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REVIEW

Nutritional and therapeutic value of fermented caprine milk

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Caprine milk is a nutritional and therapeutic food. The unique and beneficial characteristics of caprine milk that are superior to bovine milk include: better digestibility; greater buffering capacity; fat globules that are smaller in diameter and better distributed in the milk emulsion; higher content of short-chain fatty acids in the milk fat; higher content of zinc, iron and magnesium; stronger lactoperoxidase (antimicrobial) system as well as better immunological and antibacterial characteristics. The larger amounts of some minerals, such as calcium, zinc and magnesium, in caprine milk may influence the growth of lactic acid bacteria since they are a normal part of some enzymatic complexes involved in lactose fermentation. The higher whey protein content could also be significant because Lactobacillus acidophilus *and bifidobacteria grow better in the presence of higher levels of some amino acids (valine, glycine, hystidine). The use of caprine and ovine milk in cheesemaking is well known, but the production of fermented caprine milk via probiotics has not yet been developed, although many studies have highlighted the requirements for production of that kind of healthy food. During fermentation caprine milk loses its characteristic 'goaty' taste, which is unacceptable to many consumers. Moreover, the nutritive value of caprine milk increases during fermentation. The rise in the number of goat farms in Croatia has created the need to find other products that can be produced using caprine milk. According to the present situation in Croatia, there is no real possibility of producing fermented caprine milk for the global market, but many studies of fermented caprine milk have been performed.*

Keywords Caprine milk, Fermentation, Nutritive and therapeutic value, Probiotics.

INTRODUCTION

For centuries, humans have used goats for many purposes. However, although goats are present on all of the continents (FAO 2001), many authors have observed that the goat sector has not been well supported publicly or academically when compared with other animal production sectors, especially the cow sector or the bovine milk sector (Dubeuf *et al.* 2004). Moreover, in spite of some superior qualities, the economic and commercial potentialities of goats and caprine milk have not been recognised (Morand-Fehr 1996).

There are many reasons for these tendencies. More than any other mammalian farm animal, the goat is the main supplier of dairy and meat products for rural people. Official statistics indicate there are significant amounts of unreported home production, especially in the developing countries of Asia and Africa (Dubeuf and Thomas 1996; Haenlein 2004). Caprine milk production in many countries depends on competition with bovine and ovine milk products. The high milk productivity of cows as well as the many products that can be produced from sheep (wool, meat, milk with a high content of solids for cheese production) promotes their production. Furthermore, as caprine dairy products are generally in specific markets (such as dietetic milks, fresh ripened cheeses, mould ripened cheeses), their profitability depends on their relative price. As a rule, such products from caprine milk are more expensive than similar products derived from bovine and ovine milk (FAO 2001). Another major problem which exists has been described as the special organisation of goat production systems (seasonal production, size of herds, caprine milk productivity etc) (Dubeuf *et al.* 2004). The optimum situation for farming, manipulation and marketing of caprine milk and caprine milk products definitely can be seen in the USA. Today, some states of the USA have a goat breeders' association within a sector that is very active with magazines, fairs and innovative products such as new caprine cheeses, candy and cosmetic products made from caprine milk (Haenlein 2000, 2001). Finally, but importantly, the taste of caprine milk has been described specifically as 'goaty'. Because of this characteristic, sometimes 'sharp'

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goaty taste of the milk and its products, many consumers in the past have discarded caprine milk products (Haenlein 2001).

However, because of the many articles that have emphasised the special value of caprine milk in human nutrition, scientific and commercial interest in caprine milk and caprine milk products has increased progressively over the past two decades (Martin-Diana *et al.* 2003; Boyazoglu *et al.* 2005a; Biss 2007). The importance of caprine milk and meat in human nutrition has been discussed in many recent proceedings of national and international conferences, which were cited by Haenlein (2004). Its importance is also reflected in the increase in the goat population during the last 20 years, which was the largest increase of any animal population, and the increase in caprine milk production tonnage, which exceeded that of other mammalian farm animals. According to FAO data (2001), which has been cited by Haenlein (2004), the number of goat farms in the world increased by some 58% between 1980 and 2000. According to Morgan and Gaborit (2001), the production of caprine milk worldwide was 12 million tonnes, a large part of which was used for direct consumption. European caprine milk is primarily produced in the Mediterranean countries, especially Greece, France, Spain and Italy (Morgan *et al.* 2003). The Mediterranean region produces 18% of the world's supply of caprine milk (Pandya and Ghodke 2007). Apart from direct consumption, a large proportion of caprine milk in European countries has been used for cheese production, as well as for UHT caprine milk and caprine milk powder (Morgan *et al.* 2003). From the statistical data collected, it is obvious that the production as well as the processing of caprine milk into products in many European countries has a strong regional and artisanal character (Morand-Fehr *et al.* 2004; Boyazoglu *et al.* 2005b;. In the European Community, the originality of caprine and ovine milk products is protected by legislation on the Protected Designation of Origin (PDO) and the Protected Geographic Indications (PGI) (Raynal-Ljutovac *et al.* 2005). Many economic and scientific studies have proposed that artisanal caprine milk products will play an important role in global European markets in the future.

