cow milks.

The recent high demand and consumption of health foods in developed countries has resulted in increased interest in dairy goats and goat milk products.2 Goat milk protein is also hypoallergenic which is important for infants and patients who suffer from cow milk allergy. Goat milk serves three important ways for humanity, which are (i) home consumption, (ii) specialty gourmet foods, and (iii) medical-therapeutic uses.

Nutrient Composition of Goat Milk

Basic Composition

Goat milk is similar to cow milk in its basic composition. Caprine milk, on the average, contains 12.2% total solids, consisting of 3.8% fat, 3.5% protein, 4.1% lactose, and 0.8% ash (Table 1). It has more fat, protein, and ash and less lactose than cow milk. Goat milk contains slightly less total casein, but higher nonprotein 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.[3-5]

Table 1. Average Concentrations (per 100 g) of Basic Nutrients, Minerals, and Vitamins in Goat Milk Compared with Those in Cow and Human Milks

Constituents	Goat	Cow	Human
Basic nutrients			
Fat (g)	3.8	3.6	4.0
Protein (g)	3.5	3.3	1.2
Lactose (g)	4.1	4.6	6.9
Ash (g)	0.8	0.7	0.2
Total solids (g)	12.2	12.3	12.3
Calories (cal)	70	69	68
Minerals			
Ca (mg)	134	122	33
P (mg)	141	119	43
Mg (mg)	16	12	4
K (mg)	181	152	55
Na (mg)	41	58	15
Cl (mg)	150	100	60
S (mg)	2.89	-	-
Fe (mg)	0.07	0.08	0.20
Cu (mg)	0.05	0.06	0.06
Mn (mg)	0.032	0.02	0.07
Zn (mg)	0.56	0.53	0.38
I (mg)	0.022	0.021	0.007

Se (µg)	1.33	0.96	1.52
Vitamins			
Vitamin A (I.U.)	185	126	190
Vitamin D (I.U.)	2.3	2.0	1.4
Thiamine (mg)	0.068	0.045	0.017
Riboflavin (mg)	0.21	0.16	0.02
Niacin (mg)	0.27	0.08	0.17
Pantothenic acid (mg)	0.31	0.32	0.20
Vitamin B_6 (mg)	0.046	0.042	0.011
Folic acid (µg)	1.0	5.0	5.5
Biotin (µg)	1.5	2.0	0.4
Vitamin B_{12} (µg)	0.065	0.357	0.03
Vitamin C (mg)	1.29	0.94	5.00

(From Refs. 3&4, 11 and 12.)

Lipids

Fat content of goat milk across breeds ranges from 2.45 to 7.76%. Average diameters of fat globules for goat, cow, buffalo, and sheep milks are reported as 3.49, 4.55, 5.92, and 3.30 µm, respectively.3&4 Smaller fat globules make a better dispersion and a more homogeneous mixture of fat in goat milk, providing a greater surface area of fat for enhanced digestive action by lipases.4-6

Goat milk fat contains 97-99% free lipids (of which about 97% is triglycerides) and 1-3% bound lipids (about 47% neutral and 53% polar lipids).7 Goat milk fat has significantly higher levels of short- and medium-chain-length fatty acids (MCT) (C4:0-C14:0) than cow and human milks. This property has been utilized for treatment of a variety of fat malabsorption problems in patients.3-6, 8

Protein

There are five principal proteins in goat milk: α_{s2}-casein (α_{s2}-CN), β-casein (β-CN), κ-casein (κ-CN), β-lactoglobulin (β-Lg), and α-lactalbumin (α-La).3-5 β-casein is the major casein fraction in goat milk, whereas α_{s1}-casein is the major one in cow milk. Differences in amino acid composition between casein fractions of goat milk are much greater than differences between species (goat versus cow).4 The α-caseins contain greater aspartate, lysine, and tyrosine than β-casein, whereas the latter has higher leucine, proline, and valine than the former.4 Casein micelles of goat milk are less solvated, are less heat stable, and lose β-casein more readily than bovine micelles.9

Commonalities in the overall amino acid pattern were reported among the milks of many species.[10] The most abundant amino acids were glutamate (plus glutamine, 20%), proline (10%), and leucine (10%). Among the three most abundant amino acids, goat and other nonprimate milk contained greater glutamate and proline and lower leucine than human milk. For sulfur-containing amino acids, cystine was higher and methionine was lower in primate milks than in goat and other nonprimate milks.[10]

Carbohydrates

The major carbohydrate of goat milk is lactose, which is about 0.2-0.5% less than in cow milk.[5], [11] Lactose is a disaccharide made up of a glucose and a galactose molecule and is synthesized in the mammary gland. Milks of most of the lower mammalian species have a higher content of fat and a lower content of lactose than goat milk.[3] Cow milk contains minor levels of monosaccharides and oligosaccharides, but their presence in goat milk is not known.[5]

Minerals and Vitamins in Goat Milk

Minerals

Goat milk contains about 134 mg Ca and 141 mg P/100 g (Table [1]). Human milk contains only one-fourth to one-sixth of these mineral amounts. Goat milk has higher calcium, phosphorus, potassium, magnesium, and chlorine, but lower sodium and sulfur contents, than cow milk[3&4], [12] (Table [1]).

