

Nutritional and Health And Wellness Account of Goat Products: Concentrate On Health And Wellness Benefits of Goat Milk

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Abstract

Goat (*Capra hircus*) is one of the main sources of milk and meat products for human consumption. Goat milk differs from cow and human milk in both composition and nutritional properties. Goat milk and other goat-derived products contain several bioactive compounds that might be useful in patients suffering from a variety of chronic diseases. Several peptides, fats, and oligosaccharides present in goat's milk can be potentially useful in cardiovascular disease, metabolic disorders, neurological degeneration, or in promoting intestinal health. They have also shown chemo preventive properties in cancer. In addition, the oligosaccharides present in goat's milk have immunomodulatory properties, prevent adhesion of pathogenic bacteria, and have prebiotic, probifidogenic effects. Due to its potential health benefits, goat milk is particularly recommended for infants, older adults, and convalescing people. This chapter gives an overview of the biological activities of goat products and the effects of peptides, fats, and oligosaccharides present in goat milk on pathogenic bacteria, as well as their ability to regulate immunological, gastrointestinal, hormonal, and neurological responses in humans.

Interest from the consumers as well as growing concerns for physical well-being and health have increased the demand for information about the consumption of healthier foods. The intake of some active compounds present in food, the so-called nutraceuticals and functional foods, can be regarded as having beneficial effects (physical and mental) on certain functions in the human body, that go beyond their nutritional effects.

As technology and science advances, the fields of health and nutrition have focused on several emerging fields, namely nutrigenomics, or “personalized nutrition.” The study of the human genome in order to comprehend cellular response to nutrients and bioactive compounds is a promising field of work, which should lead specific dietary recommendations to prevent or aid in the treatment of certain diseases. In fact, stroke, cancer, and atherosclerosis and the general risk of diseases may be somehow minimized by introducing proper preventive nutrition and functional foods/foods as part of a healthier lifestyle that includes a balanced diet and physical activity. Ingesting a wide variety of foods, namely fruits, vegetables, whole grains, milk, meat, and eggs is one way to ensure the intake of certain bioactive compounds that are present in its constitution such as carotenoids, dietary fiber, fatty acids, flavonoids, isothiocyanates, minerals, phenolic acids, plant stanols/sterols, polyols, prebiotics and probiotics, phytoestrogens, soy protein, sulphides/thiols, and vitamins.

Functional foods are growing in reputation across the globe and are becoming a part of daily diet of consumers who are concerned with their health. The global market potential for functional foods and beverages has been estimated to be worth \$192 billion by 2020. However, the effectiveness of nutraceutical products in preventing diseases depends on preserving the stability, bioactivity, and bioavailability of the active ingredients. Functional foods are found virtually in all food categories; however, some products are not widely available in the market.

Sheep and goat products (mainly meat and dairy) have interesting characteristics in their levels of flavour, taste, aromas, and leanness as well as the specific composition of fats, proteins, amino, and fatty acids and have been traditionally consumed in certain regions of the globe. Additionally, the nutritional properties of goat milk and its lower allergenicity when compared to cow milk has sparked an interest in goat milk as a functional food, and it is now one of the current trends in healthy eating in developed countries. Moreover, the use of milk with particular nutritional properties, alone or in combination with bacterial strains with probiotic properties and capable of producing physiologically active metabolites, might become one of the options for manufacturing new dairy functional beverages.

2. Materials and methods

The present chapter intends to give a comprehensive approach of the unique characteristics of goat-derived products, which have attracted the interest of researchers worldwide. This chapter aims to explore the nutritional value and bioactivity of the constituents of these products, with an emphasis in the reduction of the risk of chronic disorders by anti-inflammatory and anti-oxidative effects. The ability of goat's milk and its derivatives to selectively encourage bacterial growth in intestinal microbiota and the beneficial effects in the metabolic, endocrine, and immune systems will also be a subject of this chapter.

3. Composition of goat milk

Milk and derived dairy products are considered an important constituent of a balanced diet. Milk, as the first food for mammals, supplies all the energy and nutrients needed for the proper growth and development of the neonate. For all mammalians, the consumption of milk ends at the weaning period except in humans, which continue consuming milk throughout their life.

The physical characteristics and composition of milk vary between species. Chemically, milk is a complex oil-in-water emulsion containing proteins, fats, carbohydrates (mainly lactose), and lower amounts of minerals, enzymes, cells, hormones, immunoglobulins, and vitamins.

The information currently available on the composition of goat milk has been published in the form of reviews . Authors are unanimous in recognizing that fresh milk composition has a dynamic nature that varies with several factors such as (a) genetics (e.g., species, breed, and individual); (b) stage of lactation; (c) health status of the individual animal; and (d) environmental factors (e.g., feed, climate, season, or method of milking).

Approximate compositions of the milks of different animals are compared in Table 1.

The basic nutrient composition of goat milk resembles that of cow milk (Table 1). Both milks contain substantially higher amounts of proteins and minerals, but lower lactose content than human milk. Nonetheless, goat milk has high concentrations of fat globules, which are smaller than those present in cow milk; these globule diameters average are approximately 3.6 and 3.0 μm against 4.0 μm , respectively. The smaller size of fat globules provides a smoother texture in goat's derived products. Furthermore, goat milk contains lower amounts of α 1-casein conferring it a higher water-holding capacity and a lower viscosity. Despite all these properties, the flavour of goat's milk is peculiar and

more intense in comparison to cow's milk, which can restrict the acceptance of its derivatives by consumers. However, goat milk is more easily digested than cow milk due to the absence of agglutinins in the former.