Cheese has been a predominant caprine milk product in European countries, especially in the Mediterranean region. Caprine milk cheese is greatly appreciated for its organoleptic properties (Buffa *et al.* 2004). Thus, 90% of the caprine milk produced in France has been sold as cheese (Agreste 2001). In Spain, except for the production of cheeses directly from raw or heat-treated caprine milk, most of the caprine milk was mixed earlier with bovine or ovine milk (Dubeuf *et al.* 2004), and the mixture of these types of milk has been used for the production of many autochthonous (regionally-produced) cheeses (Freitas *et al.* 1996; Zarate *et al.* 1997; Dubeuf *et al.* 2004; Poveda and Cabezas 2006; Pandya and Ghodke 2007). In many recent studies on autochthonous Spanish cheeses from caprine milk, the composition, microbiology, biochemistry and changes during ripening have been comprehensively described (Casla *et al.* 1996; Fresno *et al.* 1997; Lopez *et al.* 1999; Fontecha *et al.* 2006; Calvo *et al.* 2007). Some of these studies described the antimicrobial activity of lactic acid bacteria isolated from these cheeses (Casla *et al.* 1996; Herrero and Requena 2006), which is one of the points of this review. Another two Mediterranean countries famous for their artisanal caprine cheeses are Italy (Guerzoni *et al.* 1999; Suzzi *et al.* 2000; Andrighetto *et al.* 2001) and Greece (Hatzikamari *et al.* 1999). In Italy, some types of cheese have been produced from raw or heat-treated caprine milk and most of them have regional character, such as Robiola di Roccaverano (Bonetta *et al.* 2008), Montasio (Marino *et al.* 2003) and others. Furthermore, some authors cited the rich taste and aroma of Italian cheeses derived from grazing goats, which have a potential place in many gourmand kitchens around the world, although there is no capacity for export production yet (Fedele *et al.* 2005). Some of the semi-ripened Sicilian cheeses from goats also must to be mentioned. One of these is Provola dei Nebrodi, with a predominance of the probiotic strain *L. casei* in its composition (Cronin *et al.* 2007). The most famous Greek cheese produced mostly from caprine or ovine milk definitely is Feta (Anifantakis 1991b Litopoulou-Tzanetaki and Tzanetakis 1992; Bintsis *et al.* 2000). In addition to Feta, many types of artisanal cheeses have been traditionally produced in Greece from raw or heat-treated caprine milk. The consistency (firmness), duration of ripening, microbiological characteristics and sensory properties of these Greek cheeses vary, depending on the locality and traditions (Anifantakis 1991a; Hatzikamari *et al.* 1999; Xanthopoulos *et al.* 2000; Psoni *et al.* 2003).

In other European countries, outside of the Mediterranean region, the situation with respect to goat farming, as well as caprine milk products, is very different. In some countries, such as The Netherlands and the UK, simultaneously development has been recorded over last 20 years (Van Dijk 1996; Mowlem 2005; Eurostat 2007). However, in northern European countries, most of the goat farms disappeared in favour of more intensive production (bovine milk). Accordingly, the production of some traditional caprine cheeses from Norway and Sweden, such as Brunost and Gjetost, today has only rural importance with no significant influence on the global market in these countries (Rault 1998).

Although products other than milk and cheeses exist in some parts of the European market, it could be said that they have a lesser importance than caprine cheese and milk. Apart from thermally treated caprine milk (pasteurised or UHT) and a wide variety of caprine cheeses, only yoghurt made from caprine milk plays a certain role on the European market, but only in some countries and in small quantities (Pandya and Ghodke 2007). Pandya and Ghodke (2007) pointed out the following additional caprine milk products: cream, butter or butter oil, caprine milk fat, ice cream and whey protein concentrate from caprine milk. These products could have good nutritional value, because of the specific composition and structure of caprine milk.

On the Croatian global market, there exist only two products made from caprine milk produced in Croatia: UHT caprine milk and a small number of caprine cheeses, such as Caprillo or Capridur. Although there has been a trend of continuously increasing numbers of goat dairy farms in Croatia from year to year, many of them are only small rural holdings. Nevertheless, some of the exceptional caprine cheeses have been produced on these farms. As in other Mediterranean countries, cheeses made from caprine milk in Croatia have strictly regional character and the types (characteristics) of cheeses vary, depending on the tradition and the region of Croatia in which they have been produced (Feldhofer *et al.* 1994; Lukač-Havranek 1995; Tratnik *et al.* 2000; Cvrtila *et al.* 2001; Drgalić *et al.* 2002; Samaržija and Antunac 2002; Kirin 2006). Consequently, Croatian authors in their studies mention fresh caprine cheeses, soft and brined caprine cheeses, semi-hard caprine cheeses, ‘cooked’ caprine cheeses and even the possibility of producing fresh caprine cheeses enriched with probiotic starters (Tratnik 1998; Tratnik *et al.* 2002). Many of these types of cheeses have loyal consumers, and the tendency to protect their origins and geographic indications is prevalent among all producers (Samaržija and Antunac 2002), as is their desire to increase the capacity of cheese production. A very significant fact is that many types of these artisanal farm cheeses have been exported to some countries of the European Union near Croatia, but in small quantities in terms of economic significance (Slačanac 2008). Until some 20 years ago, goat husbandry was primarily based on autochthonous breeds whose purpose was kid meat production, and the production of milk was secondary. For the past 20, and especially for the past 10, years interest in the production of caprine milk based on the Alpine and Saanen breeds has increased significantly (Mioč *et al.* 2008).

The incorporation of probiotic bacteria into food products increased during the last two decades because of the beneficial effects that these microorganisms offer to the host (Fuller and Gibson 1997; Guarner and Schaafsma 1998; Saarela *et al.* 2000; Saxelin *et al.* 2000; Kehagias *et al.* 2008). Many of these products belong to the so-called ‘functional foods’ group and contain selected bacteria such as *L. acidophilus* or *Bifidobacterium* spp., providing several prophylactic and therapeutic benefits (Ishida *et al.* 2005). The viable lactic acid bacteria in fermented milk products have been associated with increased lactose tolerance, a well-balanced intestinal microflora, antimicrobial activity, stimulation of the immune system and antitumoural, anticholesterolaemic and antioxidative properties in human subjects (Kullisaar *et al.* 2003). The use of milk from small ruminants (goats or ewe) may represent one direction of innovation in the manufacturing of new products (Gomes and Malcata 1998).

According to the present situation in Croatia, there is no real possibility of the production of fermented caprine milk products for the global market, especially not products with probiotic lactic acid bacteria. Only one (or maybe two) large dairy company in Croatia intensively raises dairy goats, but for the production of cheese or heat-treated milk. Many studies over the past decade in Croatia have examined the conditions and possibilities for the production of fermented probiotic products produced from caprine milk (Božanić *et al.* 2002a,b, 2004; Tratnik *et al.* 2006). Furthermore, some of these studies done in Croatia pointed out the inhibitory effects of caprine milk fermented with probiotics against different gastrointestinal and urinary pathogens (Slačanac *et al.* 2004, 2007a,b).

