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Comparative aspects of goat and sheep milk

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Abstract

The purpose of this paper is to review the several differences in physico-chemical, medical, nutritional, biological, radioactivity and immunological aspects of goat and sheep milk. It also deals 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 a large scale in many countries.

Keywords: Goat milk; Medical; Nutritional and dairy products; Physico-chemical properties; Sheep milk

1. Introduction

Why goat and sheep milk? This is a critical question which should to be asked and answered by all who are trying to help establish a dairy goat and sheep business and industry (Haenlein, 1993), 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 (Haenlein, 1992). A good dairy goat gives about 3–4 l milk daily (Leach, 1980), which is 900–1800 kg milk in a 305-day lactation period (Haenlein, 1992; Haenlein, 1993). The value of goat and sheep milk in human nutrition has so far received very little academic attention and few facts are available (Haenlein, 1984; Haenlein, 1988; Park, 1991; Haenlein, 1992).

The purpose of this paper is to discuss research related to the physico-chemical, nutritional, medical, biological and allergic aspects of dairy products from goat and sheep milk.

2. Physico-chemical aspects

Goat and sheep milk is white in colour compared with cow milk, which is yellowish because of the presence of carotene (Saini and Gill, 1991). 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 (Babayan, 1981; Haenlein, 1993). 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 (Saini and Gill, 1991).

The components of goat, sheep, human and cow milk are given in Table 1. The gross composition of

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Table 1
Comparative composition of milk of different species [a]

Component	Goat	Sheep	Human	Cow
Fat (%)	3.80	7.62	3.67–4.70	3.67
Solid-non-fat (%)	8.68	10.33	8.90	9.02
Lactose (%)	4.08	3.7	6.92	4.78
Protein (%)	2.90	6.21	1.10	3.23
Casein (%)	2.47	5.16	0.40	2.63
Whey proteins (%)	0.43	0.81	0.70	0.60
Total ash (%)	0.79	0.90	0.31	0.73
Ca (%)	0.194	0.160	0.042	0.184
P (%)	0.270	0.145	0.06	0.235
Cl (%)	0.154	0.270	0.060	0.105
Vitamin A (IU g^{-1} fat)	39.00	25.00	32.00	21.00
Vitamin B_1 (mg per 100 ml)	68.00	7.00	17.00	45.00
Vitamin B_{12} (mg per 100 ml)	210.00	36.00	26.00	159.00
Vitamin C (mg per 100 ml)	20.00	43.00	3.60	2.00
Vitamin D (IU g^{-1} fat)	0.70	ND	0.27	0.70
Energy (Cal. per 100 ml)	70.00	ND	68.00	69.00

[a] Posati and Orr (1976); IDF (1986); Saini and Gill (1991).
ND, not-detected.

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 (Grandison,

Table 2
Amino acid composition in milk and yoghurt from goats and sheep (mg per 100 ml) [a]

Amino acid	Goat		Sheep	
	Milk	Yoghurt	Milk	Yoghurt
Ala	1.33	3.83	0.56	1.30
Arg	0.40	0.67	0.26	0.85
Asp	0.22	1.37	0.18	1.75
Gly	5.91	6.06	0.15	0.25
Glu	3.54	3.78	1.08	4.10
His	0.45	1.28	0.10	0.50
Ile	0.18	0.43	0.06	0.22
Leu	0.21	1.25	0.23	0.45
Lys	0.60	2.35	0.19	0.72
Met	0.10	0.35	0.05	0.15
Phe	0.11	0.35	0.08	0.15
Pro	0.65	4.55	0.11	4.30
Ser	3.05	3.51	0.20	2.00
Thr	3.34	2.80	0.13	0.55
Tyr	0.30	0.60	0.16	0.27
Val	0.30	0.56	0.24	0.90
Total	20.60	33.48	3.78	18.46

[a] Tamime and Deeth (1980).