Goat and cow milk differ essentially in their casein micelles (structure, composition, and size), the proportion of individual protein fractions and higher content of nonprotein nitrogen and mineral compounds found in goat milk.

3.1. Proteins

The variability in milk composition, among individual animals of the same breed, is attributed to an extensive and complex genetic polymorphism of the goat milk caseins. The protein portion has a fundamental role on the nutritional and technological value of milk. Milk proteins are made of heterogeneous groups in terms of composition and properties and are divided into casein—the main group of proteins—and whey protein fractions to a lesser extent.

The total protein content in goat milk varies from 2.6 to 4.1 g/l. Casein is composed of four fractions: α S1-casein, α S2-casein, β -casein, and κ -casein. The proportions of the milk casein fractions differ between ruminant species and the micelle characteristics also differ in regard to size, hydration, and mineralization. As reported by Grosclaude and Martin, in studies conducted using French Alpine and Saanen goats, milk from animals with low alleles FF had total casein and total protein contents of 22 and 27 g/l, respectively. These values increase to 27 and 32 g/l in milk from animals possessing strong alleles AA. Generally, goat milk contains less α S1-casein than other ruminants' milk. However, as allele frequency for this specific casein varies between breeds, its concentration in goat milk depends indirectly on the breed.

Other characteristics of goat milk proteins are their structural conformations and the amounts and subtypes of micelles, which are smaller (180 nm) than those of cow milk (260 nm) and similar to those of sheep milk (193 nm).

It has been reported that beta casein comprises the largest fraction of total goat milk casein. Although α S2-casein is relatively higher in goat milk, the α S1 fraction of cow milk alone is higher than both the α S1 and α S2-casein fractions present in goat milk. These differences might help explain the soft curd-forming properties of goat milk, as well as its better digestibility and the lower frequency of allergic reactions in children.

The nutritional value of proteins present in milk depends on its essential amino acid content. Only small differences exist in milk amino acid levels per 100 g of protein between different species, which are most likely due to differences in total protein content. A comparison of amino acid content between different species can be seen in Table 2.

Composition	Goat	Cow	Human
Energy (kcal)	70	69	68
Water (%)	87.5	87.7	86.7
Total solids (g)	12.2	12.3	12.3
Protein (%)	3.2	3.3	1.3
Fat (%)	4.0–4.5	3.8	4.1
Lactose (%)	4.6	4.7	7.2
Ash (g)	0.8	0.7	0.2

Table 1. Basic composition of different milks (mean values per 100g) (adapted from Yadav et al.)

	Goat milk	Cow milk
Essential amino acids		
Thr	138.67	115.81
Ileu	160.54	128.04
Leu	341.01	266.23
Lys	342.86	252.59
Met	77.95	71.15
Cys	30.62	23.20
Phe	175.45	133.51
Tyr	162.51	159.99
Val	210.23	147.34
Total	1639.84	1298.36

Nonessential amino acids

Arg	135.65	114.44
Hist	122.73	93.06
Asp	117.95	96.0.859
Ala	250.15	214.22
Glu	694.58	554.30
Gly	55.83	49.24
Pro	310.61	253.38
Ser	152.65	147
Total	1840.15	1522.58

Table 2. Amino acid composition of goat milk and cow milk (mg/100g milk) (adapted from Ceballos et al.).

When compared to cow milk, goat milk has higher levels of essential amino acids: threonine, leucine, lysine, cystine, tyrosine, phenylalanine, valine, and nonessential proline and glutamic acid (Table 2).

3.2. Fat

Fat content is the more quantitatively and qualitatively variable component of milk, depending on season, lactation stage, breed, genotype, and feeding. This last factor has been extensively studied, and *Sanz Sampelayo et al.* examined the influence of feeding, roughage, and lipid supplementation on the fat content of both ewe and goat milk, and the presence of fatty acids of nutritional interest, such as ruminic acid or omega-3, as well as other fatty acids with potentially detrimental effects, such as trans fats. *Chilliard et al.* showed that goat's response to lipid supplementation increased the fat content of goat milk without decrease in its protein content. Bovine, sheep, goat, and human milk fat consist of 97–98% of triglycerides, but have only low levels of phospholipids (0.5–1.5%) and free fatty acids (0.7–1.5%).

The main characteristic of goat milk fat is the high content in short- and medium-chain fatty acids (MCFA). Average goat milk fat profile of fatty acids presented levels of butyric (C4:0), caproic (C6:0), caprylic (C8:0), capric (C10:0), lauric (C12:0), myristic (C14:0), palmitic (C16:0), and

linoleic acids (C18:2) higher than those exhibited by cow milk. In contrast, goat's milk fat presented lower concentrations of stearic (C18:0) and oleic acid (C18:1) when compared to cow's milk fat. Average fatty acid composition (g/100g milk) of goat and cow milks are presented in Table 3. Considering that these fatty acids have a different metabolism from that of long-chain fatty acids they present different functional proprieties. Recent works of *Núñez-Sánchez et al.* demonstrated that goat's milk exceeds cow's milk in its content of monounsaturated and polyunsaturated fatty acids and medium chain triglycerides.