COMPOSITION AND PHYSICAL PROPERTIES

In view of its basic composition (including solids, nonfat solids, proteins, fat, lactose, ash and minerals), caprine milk is very similar to bovine milk (Table 1). However, its exact composition varies according to many factors: breed, individual animal, diet and feeding, environmental and regional (local) conditions, lactation period, health status etc. (Jenness 1980; Park *et al.* 2007). This is the logical reason for deviations in composition data for caprine milk presented by different authors in the past. Some of these deviations are shown in Tables 1, 2 and 4. The results of Morgan *et al.* (2003) clearly reveal the variability of caprine milk characteristics collected during only 1 year from different European areas (Greece, Portugal and France). The authors determined a high level of variability in the biochemical composition, bacteriological quality and technological properties of caprine milk. According to the Croatian Livestock Center (CLC 2005a,b), cited in Mioč *et al.* (2007),

Table 1 Average composition (g/kg) of basic nutrients in caprine, ovine, bovine and human milk (data compiled from Tratnik1998; Božanić *et al.* 2002; Park *et al.* 2007) (mean value calculated from the sum of the values which were presented by all cited authors)

Composition (g/kg)	*Goat*	*Sheep*	*Cow*	*Human*
Total solids	119.4	190.0	128.9	127.4
Fat	33.5	79.0	38.5	40.0
Solids, nonfat	89.0	120.0	90.0	89.0
Lactose	45.5	49.0	47.0	69.0
Protein	33.0	62.0	33.3	12.0
Casein	25.5	42.0	27.0	4.0
Albumin, globulin	7.5	10.0	6.5	7.0
Nonprotein N	4.0	8.0	2.0	5.0
Ash	8.0	9.0	7.3	3.0
Calories[a]	70	105	69	68
Cholesterol	0.10	n/a	0.13	n/a

n/a, No data.
[a]kcal/100 mL.

the average fat content in samples of caprine milk collected from small and medium enterprises (SME) in Croatia was 35.5 g/kg for the French-Alpine breed and 33.5 g/kg for the Saanen breed. The crude protein content of milk collected from SME in Croatia was approximately 30.8 g/kg for the French-Alpine and 30.5 g/kg for the Saanen breed (Mioč *et al.* 2007).

In addition, in dairy goats the lactation period is a very important factor because some characteristics and components of the content vary during lactation, to a greater degree than in bovine milk (Table 2) (Zeng *et al.* 1997; Pierre *et al.* 1998; Antunac *et al.* 2001; Chilliard *et al.* 2003). The data presented in Table 2, which incorporate the results of the above-mentioned authors for samples from different countries (regions, climates, conditions etc.), could be a good indicator for caprine milk producers, especially for caprine cheese producers, because the cheese yield and quality significantly depends on the content of fat, proteins and total solids (Fekadu *et al.* 2005). The same could be said for the production of fermented milk, because the rheological properties of the coagulum are in direct correlation with the solid contents and protein structure of the milk (Vargas *et al.* 2008). It is important to note that, in all of the cited studies, similar changes in fat and protein content during lactation were observed for the same goat breeds in different locations around the world.

The results presented in Table 1 show that ovine milk contains a higher proportion of total solids and major nutrients than caprine and bovine milk. This is a well-known fact, mentioned in many comparative studies and books (Tratnik 1998). However, in this article, a comparison between the composition and structure of caprine milk and bovine milk, as well as between related products, will be critically presented.

Physico-chemical characteristics

There are some differences in physico-chemical characteristics between caprine and bovine milk which can certainly influence their technological properties (Park 1994a, 2007). According to the results of many studies, the density of caprine milk is in the same range as that of bovine milk, but in all studies the values for caprine milk are slightly higher (Table 3). As a result of its higher density, caprine milk has a higher viscosity but lower refractive index and freezing point than bovine milk (Parkash and Jenness 1968; Jenness 1980; Haenlein and Cacesse 1984; Juarez and Ramos 1986; Park 1994a; Park *et al.* 2007). The titratable acidity of fresh, as well as heat-treated, caprine milk has been consistently higher than that of bovine milk. This has been confirmed by the results of many studies during the past 30 years (Antunac and Samaržija 2000; Park *et al.* 2007). Consequently, fresh caprine milk habitually has a lower pH value than fresh bovine milk. Differences in the specific physico-chemical fat values, and especially the protein micellar structure values, could suggest significant differences in technological properties between caprine and bovine milk (Table 3). These physico-chemical differences are the consequence of the different structures of caprine and bovine milk and have been significantly appreciable in cheeses, but also in fermented milk

Table 2 Average composition (g/kg) of caprine milk from Alpine and Saanen breeds during 200 days of lactation collected in Croatia (Antunac *et al.* 2001), France (Zeng *et al.* 1997) and Oklahoma in USA (Fekadu *et al.* 2005; Pierre *et al.* 1998)

Component(g/kg)	*50th day*	*100th day*	*150th day*	*200th day*
Total solids	113.6 ± 6.1	106.6 ± 4.8	105.7 ± 3.9	113.2 ± 3.0
Fat	33.0 ± 2.7	29.7 ± 2.9	29.2 ± 3.3	33.1 ± 2.9
Proteins	28.5 ± 0.4	27.3 ± 0.2	28.1 ± 0.2	30.2 ± 0.9
Lactose	44.2 ± 2.4	43.5 ± 2.9	42.7 ± 3.3	42.0 ± 1.4
Ash[a]	66.3	62.8	67.3	75.2

Mean values calculated from the sum of the values which were presented by all cited authors.
[a]Data from Antunac *et al.* 2001;.