1986). 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 (Haenlein, 1992; Haenlein, 1993). There are many significant differences in the amino acids of goat and sheep milk proteins (Table 2) (Tamime and Deeth, 1980), and also in the relative proportions of the various milk proteins and their genetic polymorphism (Jenness, 1980; Boulanger et al., 1984; Addeo et al., 1988; Ambrosoli et al., 1988). Sheep milk casein differs markedly from that of goat milk (Richardson and Creamer, 1976). K-casein has been isolated and characterized from goat milk (Zittle and Custer, 1966; Richardson et al., 1973) and sheep milk (Alsis and Jolles, 1967), and both were similar to cow K-casein in many respects. Sheep K-casein glycopeptide has polysaccharide fractions which closely resemble those of cow K-casein glycopeptides (Jolles and Fiat, 1979). The casein in goat milk appears to lack an electrophoretic component with the mobility of bovine αs-1-casein. The αs-2-fraction of goat casein represents a much smaller proportion of the total casein than the αs-1-moiety of bovine casein, making the β-caseins quantitatively the major proteins of goat milk (Jenness, 1980). 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 (Aschaffenburg and Dance, 1968).

β-lactoglobulin (β-Lg) has been purified and characterized in milk from goats and sheep (Bell and McKenzie, 1964; Bell and McKenzie, 1967). The existence of two genetic variants in sheep milk, β-Lg A and β-Lg B, was reported by Bell and McKenzie (1964), Bell and McKenzie (1967) and Maubois et al. (1965). Several workers have reported the amino acid composition of the sheep β-Lg variants (McKenzie, 1971) and the goat β-Lg variants (Ambrosino et al., 1969) (Table 3). Amino acid analysis of sheep β-Lg A and β-Lg B indicates that β-Lg A has one His less and one Tyr more than β-Lg B (Bell et al., 1968; McKenzie, 1971). Further studies carried out on the β-Lg of goat and sheep milk confirmed that these proteins are generally formed of two identical polypeptide chains with a molecular weight of 18 000 ± 500 daltons (Maubois et al., 1965; Philips and Jenness, 1965). These differences may explain the significant advantages of sheep milk for infants and other patients with digestive problems (Mack, 1953; Haenlein, 1993).

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

Table 3
Comparison of the amino acid composition of β-Lg (number of residues per monomer) [a]

Amino acid	Sheep		Goat
	A-variant	B-variant	
Asp	15	15	5
Thr	8	8	8
Ser	6	6	6
Glu	24	24	25
Pro	8	8	8
Gln	5	5	5
Ala	15	15	15
Cys	5	5	5
Val	10	10	10
Met	4	4	4
Ile	9	9	9
Leu	20	20	20
Tyr	4	3	4
Phe	4	4	4
Try	2	2	2
His	2	3	2
Arg	3	3	3

[a] Tamime and Deeth (1980).

Table 4
Fatty acid composition of goat, cow and sheep milk (% by weight) [a]

Fatty acid	Goat	Cow	Sheep
C4:0	2.6	3.3	4.0
C6:0	2.9	1.6	2.6
C8:0	2.7	1.3	2.5
C10:0	8.4	3.0	7.5
C12:0	3.3	3.1	3.7
C14:0	10.3	9.5	11.9
C16:0	24.6	26.5	25.2
C16:1	2.2	2.3	2.2
C18:0	12.5	14.6	12.6
C18:1	28.5	29.8	20.0
C18:2	2.2	2.5	2.1

[a] Glass et al. (1967); Jenness (1980).

in sheep milk (Table 4). The presence of relatively high levels of medium-chain fatty acids in goat milk lipids could be responsible for its inferior flavour (Parkash and Jenness, 1968; Skjevdal, 1979). 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, C12:0 and C14:0 and a considerably higher level of C10:0 in goat milk (Table 4) (Glass et al., 1967; Jenness, 1980). 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 (Haenlein, 1980; Jenness, 1980).

The carbohydrate fraction of goat and sheep milk is lactose (Parkash and Jenness, 1968). The level of lactose in goat milk is usually slightly higher than that in sheep milk (Table 1) (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 (Posati and Orr, 1976) as compared with 160 mg calcium and 145 mg phosphorus per 100 g for sheep milk (Saini and Gill, 1991). The total ash level in goat milk is slightly higher than that in cow milk, usually ranging from 0.70 to 0.85% (Parkash and Jenness, 1968). Shaffer et al. (1955), El-Alamy and Mohamad (1978), Abou-Dawood et al. (1980), Primatests (1979), Mathur (1979) and Narain-Swamy and Mathur (1983) have reported that the iron content in goat milk is between 1.50 and 2.20 p.p.m.