Lipid profile	Goat milk	Cow milk
C4:0	66.55	116.44
C6:0	171.68	77.86
C8:0	192.20	57.80
C10:0	579.10	114.91
C11:0	7.46	7.29
C12:0	232.61	130.87
C14:0	518.56	384.41
C14:1	7.19	16.87
C15:0	28.11	35.23
C15:1	3.01	2.74
C16:0	1340.97	1102.72
C16:1	51.58	52.32
C16:2 n-4	1.57	0.57
C17:0	18.44	6.27
C17:1	4.32	2.85
C18:0	493.56	378.25
C18:1 n-9, trans	19.22	55.75
C18:1n-9, cis	1245.92	742.71
C18:2 n-6	142.39	82.31
CLA n-7, cis-9, trans-11	18.70	13.79
CLA n-6, trans-10, cis-12	3.53	1.82
CLA n-7, cis-9, cis-11	1.05	–
CLA n-5, cis-11, trans-13	12.42	–
CLA total	35.75	15.62
C18:3 n-3	27.72	8.55
C20:0	2.49	3.76
C20:1 n-9	1.57	1.03
C20:2 n-6	5.49	1.48
C20:3 n-6	-	0.80
C21:0	1.44	0.23
C22:0	4.05	3.99
C23:0	0.26	0.91
C24:0	0.66	0.68
C24:1 n-9	0.92	–

C6-14	1695.70	790.02
SFA	3683.10	2436.41
MUFA	1342.67	874.27
PUFA	213.25	109.32
PUFA n-6	146.97	86.41
PUFA n-3	26.81	8.55
PUFA n-6/n-3	5.49	10.49

Table 3. Fatty acid composition (mg/100g milk) of goat and cow milk fat (adapted from Ceballos et al.).

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

3.3. Carbohydrates

Lactose is the main carbohydrate in milk: about 44% in goat milk and 49% in sheep milk. Its concentration does not vary excessively. However, goat milk lactose content is often largely increased by dietary plant oil supplementation in contrast to cow milk.

3.4. Minerals

Raynal-Ljutovac et al. presented an update of the composition of goat and sheep milk products. In this document, authors complicated data available concerning the main mineral composition of goat and sheep milks (Table 4). Goat milk is distinguished by its high chloride and potassium content. A more recent study by *Trancoso et al.*, focusing on goat milk from the main Portuguese indigenous breeds (Serrana, Serpentina, Charnequeira, and Algarvia), also obtained similar results regarding mineral composition in the milk produced by these animals. *Raynal-Ljutovac et al.* indicated that caprine milk provided a great amount of magnesium, calcium, and phosphorus with a normal Ca/P ratio in milk as 1.20.

	Goat (per L)	Sheep (per kg)
Calcium (mg)	1260	1950–2000
Phosphorus (mg)	970	1240–1580
Potassium (mg)	1900	1360–1400
Sodium (mg)	380	440–580

Chloride (mg)	1600	1100–1120
Magnesium (mg)	130	180–210
Ca/P (mg)	1.3	1.4
Zinc (µg)	3400	5200–7470
Iron(µg)	550	720–1222
Copper (µg)	300	400–680
Iodine (µg)	80	53–90
Selenium (µg)	20	31

Table 4. Mineral composition of goat and sheep milk (adapted from Balthazar et al.)

As shown in Table 4, goat milk is characterized by its lower concentration of iron, zinc, and copper. *López-Aliaga et al.* reviewed the mineral bioavailability, apparent digestibility coefficients, and the balance of calcium, phosphorus, magnesium, iron, copper, and zinc after the consumption of a goat milk diet compared with bovine milk diet in resected rats. In their work, they concluded that based on the particular biological, nutritional, and metabolic characteristics, goat milk can be an excellent natural food in cases of malabsorption syndrome and present a dietary alternative to bovine milk. Although goat milk has a low iron concentration, it has a higher bioavailability than in cow milk due to the presence of higher amounts of nucleotides that in turn increase absorption in the intestine.

As far as contaminant metals are concerned, concentrations differ between different studies and sampling (feeding, geographic areas, pollution...), and it is therefore difficult to compare species and breeds. According to *Trancoso et al.*, in goat milk from the main Portuguese indigenous breeds, the values for the potentially toxic elements such as Cd, Pb, Co, and Ni are well below the value stipulated by the Commission of the European Communities Directive EC n° 333 for Pb in milk (0.02 mg/kg). Therefore, consumption of caprine milk does not constitute a risk for human exposure to toxic elements at present in Portugal.

3.5. Vitamins

Goat milk is an adequate source of vitamin A, thiamine, riboflavin, and niacin [11, 36, 38]. However, it presents low levels of folates, as well as vitamin B12, vitamin E, vitamin C, and vitamin D (Table 5).

	Goat milk	Cow milk
Fat soluble vitamins A		
Retinol (mg)	0.04	0.04
Beta-carotene (mg)	0.00	0.02
D (µg)	0.06	0.08
Tocopherol (mg)	0.04	0.11
Water soluble vitamins		
B1 Thiamin (mg)	0.05	0.04
B2 Riboflavin (mg)	0.14	0.17
B3 Niacin (PP) (mg)	0.20	0.09
B5 Pantothenic acid (mg)	0.31	0.34
B6 Piridoxin (mg)	0.05	0.04
B8 Biotin (µg)	2.00	2.00
B9 Folic acid (µg)	1.00	5.30
B12 Cobalamin (µg)	0.06	0.35
C Ascorbic acid (mg)	1.30	1.00

Table 5. Vitamin content of goat and cow raw whole milk (per 100g) (adapted from Raynal-Ljutovac et al.)