Table 3 Basic physico-chemical properties of caprine and bovine milk; comparison of the physico-chemical values characteristic of lipid and protein properties (data compiled from Park *et al.* 2007)

Basic physico-chemical properties	*Caprine milk*	*Bovine milk*
Specific density	1.029–1.039	1.023–1.039
Viscosity, C_p	2.12	2.0
Surface tension (dynes/cm)	52.0	42.3–52.1
Conductivity (Ω/cm)	0.0043–0.0139	0.0040–0.0055
Refractive index	1.45 ± 0.39	1.451 ± 0.35
Freezing point (deg H)	0.540–0.573	0.530–0.570
Acidity (g/kg lactic acid)	1.4–2.3 (6.80 °SH)[a]	1.5–1.8 (6.70 °SH)[a]
pH	6.50–6.80	6.65–6.71
Lipid values		
Unsaponifiable fat (%)	0.41 ± 0.02	0.41 ± 0.02
Acid value	0.47 ± 0.02	0.48 ± 0.05
Iodine value	19–20	27.09 ± 1.26
Saponification value	228.6 ± 5.24	232.3 ± 7.61
Reichert Meissl value	1.80 ± 0.35	25–33
Polenske value	3.49	4.55
Protein values		
Noncentrifugal casein[b]	8.7	5.7
Average diameter	260	180
Hydration of micelle	1.77	1.9
Mineralization of micelle[c]	3.6	2.9

[a]Božanić *et al.* 2002.
[b]Percentage of total casein.
[c]g/Ca/100 casein.

production, as differences in the following sensory characteristics: consistency, flavour, odour, colour, stability during storage and syneresis degree. The data presented in Table 3 (Park *et al.* 2007) show that caprine milk has a significantly higher content of noncentrifugal casein, a higher average diameter of micelles as well as a higher potential of micelle mineralisation than bovine milk. All of these differences in characteristics of the physico-chemical values follow from the different compositions and structures of the milk fat and protein system of caprine and bovine milk. Some of these characteristics could have an important influence on some of the technological properties during the manufacture of fermented milks and cheeses, such as acidification ability (Morgan *et al.* 2003), whey drainage ability (Jaubert and Kalantzopoulos 1996) and heat stability (Fox and Hoynes 1976).

Lipids

Of all of the basic nutrients present in milk, perhaps the greatest difference between caprine and bovine milk is in the composition and structure of the milk lipids. Lipids are the most important components of milk in terms of the physical and sensory characteristics that they impart to dairy products (Tamime and Marshall 1997; Park *et al.* 2007). Milk lipids has an influence on the flavour, consistency and texture of dairy products (Božanić *et al.* 2002b). Milk lipids is a complex mixture of different lipid substances with more than 200 different fatty acids (FA), but only 15 of the FA in milk are present in amounts greater than 1% (Jandal 1996).

Cerbulis *et al.* (1982) showed that the lipid fraction of whole caprine milk contains 97–99% free lipids and 1–3% bound lipids (bound lipids include neutral lipids, glycolipids and phospholipids, similar to bovine milk). As in bovine milk, the triacylglycerols (TAG) in caprine milk constitute the biggest component of the milk lipids (approximately 98%) (Park 2006).

One of the basic nutritional advantages of caprine milk lipids vs bovine milk lipids is the structure, size and arrangement of the fat globules in caprine milk. Lipids are present in milk in the form of globules, which in caprine milk have a significantly smaller diameter than those of bovine milk (Table 4). Apart from their smaller diameter, the fat globules in caprine milk are better distributed in the milk lipids emulsion in comparison with the fat globules in bovine milk (Mehaia 1995; Attaie and Richter 2000). According to Park *et al.*

Table 4 Fat globule size distribution in caprine and bovine milk (data compiled from Mehaia 1995)

Parameter	*Caprine milk*	*Bovine milk*
Determined fat content (%)	3.10	3.40
No. of globules/mL milk	1.9×10^9	1.5×10^9
Average diameter (μm)	3.10	3.60

(2007), the fat globules in caprine milk are characteristically abundant in diameter less than 3.5 µm, with 65% than 3.0 µm. The smaller diameter of the fat globules, as well as better distribution in the lipids emulsion, has a significant influence on digestibility in the human organism (Park 1994b). For that reason, caprine milk is more digestible and undergoes more efficient lipid metabolism in the human intestinal tract compared with bovine milk. The smaller diameter, larger number and better distribution of fat globules in caprine milk could also have a technological impact. Parkash and Jenness (1968) stated that bovine milk creams up more rapidly than caprine milk. The fundamental physico-chemical reason for this is agglutination, which causes clustering of the fat globules in milk, but agglutinin is not present in caprine milk. Jenness (1980) used the term 'naturally homogenised milk' for caprine milk. Consequently, the separation rate of caprine milk lipids is considerably higher than that of bovine milk lipids.

Another significant difference between caprine and bovine milk lipids is in the composition of their FA. Caprine milk is much higher in butyric (C_4:0), caproic (C_6:0), caprylic (C_8:0), capric (C_{10}:0), lauric (C_{12}:0) and myristic (C_{12}:0) acid (Haenlein 2004). These lipid components have been called short and medium chain fatty acids (SCFA and MCFA). Caprine milk contains on average 38% of MCFA (C_6–C_{14}) in milk lipids, whereas bovine milk contains only on average 18% of MCFA (Mehaia 1995). In addition, caproic, caprylic and capric acids (FAs named according to the term 'caprine') constitute 20% of all FA in caprine milk. In contrast, the FA content of bovine milk includes only 6% of these three FA (Table 5). SCFA and MCFA, as well as medium chain triglycerides (MCT), have become established medical treatments for an array of clinical disorders, such as intestinal resection, malabsorption syndromes, chyluria, hyperlipoproteinaemia, infant malnutrition, premature infant feeding, cystic fibrosis, coronary by-pass, steatorrhoea and gallstones (cited in Haenlein 2004). All these medical treatments are the consequence of the unique metabolic ability of SCFA, MCFA and MCT to provide direct energy instead of being deposited in adipose tissue, as well as their ability to lower serum cholesterol and inhibit cholesterol deposition in blood vessels (Babayan 1981; Alferez *et al.* 2001; Božanić *et al.* 2002; Haenlein 2004). In addition to their nutritional and therapeutic significance, SCFA, MCFA and MCT have a technological impact because they influence the specific flavour and aroma of caprine milk products (Park *et al.* 2007).