There is a close inverse relationship between lactose content and the molar sum of sodium and potassium contents of goat and other species' milks.[4], [12] Chloride is positively correlated with potassium and negatively with lactose, but sodium is not significantly correlated with K, Cl, and lactose. Concentrations of trace minerals are affected by diet, breed, animal, and stages of lactation.[12] The average mineral content of goat milk is higher than that of cow milk. However, goat milk has a lower degree of hydration, and has an inverse relationship between the mineralization of the micelle and its hydration.[13]

Vitamins

Goat milk has a higher amount of vitamin A than cow milk. Caprine milk is whiter than bovine milk because goats convert all β-carotene into vitamin A in the milk. Goat milk supplies adequate amounts of vitamin A and niacin, and an excess of thiamin, riboflavin, and pantothenate, for a human infant (Table 1). A human infant fed solely on goat milk is oversupplied with protein, Ca, P, vitamin A, thiamin, riboflavin, niacin, and pantothenate in relation to the Food and Agriculture Organization and World Health Organization (FAO-WHO) requirements.4 Vitamin B levels in goat and cow milks are a result of rumen synthesis, and are somewhat independent of diet.3

Goat milk, however, is deficient in folic acid and vitamin B_{12} compared to cow milk.3&4, 6 Cow milk has 5 times more folate and vitamin B_{12} than goat milk, and folate is necessary for the synthesis of hemoglobin.4, 6 Goat milk and cow milk are equally deficient in pyridoxine (B_6) and vitamins C and D, and these vitamins must be supplemented from other food sources.4

Minor Constituents in Goat Milk

The lactoferrin, transferrin, and prolactin contents of goat milk are comparable to those of cow milk. Human milk contains more than 2 mg lactoferrin/ml, which is 10-100-fold higher than in goat milk. The high level of folate-binding protein in goat milk lowers the available level of folic acid in this milk (Table 2).

Table 2. Caseins, Minor Proteins, and Enzyme Contents of Goat Milk Compared with Those of Cow and Human Milks

Proteins	**Goat**	**Cow**	**Human**
Protein (%)	3.5	3.3	1.2
Total casein (g/100 ml)	2.11	2.70	0.40
α_{s1} (% of total casein)	5.6	38.0	-
α_{s2} (% of total casein)	19.2	12.0	-
β (% of total casein)	54.8	36.0	60-70
κ (% of total casein)	20.4	14.0	7.0
Whey protein (%) (albumin and globulin)	0.6	0.6	0.7
Nonprotein N (%)	0.4	0.2	0.5
Lactoferrin (µg/ml)	20-200	20-200	< 2,000
Transferrin (µg/ml)	20-200	20-200	50 <
Prolactin (µg/ml)	44	50	40-160
Folate-binding protein (µg/ml)	12	8	-
Immunoglobulin			
IgA (milk: µg/ml)	30-80	140	1,000

IgA (colostrum: mg/ml)	0.9-2.4	3.9	17.35
IgM (milk: µg/ml)	10-40	50	100
IgM (colostrum: mg/ml)	1.6-5.2	4.2	1.59
IgG (milk: µg/ml)	100-400	590	40
IgG (colostrum:mg/ml)	50-60	47.6	0.43
Lysozyme (µg/100 ml)	25	10-35	4-40
Ribonuclease (µg/100 ml)	425	1,000-2,000	10-20
Xanthine oxidase (µl O_2/h/ml)	19-113	120	-

(From Refs. 4, 7, 9, and 13.)

The amount of immunoglobulin IgG type in both goat and cow milk is much higher than in human milk, whereas human milk contains greater levels of IgA and IgM immunoglobulins than either goat or cow milk (Table 2).

Concentrations of lysozyme, ribonuclease, and xanthine oxidase in goat, cow, and human milks are highly variable among and within species (Table 2). Xanthine oxidase activity of goat milk is less than 10% of that of cow milk.5 Goat milk contains less lipase and alkaline phosphatase than cow milk.3, 5

Variations in Goat Milk Composition

The composition and yield of goat milk and milks of other species vary with breed, animals within breed, environmental conditions, feeding and management conditions, season, locality, and stage of lactation.3&4, 12, 14 High variability in goat milk composition between different seasons and genotypes has also been noted.4&5 The casein composition of goat milk is influenced by genetic polymorphism on the casein loci.

Table 3. Protein variants in goats

Locus	Protein variants	DNA polymorphisms
α_{s1}-casein	A,B_1,B_2,B_3,C,D,E,F,G,O	A,B,C,D,E,F,G,O
α_{s2}-casein	A,B,C	*Eco*RI and *Eco*RV polymorphic patterns By using a cDNA bvine probe
β-casein	A,B,O	Point mutation in exon 7
κ-casein	A,B	*Bam*HI, *Eco*RV and *Pvu*II polymorphic patterns by using a cDNA bovine probe
α-lactalbumin	A,B	Nothing existing
β-lactoglobulin	A,B	Nothing existing

(From Ref. 15).

These milk protein polymorphisms are caused either by the substitution of amino acids or by the deletion of several of them, and these polymorphisms can be detected through electrophoresis of milk and/or analysis of DNA (15&16). Polymorphism of α_{s1}-casein

controls the level of α_{s1}-casein excretion in milk, and more than 18 allelic genotypes have been identified in goat milk (17). The allele frequencies at the α_{s1}-casein locus vary with breed.15 A polymorphism with 7 alleles (A, B_1, B_2, B_3, C, D, E, F, G, O) was found in most European dairy goat breeds such as Alpine, Saanen, Poitevine, Garganica, Maltese, Murciana-Granadina, Malaguena (Table 3) (15,17).

Conclusion

Although goat milk is similar to cow milk in its basic composition, the significance of goat milk and its products in human nutrition and well-being can never be underestimated. Goat milk products provide essential nutrients in human diet, as well as income sources for the survival of mankind in ecosystems of many parts of the world. The contribution of dairy goat products is also greatly valued by those who have cow milk allergy and other nutritional diseases. Goat milk has some unique differences in several important constituents and physical parameters, including proteins, lipids, minerals, vitamins, carnitine, glycerol ethers, orotic acid, enzymes, fat globule size, casein polymorphisms, which are significant in human nutrition.

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