Compared to cow milk, goat milk has lower amounts of vitamin E, folic acid, and vitamin B12, which can result in “goat milk anemia” if additional sources for these vitamins are not present in the diets.

In conclusion, nutritionally, goat milk is comparable to cow milk as it contains similar levels of calcium, potassium, phosphorus, and many other nutrients that confer health benefits (see Tables 1,2,3 and 5). However, goat milk contains higher levels of 6 out of the 10 essential amino acids than cow milk. It is also richer in monounsaturated and polyunsaturated fatty acids and medium-chain triglycerides, while containing less lactose than cow’s milk.

The most appealing property of goat milk is its superior digestibility, which can make it particularly helpful in attenuating irritable bowel type symptoms.

4. Goat-derived products and nutritional value

The use of goat products was first closely related to a number of medical problems namely food allergies involving cow milk proteins. Cow milk allergy is relatively common during the first 3 years of life. Several studies report that the use of goat milk resolves 30 and 40% of the cases [12].

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.

Goat milk products are considered dairy products with greatest marketing potential. Therefore, several characteristics of goat milk are currently the focus of increased research interest.

Two glasses (0.5 l) of goat milk or the equivalent amount of cheese or yoghurt can provide up to 94% of the recommended adult daily dietary allowance (RDA) of essential amino acids, 83% of calcium, and 78% of riboflavin needs, while also being a dietary source of other minerals and vitamins, albeit to a lesser extent.

4.1. Goat cheese

Literature is exiguous concerning the impact of technology (cheese-making) on every nutrient of cheese, other than fat and proteins. Most studies focus on the gross composition (fat, protein, and lactose contents) of Spanish, Italian, and Greek hard or semi-hard cheeses obtained from small ruminants. Gross composition is mostly dependent on the type of cheese and can be classified according to its dry weight. Although both caprine and ovine milk have been widely used in cheese-making, production of fermented caprine milk using probiotics has not yet been developed, despite the existence of studies showing the requirements for its production. Fermentation increases the nutritional value of caprine milk and improves its flavour, making it more tolerable to the average consumer than raw goat milk.

A review by *Haenlein* focused on several aspects of yoghurt and cheese goat composition. The benefits for human digestion included proteins with different polymorphisms, forming a softer curd on digestion and cheese-making, and the high content in short chain, medium chain, and mono and polyunsaturated fatty acids.

Regarding cheese produced from goat milk, three categories can be distinguished: traditional cheeses (produced on farms) and prepared mainly for home consumption; cheese produced on farm scale under improved conditions (frequent, for instance, in France, which produces more than 90 varieties of goat cheese) and cheese produced with a mix of sheep and goat milks (produced in all Mediterranean countries, except France).

The production of cheese from goat milk dates back to many centuries. In recent years, the production of cheese from goat milk has acquired commercial advantage in several Western European countries because legislation is not as restrictive for this kind of milk or its products as it is for cow milk products. In France, for example, the production of goat cheese increased approximately 13% (in the same year) while cow cheese increased only 1%. The consumption of goat cheese has been expanding at approximately 20% per year.

The composition and characteristics of cheese is highly affected by the characteristics of the milk used in its production. The substitution of sheep milk by goat milk in dairy products is a frequent problem because sheep milk has a higher price. The existence of mixed flocks of goats and sheep might result in accidental or fraudulent mix-ups, affecting profitability as well as the properties and quality of the resultant cheese.

Calf rennet was shown to hydrolyze goat casein forming characteristic breakdown of products from individual caseins: β -I to β -V derived from β -casein as well as other primary hydrolyzed products derived α s1-casein; para-K-casein formed from K-casein and other degradation products obtained from α s2-casein. Under the same conditions, both β -casein and α s1-casein present in goat milk seemed to be more sensitive to hydrolysis than their bovine counterparts.

Goats milk Gouda cheese is usually made in artisanal units by traditional technology passed on from generation to generation and has a special taste and flavour. However, cheese made under these conditions may not have the minimum hygiene and sanitary standards necessary to obtain a product with minimum quality. In the Eastern Mediterranean, an area favourable to small ruminants, most of the cheese is also produced in small artisanal units, with high temperatures and a lack of refrigeration units. The majority of productions also do not include pasteurization leading to brucellosis, listeriosis, and food poisoning due to enterotoxin production by Staphylococci. Therefore, in these areas “white brined cheeses” (WBC), which are ripened and stored under brine until consumption, such as Feta, Domiati, and Beyaz-Peynir, are particularly common and constitute a large share of the cheese market

(>50%). Whey cheeses (such as the Myzithra, Manouri, Lor, Anari, Urda, and Skuta) are also traditional products from the Eastern Mediterranean, as the whey obtained from producing sheep's and goat's milk cheese has a very high protein content. The addition of goat or sheep milk or cream to the whey improves the yield of this type of cheese.

Karagozlu et al. studied the Cimi Tulum cheeses (made from goats' milk) during 90 days of ripening period. These cheeses contain 57.73% total solids; 30.01% fat; 3.51% salt; 22.27% protein; 2.92% water soluble nitrogen, and 1.75% lactic acid. During the ripening process, the amounts of total solids, fat, salt, protein, water soluble nitrogen, and free fatty acids have all been shown to increase, whereas the salt and fat ratios of the total solid content have decreased. The percentages of fatty acid composition of these cheeses were 31.73% of oleic acid, 24.19% of palmitic acid, and 9.32% of myristic acid.