Ceballos *et al.* (2009) by identical methodology analysed the composition of caprine and bovine milk produced under similar conditions. As in other studies which compared the composition of caprine and bovine milk lipids around the world, they found higher proportions of MCFA (C_6–C_{14}) in caprine milk lipids, but also higher proportions of n-3 and n-6 polyunsaturated fatty acids (PUFA) as well as conjugated linoleic acid (CLA). Furthermore, Haenlein (2004) and Park *et al.* (2007) reported that caprine milk lipids have a higher content of monounsaturated fatty acids (MUFA). Similarly as for MCT, Haenlein (1992) emphasised the beneficial properties of MUFA and PUFA for human health, especially for cardiovascular conditions. CLA also has been identified as a significant nutrient for humans. Data from animal models have been used to prove that the CLA has anticarcinogenic properties and an antiatherogenic effect (Parodi 2003; Lee *et al.* 2005).

In summary, because of the smaller diameter and better distribution of fat globules in the milk emulsion as well as the higher contents of SCFA, MCFA, MCT, PUFA and CLA, it has been concluded that caprine milk lipids has a higher

Table 5 Content (g/kg) of the main fatty acids in caprine and bovine milk (Božanić *et al.* 2002)

	Caprine milk		*Bovine milk*
Fatty acid[a]	*Range*	*Mean value*	*Mean value*
$C_{4:0}$	14.9–42.3	29.9	33.0
$C_{6:0}$	42.8–88.2	65.2	16.0
$C_{8:0}$	17.0–41.2	25.2	13.0
$C_{10:0}$	85.9–126.4	104.1	30.0
$C_{10:1}$	1.9–3.8	2.4	n/a
$C_{12:0}$	38.0–73.2	56.4	31.0
$C_{12:1}$[b]	1.0–4.0	1.9	n/a
$C_{14:0}$	107.0–152.6	128.1	95.0
Iso-$C_{15:0}$[a]	01.2–01.5	1.3	n/a
Anteiso $C_{15:0}$[a]	01.7–2.4	2.1	n/a
$C_{14:1}$[a]	1.7–2.0	1.8	n/a
$C_{16:0}$	273.5–406.6	348.0	288.0
Iso-$C_{16:0}$[a]	1.7–4.0	2.4	n/a
Iso-$C_{17:0}$[a]	2.4–5.2	3.5	n/a
Anteiso $C_{17:0}$[a]	3.0–5.0	4.2	n/a
$C_{16:1}$[a]	10.0–27.0	15.9	n/a
$C_{17:0}$[a]	5.2–9.0	7.2	n/a
$C_{17:1}$[a]	2.4–4.8	3.9	n/a
$C_{18:0}$	47.3–99.3	68.4	146.0
$C_{18:1}$	103.4–170.8	132.6	298.0
$C_{18:2}$	25.4–48.1	36.0	25.0
$C_{18:3}$	2.0–17.2	8.8	7.7[c]
$C_{20:0}$[a]	0.8–3.5	1.5	n/a
$C_{18:2}$[d]	3.2–11.7	7.0	6.0[b]

n/a, No data.
[a]g/kg of total fatty acid methyl esters.
[b]CLA total.
[c]Data compiled from Park *et al.* (2007).
[d]Data compiled from Ceballos *et al.* (2009).

nutritional and potential therapeutic value than bovine milk.

Proteins

Milk proteins play the most significant role in the production of many dairy products. In addition, some milk proteins have been extensively used in other branches of the food industry (Kinsella *et al.* 1989). On the contrary, the nutritional impact of milk proteins on human health and conditions is well known (Mulvihill and Fox 1989; Tratnik 1998).

The principal proteins in caprine milk are about the same as in bovine milk (Park *et al.* 2007). Milk proteins occur in two distinct phases: the unstable micellar phase composed of caseins (as suspended micelles) and the soluble phase composed of whey proteins (Kinsella *et al.* 1989; Mulvihill and Fox 1989; Tratnik 1998).

Casein is the basic protein in milk (constituting about 80% of total milk proteins). The caseins (CN) in caprine milk are about the same as in the milk of cows or sheep: α_{s1}-CN, α_{s2}-CN, β-CN and κ-caseins. A comparison of the structural features of the casein fraction between bovine and caprine milk is presented in Table 6, and the percentages of the main casein fractions in caprine and bovine milk are presented in Table 7. Caprine milk shows a specific variability in the nature and contents of the protein fraction. In general, caprine milk contains higher amounts of the β-CN fractions, lower amounts of the α_s-CN fractions and approximately equal amounts of the κ-CN fractions (Table 7). In contrast to bovine milk, β-CN is the major protein of caprine milk. It has very important impact on the structural but also on the nutritive differences between caprine and bovine milk (Haenlein 2004). However, the essential singularity of caprine milk, which has been extensively studied by many authors in the past, is the polymorphism of α_{s1}-CN (Grosclaude 1995; Pierre *et al.* 1998; Clark and Sherbon 2000; Recio and Visser 2000). Moioli *et al.* (1988) mentioned 10 different genetic variations of α_{s1}-CN in caprine milk (A, B1, B2, B3, C, D, E, F, G, 0), but since 1988 some authors have mentioned novel types of α_{s1}-CN that have been identified. All of the previously mentioned types (genetic variants) have been connected to the amount of α_{s1}-CN in caprine milk. The '0' type indicates its absence in some caprine milk (Remeuf 1993). Two types of α_{s1}-CN (F and G) are associated with low levels of α_{s1}-CN in caprine milk (0.45 g/L), two (E and I) with medium levels of α_{s1}-CN in caprine milk (1.1–1.7 g/L) and eight of the currently identified types (A, B1, B2, B3, B4, C, H and L) with high levels of α_{s1}-CN in caprine milk (3.5 g/L) (Remeuf 1993; Chianese *et al.* 1997; Grosclaude and Martin 1997). From the physico-chemical as well as the technological point of view, the level of α_{s1}-CN in caprine milk influences its coagulation properties. Higher levels of α_{s1}-CN are responsible for longer coagulation times of caprine milk. Accordingly, a 'high α_{s1}-CN type' of caprine milk has the longest coagulation time. In spite of that, caprine milk with a high level of α_{s1}-CN is the best choice for cheesemaking because it has a better yield and greater firmness of the cheese curd. In addition, Chilliard *et al.* (2006) mentioned that caprine α_{s1}-casein influences the milk FA composition, which also influences the quality of the cheese or fermented milk. From the point of view of nutrition, caprine milk with low levels of α_{s1}-CN is more digestible than caprine milk with high levels of α_{s1}-CN (Haenlein 2004).