Table 5
Vitamin content of goat and sheep milk [a]

Vitamin	Goat	Sheep
Vitamin A (IU l^{-1})	2074.0000	1460.0000
Vitamin B_1 (mg l^{-1})	0.4000	0.6900
Vitamin B_2 (mg l^{-1})	1.8400	3.8200
Niacin (mg l^{-1})	1.8700	4.2700
Vitamin B_6 (mg l^{-1})	0.0700	–
Pantothenic acid (mg l^{-1})	3.4400	3.6400
Biotin (mg l^{-1})	0.039	0.093
Folic acid (mg l^{-1})	0.0024	0.0024
Vitamin B_{12} (mg l^{-1})	0.0006	0.0064
Vitamin C (mg l^{-1})	15.0000	43.0000

[a] Hartman and Dryden (1965).

Table 6
Phospholipid fractions of goat and sheep milk (mol %) [a]

Phospholipid	Goat	Sheep
Phosphatidyl choline	25.70	29.00
Phosphatidyl ethanolamine	33.20	36.00
Phosphatidyl serine	6.70	3.10
Phosphatidyl inositol	5.60	3.10
Sphingomyelin	29.90	28.30
Lysophospholipid	0.50	–

[a] Jenness (1980); IDF (1986).

Lipase activity has been found in the milk of both goats and sheep (Chandan et al., 1968; Jandal, 1995a), but little or no lysozyme activity has been found (Chandan et al., 1965; Chandan et al., 1968). Xanthine oxidase has been reported in sheep and goat milk (Modi et al., 1959; Brown and Zikakis, 1977), and it has also been reported to contain more rhodanase than cow milk (Alfonso and Bertran, 1953). 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, cyanocobalamine and folic acid (Table 5) and may be deficient in pyridoxine (Jenness, 1980). Several cases of anaemia attributed to goat milk diets were reported to have been cured by the patients being given folic acid (Jenness, 1980).

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 (Table 6) constitute only a small fraction (Jenness, 1980; IDF, 1986).

3. Rennet coagulation

Table 7 shows the ranges in the levels of fat, casein and calcium in milk from goats, cows and

Table 7
Ranges in level of fat, casein and Ca in milk from goats, cows and sheep [a]

Component	Goat	Cow	Sheep
Fat (%)	2.75–6.43	1.38–5.10	5.79–6.45
Casein (%)	2.14–3.18	2.28–3.27	3.78–5.20
Ca (%)	0.10–0.14	0.10–0.13	0.16–0.18

[a] Grandison (1986).

sheep. The levels of all three components were greater in sheep milk than in cow or goat milk. These differences in composition were reflected in coagulation properties. Sheep milk generally produced firmer curds as a result of the higher casein levels, while values for cow and goat milk tended to overlap. Sheep milk also tended to clot more rapidly than cow or goat milk (Grandison, 1986).

4. Medical aspects

Goat milk is prescribed by many doctors for children who are sensitive to cow milk, and is an alternative for people who are allergic to cow milk (Saini and Gill, 1991). Approximately 40% of all patients who are sensitive to cow milk proteins tolerate goat milk proteins (Brenneman, 1978; Zeman, 1982; Haenlein, 1993), possibly because lactalbumin is immunospecific between species (Hill, 1939). Goat milk is very useful for people suffering from problems such as acidity, eczema, asthma, migraine, colitis, stomach ulcer, digestive disorder, liver and gallbladder diseases and stress-related symptoms such as insomnia, constipation and neurotic indigestion (Babayan, 1981). These patients may in future turn more to goat milk and its products to solve their problems.

5. 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 (Babayan, 1981). 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 10–20% 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 (Jenness, 1980).

The proteins in goat milk are digested more readily and their constituent amino acids absorbed more efficiently than those of cow milk (Boulanger et al., 1984).

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 (Schwabe et al., 1964; Greenberger and Skillman, 1969; Kalser, 1971; Tantibhadhyangkul and Hashim, 1975; Tantibhadhyangkul and Hashim, 1978; Haenlein, 1992). 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 (Gupta and Mathur, 1991).