El-Sheikh et al. studied the effect of ripening conditions in blue cheese produced from cow's and goat's milk and concluded that blue cheese (Roquefort-style) had similar properties to the ones made from cow's milk.

Queiroga et al. evaluated the nutritional, textural, and sensory characteristics of coalho cheese made from goat's (CGM) or cow's milk (CCM) and their mixture (CCGM) during cold storage for 28 days. The choice of milk only seemed to have influenced the moisture, fat, and salt contents of the cheeses. CGM and CCGM showed higher amounts of short and medium-chain fatty acids (such as C6, C8, C10, and C12), and long-chain polyunsaturated fatty acids C18:2n6c. They also showed lower C16 and C16:1 contents. Their properties seem to have been maintained throughout storage time.

Main goat cheese types can be classified as follows:

- 1. Fresh and soft cheese:** Gibna Beida (Sudan), Feta (Greece), and Saint Mareá and Camembert (France). Fresh type is prepared by acid curdling with a small dose of rennet. It is consumed the day after being prepared, and it contains 60–80% moisture. It has a texture similar to Queso-Blanco (Latin America). Soft cheese is produced as fresh cheese, but it is ripened for 10–30 days, and it has 55–60% moisture. For instance, Saint Moreé is surface-ripened cheese prepared by a 24 h coagulation step at 17–20°C after addition of mesophilic lactic culture (20 ml/L) and a rennet solution (6 ml/100L) and has a specific goat cheese aroma and has seven acid compounds present: hexanoic, octanoic, nonenoic, decanoic, 3-methylbutanoic, 4-methyl octanoic, and 4-ethyl octanoic

acids; some were already of value in 2 days-old cheese, whereas some others only reached this value after 31.

2. Blue-veined cheese: Savoy (France), Roquefort (France), and Cabrale (Spain). Curd of this cheese is prepared with lactic acid culture and rennet. It has a greenish or bluish marbled appearance after 1–2 hours of curdling and inoculated with penicillium. After salting and piercing, the cheese is ripened for 1–4 months at 9–10°C and 90–95% RH.

3. Semi-hard cheese: Edam (the Netherlands). It contains 40–50% moisture and is prepared by using mesophilic started and rennet. After curdling, cutting the curd, scalting, molding, pressing, and salting, the curd is waxed and ripened for 1–5 months at 8–10°C and 90–95% RH.

4. Hard cheese: Chevrotin (France), Kefalotili (Greece), Ras (Egypt), and Manchego (Spain). It contains 30–40% moisture and is produced in warm countries or in mountainous area. Regarding Chevrotin cheese, it is prepared by culture and rennet curdling. It is preserved for 1–3 months submerged in olive oil.

Hassan et al. fortified goat cheese with caramel, cocoa, and cocoa with walnuts, and these cheeses were prepared in order to be directed to children feeding, given its protein content. The ω -6/ ω -3 ratios were at levels 6.0, 7.7, and 4.7, respectively.

The study made during ripening by **Niro et al.** compared the physicochemical, microbiological, and sensorial characteristics of Caciocavallo cheeses, made from cow milk and a mixture of cow with ewe or goat milk. Different percentages of goat milk added milk to cow milk influenced compositional and nutritional characteristics of these cheeses.

4.2. Goat yoghurt

The preparation of goat yoghurt is made using similar processes to those used in the production of cow milk yoghurt, but it has different organoleptic properties as well as nutritional composition. It presents less viscosity, has softer consistency flavor and higher acidity, during storage. Goat yoghurt has free caproic, caprylic, lauric, and myristic acids. While palmitic and stearic acids were approximately equal, oleic, linolenic, and palmitic acids were lower when compared with cow yoghurt. Regarding amino acid content, goat yoghurt showed about 4 mg/100g of Gly and Pro; 2

mg/100g of Lys, Thr, Ser, Glu, and Ala; and 1–2 mg/100g His, Asp and Leu. Regarding Arg, Val, Meth, and Phe, their concentrations were inferior to 1mg/100g.

There are significant changes in gross nutrients between fresh goat milk and yoghurt. Eissa et al. found a decrease in lactose content and pH of the yoghurt after fermentation. Cold storage also resulted in significant changes in gross composition of goat yoghurt. The number of total bacteria and yeast increased significantly within 10 days of storage, decreasing thereafter. Goat milk yoghurt showed in this study lower sensory scores than cow milk yoghurt.

Bano et al. concluded that mixing 75% of goat milk and 25% sheep milk in manufacture of yoghurt improved color, flavour, and texture scores of the resultant yoghurt.

Uysal-Pala et al. showed that drinkable yogurts made from different goat breeds' milk and made with normal and probiotic cultures were evaluated for their sensory characteristics. Yoghurt manufacture with cows and with goats' milk (100, 75, 50 and 25%) substitution blend with cow's milk revealed that goats milk yoghurt (100%) had the highest protein content (4.2%), fat (4.3%) and caproic (c6), caprylic (c8) capric (c10), and total solids (16.2%). Generally, goat's milk yoghurt samples (100, 75, and 50%) were mostly significantly preferred to 25% goat's milk yoghurt sample at ($P > 0.05$).