Except with the α_{s1}-CN type of milk, the curd firmness of caprine milk products is positively correlated with the contents of β-CN and calcium but negatively correlated with the average micellar size (Božanić *et al.* 2002b). Furthermore, the coagulation velocity of caprine milk is positively correlated with the α_{s1}-CN/β-CN ratio and the total calcium content (Alichandis and Polychroniadou 1997).

Many studies of the nutritional properties of the caprine milk protein system have been published. In general, it has been emphasised that the proteins of caprine milk are more digestible than the proteins of bovine milk (Park 1994b; Park *et al.* 2007). In addition, better absorption of the amino acids from caprine milk in comparison with those

Table 6 Composition of the structural features of the caseins in bovine and caprine milk (Martin *et al.* 2003)

	Caprine milk			Bovine milk		
Caseins	*Amino acids*[a]	*Amino acids*[b]	*P-sites*[c]	*Amino acids*[a]	*Amino acids*[b]	*P-sites*[c]
α_{s1}-CN	199	15	11/11	199	15	9/9
α_{s2}-CN	208	15	16/N.D.	207	15	17/N.D.
β-CN	207	15	6/6	209	15	6/5
κ-CN	171	21	6/3	169	21	5/3

[a]Number of amino acid residues in the mature chain of the protein.
[b]Number of amino acid residues in the signal peptide.
[c]Number of phosphorylation sites (putative/actual).
N.D, no data.

Table 7 Percentages of the main casein fractions in caprine and bovine milk (data compiled from Božanić *et al.* 2002)

Caseine fraction	*Caprine milk*	*Bovine milk*
α_s-CN	26	56
β-CN	64	33
κ-CN	10	11
α_s-CN/ β-CN	0.41	1.70

of bovine milk in the human digestive tract has been also reported (Haenlein 2004). The casein micelles in caprine milk differ markedly from those in bovine milk in exhibiting a less complete sedimentation rate, greater β-CN solubilisation, more calcium and phosphorus, less solvation and lower heat stability (Jenness 1980). Curd of caprine milk is weaker than curd of bovine milk, which has a direct influence on digestibility in the gastrointestinal tract. Experiments performed by Haenlein (1992) showed that the addition of a strong acid to caprine milk causes the formation of smaller and less dense clusters compared with those in bovine milk. Furthermore, caprine milk has a higher amount of biologically valuable whey proteins than bovine milk, β-lactoglobulin and α-lactoalbumin (Park 1994b). Data presented in Table 8 show the results of comparative analyses of the amino acids in caprine and bovine milk. In spite of the ever present variability of the data, the results of comparative studies in the past showed higher amounts of some essential amino acids in caprine milk than in bovine milk. Data published in official USDA tables show higher levels of 6 of the 10 essential amino acids in caprine milk than in bovine milk: threonine, lysine, isoleucine, cystine, tyrosine and valine (Posati and Orr 1976; cited by Haenlein 2004). In studies with experimental animals (rats), Barrionuevo *et al.* (2002) found that a higher content of cysteine, which has been ordinarily derived from cystine, improves the intestinal absorption of copper and iron in experimental animals. The data of Urbiene *et al.* (1997), presented in Table 8, also show that caprine milk contains higher levels of free amino acids than bovine milk. Taurine is the most representative free amino acid in caprine milk (Tripaldi *et al.* 1998). Among the free amino acids, the taurine content is significantly higher in caprine milk and more similar to that of human milk (Mehaia and Al-Kanhal 1992). Taurine is widely distributed in the fluids and tissues of the human organism, and is considered to be a 'conditionally essential amino acid' in human beings (Huxtable 1993). Taurine is involved in many important roles in the human organism, such as formation of the infant brain, formation of bile salts, calcium flux, neuron excitability and the stabilisation of membranes (Huxtable 1993). Furthermore, cardiomyopathy, epilepsy, lack of growth and some other disturbances have been induced by taurine deficiency in human tissues (Tripaldi *et al.* 1998).

Table 8 Analysis of the amino acids in caprine and bovine milk (Urbiene *et al.* 1997)

Amino acids	*Caprine milk*	*Bovine milk*
a) Total amino acids (mg %)	2989	3199
b) Total free amino acids (mg %)	2.51	2.38
c) Total free essential amino acids (mg %)	1210	1280
b/a[a]	0.084	0.074
c/a[b]	40.48	40.01

[a]Essential amino acids/total amino acids.

[b]Free essential amino acids/total amino acids.

In addition to these bioactive protein compounds, many researchers have isolated other bioactive peptides from caprine milk, especially in the past decade. Among them, antimicrobial peptides derived from caprine whey and caseins definitely could have certain biological impacts in humans, but further investigations are necessary to clearly define their biological functions (Park *et al.* 2007). This is especially relevant to nonprotein nitrogen (NPN) compounds. The NPN contents of caprine milk, similar to human milk, are higher than in bovine milk. According to some authors (Feldhofer *et al.* 1994), this is one of the reasons why caprine milk has been identified as 'a healthy' milk.

Other constituents

As in bovine milk, lactose is the major carbohydrate in caprine milk. Lactose is a valuable nutrient because it favours the absorption of calcium, magnesium and phosphorus, and the utilisation of vitamin D (Campbell and Marshall 1975). According to the results of published studies, the content of lactose in caprine milk is slightly, but not significantly, lower than in bovine milk (Table 1). Caprine milk is significantly rich in lactose-derived oligosaccharides compared with bovine milk. Milk oligosaccharides are thought to be beneficial for human nutrition because of their prebiotic and anti-infective properties (Kunz *et al.* 2000).