6. Biological aspects

The biological value and digestibility coefficient of goat milk casein were found to be 89.29 and 92.42, respectively (Kumar et al., 1986). Goat milk is easier to digest because of its natural homogenization, which is superior to the mechanical homogenization of cow milk. This is because it takes approximately 20% less time to digest goat milk as the size of its fat globules varies from 0.1 to 10 microns, with the greater proportion being less than 2 microns, while the reverse is true in cow milk (Cornell and Pallansch, 1966; Saini and Gill, 1991). This in turn indicates, and may explain, the significant differences in the ability to digest cow milk shown by infants and other patients (Mack, 1953).

7. Microbiological aspects

Goat and sheep milk is perishable and fragile. It can easily be spoilt if the animals are given unsuitable feed or are handled in the wrong way before and during milking, or if the milk is handled incorrectly during and after milking, including the processes of cooling and transportation (Haenlein, 1987). Much more research is needed into somatic cell and bacteria counts in goat and sheep milk in order to provide reliable data on bacterial populations and their origins.

8. Immunological aspects

There is extensive immunological cross-reaction of cow and goat milk proteins (Saperstein, 1974). The non-allergenic properties of goat milk are due to the fact that most of the milk proteins are unable to pass through the walls of the digestive tract in their original, undigested, allergenic states (Saini and Gill, 1991). The immunological behaviour of the β-Lg of goat and sheep milk suggests that the differences in amino acid composition do not affect the antigenically active sites of these molecules (Johke et al., 1964; Lyster et al., 1966; Bell et al., 1968).

9. Radioactivity aspects

Kandarakis and Anifantakis (1986) found that of the I-131, Cs-134 and Cs-137 in artificially contaminated ewes' milk, 4, 3 and 3%, respectively, was transferred to the cream on skimming, 17, 10 and 9%, respectively, was transferred to Kefalotyri cheese, 5, 4 and 4%, respectively, was transferred to Myzithra cheese, and 45, 38 and 34%, respectively, was found in strained yoghurt. In goat milk, on the other hand, the content of I-131, Cs-134 and Cs-137 was 41, 32 and 28%, respectively, in cream, 84, 53 and 47%, respectively, in Kefalotri cheese, 64, 64 and 62%, respectively, in Myzithra cheese, and 86, 75 and 72%, respectively, in strained yoghurt. An activity of over 600 Bq l^{-1} was detected for Cs-134 plus Cs-137 in goat milk in high pasture areas (Ron, 1986). Naghmoush et al. (1983) showed a progressive decline in all experimental groups of microorganisms in goat milk with the application of ascending doses of gamma-irradiation. They observed a decrease in the total bacteria count in raw goat milk from 15×10^3 to 14×10 after 0.75 M rad irradiation. There was no marked change in titratable acidity or pH in goat milk after exposure to different doses of gamma-irradiation, but there was an effect on the organoleptic properties of the milk. Goat milk tasted slightly caramelized after heat treatment, but became markedly oxidized on exposure to 0.75 M rad and there were also detectable changes in the colour (Grover et al., 1987).

10. Heat treatment effect

Lythgoe (1940) 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 (Chandan et al., 1968; Jandal, 1995a). 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 (Colling et al., 1951). 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 (Khaton and Joshi, 1987). 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 (Yaygin and Mehanna, 1988). The average contents of conjugated and free forms of biliverdin were 1.98 and 3.72 μs per 100 ml in Awassi sheep milk and 5.93 and 11.16 μg 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 (Jandal, 1993; Jandal, 1995b). 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 (Jandal, 1995a).

11. 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 (Loewenstein et al., 1980; IDF, 1986; Mann, 1988).

Goat and sheep milk and their products have been produced and consumed over many centuries in certain regions of the world, apart from such well-known products as Roquefort cheese (Mann, 1988) and Leben (Jandal, 1988; Jandal, 1994). Goat milk is not considered suitable for the manufacture of ghee (Arora and Singh, 1986), the main reason being its relatively small fat globules which present problems during cream separation and its typical odour and flavour (Skjevdal, 1979).

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