Al-Abdulkarim et al. studied a sample of dried fermented goat's milk product (Oggtt) obtained from the local market of Riyadh (Saudi Arabia), which was stored for 6 months at 4°C and subjected to chemical composition analysis before and after storage. After storage, total ash decreased nonsignificantly ($P < 0.05$) from 8 to 7.6%, total carbohydrates decreased nonsignificantly ($P < 0.05$) from 35.5 to 33.8%, protein increased nonsignificantly ($P < 0.05$) from 16 to 16.1 g/1, fat content was found to have the same values in all samples before and after storage at 5%, lactose increased nonsignificantly from 28.4 to 29%, acidity decreased ($P < 0.05$) significantly from 0.45 to 0.39%, and pH decreased nonsignificantly from 4.3 to 4%. On the other hand, mineral composition showed ($P < 0.05$) nonsignificant results before and after storage. Ca concentration decreased from 118 to 114 mg/kg and K concentration increased from 185.8 to 188.8 mg/kg. This is a stable product and presents good nutritional value in comparison to daily requirements for healthy human life.

4.3. Goat butter

The production of butter from goat milk is not very common, and sometimes it is artificially colored in order to look similar to cow butter . There is a difficulty in cream separation, a softer texture, and it

presents high tendency to hydrolytic rancidity. Idoui et al. [62] studied a traditional butter from Eastern Algeria. The results showed the presence of lactic acid bacteria ($3.51 \times 10^5 + 2.44$ cfu/g), psychrotrophic bacteria ($1.11 \times 10^5 + 1.31$ cfu/g), moulds and yeasts (39.08×10^2 cfu/g), lipolytic bacteria ($4.41 \times 10^3 + 5.91$ cfu/g) and the absence of total coliforms except in one sample. An analysis of fatty acids was made by GC-MS that showed a prevalence of saturated fatty acids, namely palmitic acid with a low rate of unsaturated fatty (oleic acid).

4.4. Goat meat

Goats are animals with fairly low-fat content. Several authors have indicated that the fat content of goats is 47–54% lower than that of cattle and sheep. The introduction of goat meat in diet may become an important measure for the prevention of cardiovascular diseases

Banskalieva et al. also pointed out that further experimentation is needed to characterize interactions between factors such as race, age, and nutritional status in the lipid profile of goat for a better understanding of their meat quality. Little is known about the lipid profile of goat meat, but some studies indicate that oleic, palmitic, stearic, and linoleic are the predominant acids in muscles. *Rhee* reported that goats have higher concentrations of desirable fatty acids than cattle and sheep, but at levels similar to lean meat of pigs.

Several factors such as race, gender, stress, environment, management, diet, weight, and health condition affect the chemical composition of goat meat. Studies have shown that the average composition of meat obtained from Serbian white goats to be estimated around 75.42% water, 3.55% fat, 19.95% protein, and 1.06% minerals, whereas meat obtained from Balkan goats had a similar composition, with a water content of 74.51%, 3.92% fat, 20.55% protein, and 1.04% minerals. The energetic value was similar in both breeds and is around 580 kJ per 100 g of meat.

The quality of goat meat is influenced by its water content. The muscles contain approximately 75% water, which is distributed within the myofibrils, between themselves, between the cell membrane (sarcolemma), and between the muscle bundles. The cooling or freezing mode after slaughter, especially during the rigor, is of great importance for the percentage of water that will remain in the meat.

Adipose tissue of slaughtered animals contains 50–95% fat, 3–35% water, 2–15% protein, and 0.1–0.6% mineral matter. The composition of adipose tissue is highly variable and depends of nutritional

status, breeding, age, and type of animal. In each cell, there are 40–50 types of fats, which represent about 5% of the organic matter present in cells. The amount of fat per cell varies from tissue to tissue, for instance, cells of the nervous system are extremely rich in fats. Diet influences the deposition of fat in the muscular tissue, as well as the saturated (SFA) and polyunsaturated fatty acid (PUFA) concentrations in cattle.

In ruminants, lipids from meals suffer hydrolyzation and biohydrogenation processes in the rumen, resulting in absorption of saturated fatty acids in the digestive tract. This fact could help explain the higher percentage of saturated fats in meat products obtained from ruminants. Several studies have been conducted in an attempt to determine the fatty acid profile of goat meat. However, the role of certain processes such as biohydrogenation, transition of unsaturated into saturated fatty acids, elongation of fatty acid chains, metabolism, and deposition rate are yet to be fully understood.

The composition of the fat in goat meat and other ruminants differs from that of monogastric animals, having larger amounts of SFA and lower quantities of PUFA, with C18:1 and C18:2 trans and cis isomers of FA are also present in goat meat. In animals, the main PUFA (C18:2n-6 and C18:3n-3) are obtained from the diet. However, in ruminants, these products suffer biohydrogenation processes in the digestive tract, originating saturated fats as well as other intermediate products, which include cis and trans C18:1 isomers and C18:2 trans isomers, conjugated or unconjugated. While grain feeds are a food source of C18:2n-6, green grass on pastures are richer in C18:3n-3, which is more desirable as it could lead to higher contents of omega-3 fatty acids in meat products.