The macrobiotic and trace mineral contents of caprine milk are affected by diet, breed, individual animal and stages of lactation (Park *et al.* 2007). The mineral contents of caprine and ovine milk are much higher than those of human milk (Park *et al.* 2007). In comparison with bovine milk, caprine milk has more Ca, P, K, Mg and Cl, and less Na and S (Table 9). Because of the higher content of K and Na, caprine milk has a specific slightly salty taste (Božanić *et al.* 2002b). Calcium plays an

Table 9 Mineral and vitamin contents (g/kg) of caprine and bovine milk (data compiled from Park *et al.* 2007)

Constituents	*Caprine milk*	*Bovine milk*
Mineral		
Ca	1.34	1.22
P	1.21	1.19
Mg	0.16	0.12
K	1.81	1.52
Na	0.41	0.58
Cl	1.50	1.00
S	0.28	0.32
Fe	0.0007	0.0008
Cu	0.0005	0.0006
Mn	0.00032	0.0002
Zn	0.0056	0.0053
I	0.00022	0.00021
Se	0.0000133	0.0000096
Al	n/a	n/a
Vitamin		
Vitamin A (IU)	185	126
Vitamin D (IU)	2.3	2.0
Thiamine	0.00068	0.00045
Riboflavin	0.0021	0.0016
Niacin	0.0027	0.0008
Panthotenic acid	0.0031	0.0032
Vitamin B6	0.00046	0.00042
Folic acid	0.00001	0.00005
Biotin	0.000015	0.000020
Vitamin B12	0.00000065	0.00000357
Vitamin C	0.0129	0.0094

important role in the construction and protection of bones in humans, but it has many other biological functions connected to human vitality and well-being (Park 1994b; Tratnik 1998). The average absorption of calcium from food in the human small intestine is about 20% (Božanić *et al.* 2002b). Milk and dairy products are the best foodstuffs for providing a source of calcium in the human diet. The phosphorus in milk occurs in other types of compounds: inorganic salts (about 33%), organic esters (about 20%) and colloidal inorganic phosphate (39%) (Tratnik 1998). Together with calcium, phosphorus plays many positive roles in the human organism. In addition to the total amounts of calcium and phosphorus, the Ca/P ratio has important nutritional significance (Hill 1998). For humans, the ideal P_2O_5/CaO ratio is assumed to be the same as in human milk (1.4). The P_2O_5/CaO ratio in caprine milk is nearer to that of human milk than bovine milk (Slačanac 2004).

Caprine and bovine milk, similar to human milk, contain many trace minerals, but only a few of them play important biological roles in the human organism. Fe and Cu have been most thoroughly investigated because of their role in lipid oxidation (Božanić *et al.* 2002b). The levels of Fe in caprine and bovine milk are significantly lower than in human milk (Table 9). In contrast, caprine and bovine milk contain a significantly higher content of iodine than human milk, which would be important for human nutrition since iodine and thyroid hormones are involved in determining the metabolic rate of physiological body functions (Underwood 1977). Caprine and human milk contain higher levels of Se than bovine milk. Furthermore, the glutathione peroxidase content is higher in caprine than in bovine and human milk (Debski *et al.* 1987). Glutathione peroxidase is an important ingredient of milk because it forms part of a defence system against undesirable micro-organisms. Caprine milk contains 40% less citrate than bovine milk (Morgan *et al.* 2000).

Overall, caprine milk is an excellent source of biodigestible calcium, phosphorus and magnesium because it contains higher amounts of these minerals in soluble form (Gueguen 1997). Results presented by Remeuf (1993) show that in European goat breeds soluble Ca ranged from 30 to 38%. The levels of soluble Mg and P in caprine milk were 66 and 39%, respectively.

Milk contains almost all the known vitamins. Caprine milk has a higher content of vitamin A than bovine milk because goats convert all β-carotene from foods into vitamin A in the milk. For that reason, caprine milk is always whiter than bovine milk. Caprine milk supplies adequate amounts of vitamin A and excess amounts of thiamin, riboflavin and pantothenate for the human infant (Park *et al.* 2007). Compared with bovine milk, caprine milk has a fivefold lower level of folic acid and vitamin B_{12}, which causes 'caprine milk anaemia' (Davidson and Townley 1977). Caprine milk and bovine milk are both deficient in vitamins B_6, C and D, which are very important in infant nutrition (Park *et al.* 2007).

THERAPEUTIC EFFECTS OF CAPRINE MILK

The most significant therapeutic role of caprine milk compared to bovine milk is its hypoallergenic value (Park 1994b). 50% of the human population (according to some authors 40–100%) who were allergic to bovine milk tolerated caprine milk (Park 1994b). Results presented by Saini and Gill (1991) show that only one of 100 children who were allergic to bovine milk were also allergic to caprine milk. The reason for the hypoallergenic value of caprine milk in comparison to bovine milk is the difference between their protein structures (Imafidon *et al.* 1991). Results of *in vitro* studies, obtained by Almaas *et al.* (2006), showed that caprine milk proteins were digested by human gastric and duodenal enzymes faster than bovine milk proteins.