Meat products derived from ruminants are a dietary source of CLA. C18:2 cis-9, trans-11 is the most frequent isomer of CLA, and is also present in higher amounts in the meat of ruminants fed on pasture than in the meat of ruminants fed with grain. Despite the fact that a fraction of this fatty acid occurs in the rumen, about 70–80% of the acid present in the tissues results from endogenous transformation C18:1 trans-11 by the enzyme Δ^9 desaturase. Therefore, the difference in CLA concentration in the tissues results mainly from the amount of C18:1 trans-11 absorbed in the rumen.

5. Nutrient functionality

Nowadays, nutrients have emerged as an important research topic in food and nutrition sciences as they appear to be able to modulate the inflammatory status of humans. Dairy products represent a particularly interesting food type to study in the context of inflammation, mostly because of milk's

ability to support the development of the immune system of the newborn, to inhibit bacterial growth, and to provide anti-oxidative and anti-inflammatory protection. Some of these properties might still be maintained in the context of the consumption of dairy products by human adults. Additionally, the ability of milk and milk-products to deliver supplements to the human organism able to modulate the gut microbiota, a key regulator of immunity, is another factor which might help influence immune and inflammatory processes.

Recently, reviews *by Hsieh et al.* have described the effects of different bioactive components of milk and dairy products in preventing low-grade systemic inflammation and in acting as coadjuvants in conventional therapies.

In the following sections, after a brief overview structure and function of the immune system, we will focus on the effects of several bioactive compounds found mainly in goat milk and their effects in low-grade systemic inflammatory diseases and immunity.

5.1. Food allergy

Specific immune response also plays a lead role in food allergy. The term “allergy” can be used to define an abnormal adaptive immune response directed against noninfectious environmental substances (allergens), including noninfectious components of certain infectious organisms. After antigen contact, the body responds with an excessive reaction (IgE antibodies, histamine release). The symptoms are dramatic and acute. In allergic disorders, such as some food allergies, these responses are characterized by the involvement of allergen-specific IgE and T helper 2 (TH2) cells that recognize allergen-derived antigens.

Recent studies suggest that the consumption of dairy products is inversely associated with low-grade systemic inflammation . The cross-sectional nature of these studies precludes definite conclusions on the cause-and-effect relation between dairy food consumption and inflammatory outcomes. Considering distinctive proprieties of goat milk, we will summarize some of the bioactive compounds present in goat’s milk and dairy products and their effects on health.

6. Anti-inflammatory effects of goat milk and its derivatives

6.1. Bioactive peptides

Bioactive peptides (BP) have been defined as specific protein fragments that have a positive impact on body functions or conditions and may ultimately influence health. According to Atanasova and Ivanova, goat milk is as “close to perfect food as possible in nature.” As we have previously described, the protein present in goat milk is comprised of about 80% caseins and 20% whey proteins. Some of the peptides and proteins in milk present direct biological activity, while other proteins have a latent biological activity, which is activated only upon proteolytic action. For example, the active forms of caprine calmodulin (calcium-binding protein) are the soluble C-terminals obtained as a by-product from the action of chimosin on k-casein during the milk clotting process of cheese-making. These peptides are also important sources of bioactive ACE-inhibitory and anti-hypertensive peptides. Moreover, goat milk possesses other minor proteins including immunoglobulins, lactoferrin, transferrin, ferritin, protease peptone, prolactin, and folate-binding protein with biological activity.

Furthermore, a variety of naturally formed bioactive peptides have been found in fermented dairy products, such as yoghurt and cheese. The main bioactive peptides of goat milk and its derivatives will be described below.

6.1.1. Biopeptides that lower blood pressure

Several epidemiological studies have linked dietary intake of milk and dairy foods with a decreased risk of hypertension. Their high mineral content (in calcium, potassium, and magnesium) and certain proteins present in these products (as well as their hydrolysates) have been thought to be involved in the anti-hypertensive effect of these products. Angiotensin-converting enzyme (ACE) is a multifunctional enzyme that acts as one of the main regulators of blood pressure. ACE inhibition, restrain the formation of angiotensin II or block its receptors leading to arteriolar vasodilation and a reduction of total peripheral resistance. Therefore, ACE inhibition is currently considered as one of the best strategies for hypertension treatment.

6.1.2. Antimicrobial peptides

The antimicrobial activity of milk is mostly attributed to the presence of immunoglobulins and other proteins, such as lactoferrin, lactoperoxidase, and lysozyme. It is generally accepted that the total antibacterial effect in milk is greater than the sum of the individual contributions of immunoglobulin and nonimmunoglobulin defensive proteins. This might be because naturally occurring proteins and

peptides act synergistically with peptides that result from metabolization of inactive protein precursors . The proteins present in milk proteins have been proven to act as antimicrobial peptide precursors, thus improving the ability of natural defences to eliminate invading pathogens. Consequently, food proteins can be considered components of nutritional immunity. A paper by *Budiarti et al.* demonstrates the presence of Alpha-S2 casein in Ethawah goat milk and yoghurt. This protein contains eight bioactive peptides, with different effects, such as anti-osteoporotic or anti-inflammatory effects, and it was not found in cow fresh milk. More recently, *Triprisila et al.* reported the effect of antimicrobial activity from CSN1S2 protein as a member of casein protein from Ethawah breed goat milk and yoghurt against pathogen Gram-positive bacteria (*Listeria monocytogenes*, *Staphylococcus aureus*, and *Bacillus cereus*) and Gram-negative bacteria (*Escherichia coli*, *Salmonella typhi*, and *Shigella flexneri*). The results of their work showed a greater inhibitory effect on Gram-positive bacteria than on Gram-negative bacteria. They also demonstrated that milk has a higher antimicrobial activity than yoghurt.

6.1.3. Antioxidant peptides

Antioxidant peptides are particularly interesting because they can potentially prevent or delay oxidative stress as well as low-grade systemic inflammation associated chronic diseases. In this sense, milk proteins as well as milk-derived proteins have been considered as potential carriers for the delivery of antioxidant peptides in the gastrointestinal tract, where they may exert direct protective effects by scavenging reactive oxygen species and reducing the oxidative stress. Only a few studies on the antioxidant properties of goat milk protein-derived peptides have been performed. *Silva et al.* identified three antioxidant peptides in a water extract from a goat cheese-like system made using an extract from *Cynara cardunculus*. *Nandhini et al.* found that goat milk fermented with *Lactobacillus plantarum* had potent radical scavenging and lipid peroxidation inhibition activity, although they did not identify the active peptides. *Li et al.* identified antioxidant peptides in a goat's milk casein hydrolysate made using two enzymes (alcalase and pronase), although some of which did not match with the goat casein sequences available in protein databases. *De Gobba et al.* isolated and identified antioxidant peptides formed from goat's milk protein fractions by enzymatic hydrolysis using trypsin and subtilisin, both individually and in combination. They found hydrolysates with high radical scavenging activity attributed to the presence of short peptides. Furthermore, an abundance of tyrosine in novel casein-derived peptides seems to play an important role in the radical scavenging capacity of

the peptides. Also, peptide fractions with a high abundance of phenylalanine showed the ability to prevent the formation of secondary lipid oxidation products.

6.1.4. Prevention of milk allergy

Cow's milk allergy is a common disease of infancy and childhood, and its prevalence is about 2.5% during the first 3 years of life. It is an IgE-mediated allergy, meaning that body produces IgE antibodies against certain protein (allergens) in cow milk. Repeated ingestions of milk lead to identification of antigens present in milk by these IgE antibodies, triggering an immune response that causes symptoms such as eczema, respiratory symptoms (wheezing or asthma), gastrointestinal symptoms, or anaphylaxis. Some proteins, namely α S1-casein and β -lactoglobulin (the structures and composition of which vary between animal species) are known to be important allergens in cow's milk allergy. The allergy-causing properties of β -lactoglobulin can be partially eliminated by heat denaturation. However, caseins maintain the capability of binding to IgEs even after a strong denaturing process. Because the content of α S1-casein is low in goat milk, it is plausible that for children with high sensitivity to α S1-casein of cow milk, goat's milk could be considered an alternative source of milk. More recently, several studies report extensive cross-reactivity between cow and goat milk, caused by cow milk-specific IgE antibodies. Because of the cross reactivity, all scientific reports dissuade persons with cow milk allergy to ingest goat milk. Interestingly, allergy to goat's and sheep's milk without allergy to cow's milk has been reported. However, this food allergy develops later in childhood and not in early childhood as cow's milk proteins allergy, and all the children tolerated cow's milk. Cow milk proteins have been shown to have higher binding capacity to IgE and IgG than proteins present in goat milk. In animal models, cow milk has induced higher lymphocyte proliferation, IL-4 production, histamine secretion, and IgG production, which indicates a more exacerbated allergic response.

6.2. Bioactive lipid components of goat milk

Milk lipids have a complex composition, consisting of a variety of bioactive substances with various health effects. Lipids in milk are organized in unique structures: milk fat globules. These structures are important in delivering essential nutrients to the neonate, as they increase bioavailability of lipids. Fat globules have also recently an object of interest in food science, namely their use as a method of delivering other beneficial bioactive nutrients. As previously described, caprine milk has more fat globules than cow milk, with a smaller size. These characteristics are important, as they increase the

surface area of the globules in contact with pancreatic lipase in the intestinal tract. This allows for better digestibility and a more efficient lipid metabolism, when compared with cow milk fat. Goat milk is therefore recommended for infants, elderly, and convalescing people.

There are several lipid components that have bioactive functions, such as short- and medium-chain fatty acids (MCT), phospholipids, cholesterol, gangliosides, and glycolipids, etc. Goat milk has a relatively high amount of saturated fatty acids (SFAs; 53–72%) and a relatively low content of polyunsaturated fatty acids (PUFAs; 2–6% of fatty acid composition); the remaining fat is constituted by monounsaturated fatty acids (MUFAs).

6.3.2. Anti-inflammatory activity

Martinez-Ferez et al. suggested that goat milk oligosaccharides may have an anti-inflammatory action. Their research aimed to investigate whether goat's milk oligosaccharides could inhibit the adhesion of monocytes to human umbilical vein endothelial cells. The results of this research indicated that goat's milk oligosaccharides may in fact act as anti-inflammatory agents in the newborn infant, an effect that had already been demonstrated for human milk oligosaccharides and that can be attributed to the structural similarities between goat and human milk oligosaccharides.

7. Conclusions and future prospects

Goat milk and other goat-derived products present unique characteristics and their nutritional value, as well as their potential health effects, have been the object of a fair amount of investigation. The composition of goat milk does not differ remarkably from that of cow milk, while presenting more similarities with human milk, making it more easily tolerated. Moreover, the superior digestibility of goat milk, its fatty acid composition, and the presence of various bioactive compounds in its constitution make goat milk potentially helpful in the treatment or even the prevention of certain medical conditions.

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