The higher content of SCFA, MCFA and MCT, as well as the smaller diameter of the fat globules in caprine milk compared with those in bovine milk, also has important therapeutic significance. SCFA and MCFA have been used in the treatment of many physiological disorders in humans such as malabsorption, cystic fibrosis, coronary disorders, intestinal disorders and regulation of cholesterol levels (Jandal 1996). The naturally homogenised fat in caprine milk, unlike the processed fat in bovine milk, could be the great advantage of caprine milk consumption in the prevention of atherosclerosis (Haenlein 1992). Kullisaar *et al.* (2003) showed that the consumption of caprine milk fermented with probiotic strain *L. fermentum* ME-3 improved antiatherogenicity in 21 healthy subjects: it prolonged resistance of the lipoprotein fraction to oxidation, lowered levels of peroxidised lipoproteins, oxidised LDL and enhanced total antioxidative activity. Songiseep *et al.* (2005) reported that the reduction of oxidative stress when using fermented caprine milk formula provided a defence against enteric infection. In a study conducted on rats with malabsorption syndrome, the digestive utilisation of the fat was greater in the rats receiving a diet of caprine milk than in those given a cow milk-based diet. At the same time, the consumption of caprine milk reduced the levels of cholesterol (Alferez *et al.* 2001). Moreover, Alferez *et al.* (2006) reported that dietary caprine milk improves iron bioavailability in rats with induced ferropenic anaemia in comparison with bovine milk, and influenced an increase in Fe deposits in target organs. In addition to iron bioavailability, the beneficial effects of caprine milk on the nutritive utilisation of protein, magnesium, calcium, phosphorus, zinc and selenium were demonstrated in rats with resection of the distal small intestine (Alferez *et al.* 2003; Lopez-Aliaga *et al.* 2003). Better digestibility of caprine milk proteins, as well as the softer curd of fermented caprine milk products compared with those of bovine milk, also has therapeutic advantages. For that reason caprine milk could be used as an alternative food in the diet of patients with ulcers and ulcerative colitis (Park 1994b). It was cited above that caprine milk contains more Se and glutathione peroxidase than bovine milk. Se influences glutathione peroxidase activity. Gluathione peroxidase binds radicals in the human organism and influences cancer prevention (Desjeux 1993). In addition to these scientifically confirmed positive therapeutic effects of caprine milk, many anecdotal and medical benefits of caprine milk have been reported in the popular press. Positive effects in patients with pulmonary disorders are one of these benefits (Haenlein 2004). The nutritive value of some types of food can be presented by correlation of the food composition and human dietary allowances. The nutrient intake in one cup of caprine or bovine milk compared with the recommended human daily dietary allowances (RDA) is presented in Table 10.

Table 10 Nutrient intake in one cup of milk (245 g) compared with RDA (recommended human daily dietary allowance) (Haenlein 1996)

Nutritients	*Caprine milk*	*Bovine milk*	*RDA*
Tryptophan (g)	0.106	0.113	0.5
Threonine (g)	0.398	0.362	1.0
Isoleucine (g)	0.505	0.486	1.4
Leucine (g)	0.765	0.786	2.2
Lysine (g)	0.708	0.637	1.6
Methionine (g)	0.196	0.201	2.2
Cystine (g)	0.113	0.074	–
Phenylalanine (g)	0.377	0.388	2.2
Tyrosine (g)	0.437	0.388	–
Valine (g)	0.585	0.537	1.6
Ca (mg)	326	291	800
Mg (mg)	34	33	200
P (mg)	270	228	800
K (mg)	499	370	–
Thiamine (mg)	0.117	0.093	0.8
Riboflavin (mg)	0.337	0.395	0.9
Niacin (mg)	0.676	0.205	14
C18:2 (g)	0.26	0.18	–
C18:3 (g)	0.10	0.12	–

DEVELOPMENT OF FERMENTED CAPRINE MILK WITH PROBIOTICS

Sensory and physico-chemical characteristics of fermented caprine milk

During fermentation caprine milk loses its characteristic ‘goaty’ taste, which has been unacceptable for many consumers (Haenlein 2004). Many studies on fermented caprine milk products have been published in the past decade, but on the global European market fermented caprine milk products (especially products with probiotics) still account for a minor proportion. Caprine yoghurt is very popular in the United States as a specialty product and as a substitute for bovine milk products for those who have allergies to bovine milk (Haenlein 1996). In the European Union, caprine milk products are considered to be the dairy product with the greatest marketing potential and, therefore, several characteristics of caprine milk are currently the focus of increased research interest (Casalta *et al.* 2005). Today, caprine yoghurt is traditionally produced in the Mediterranean peninsula, the Middle East, southern Russia and the Indian subcontinent (Malek *et al.* 2001; Karademir *et al.* 2002; Stelios and Emanuel 2004; Tamime and Robinson 2007). Most of the fermented caprine milk products other than yoghurt have a strong traditional character, such as Chhana (Pandya and

Ghodke 2007), Labneh (Nsabimana *et al.* 2005) or Rob (Abdelgadir *et al.* 1998).

Unfortunately, there are many technological difficulties associated with producing fermented caprine milk with good sensory properties. Many of them are connected with the specific composition and structure of caprine milk. The consistency of fermented caprine milk products has been determined to be one of the critical problems (Farnsworth *et al.* 2006). Caprine milk has a slightly lower casein content than bovine milk, with a very low proportion or absence of α_{s1}-casein, and a higher degree of casein micelle dispersion (Vegarud *et al.* 1999). Seasonal changes in the composition of caprine milk also influence the consistency of fermented caprine milk products (Guo 2003). All these factors influence the rheological properties of the curd in fermented caprine milk, which is much weaker than that of bovine milk (Novaković *et al.* 1997, 1998). Another problem is over-acidification of fermented caprine milk products in comparison with those of bovine milk (Rysstad and Abrahamsen 1983). In constant scientific trials to improve the sensory quality of fermented caprine milk products, many experiments were performed (Martin-Diana *et al.* 2003). In many of them, the nonfat solids content of caprine milk was enhanced with different procedures. Procedures such as concentration of the milk by membrane processes, the addition of stabilisers such as pectins or inulin, and employment of exopolysacharide-producing lactic acid bacteria have been used to improve the textural characteristics of fermented caprine milk, as in low fat fermented milk (Hess *et al.* 1997; Duboc and Mollet 2001). The addition of skim milk powder (SMP) and whey protein concentrate (WPC) was also used to increase the total solids in caprine milk before fermentation (Herrero and Requena 2006; Tratnik *et al.* 2006). Apart from these ordinary procedures for increasing nonfat solids in milk, some alternative methods were used on a trial basis to improve the consistency of fermented caprine milk products. Farnsworth *et al.* (2006) reported that the microstructure of caprine milk yoghurt can be improved by treatment of the milk with transglutaminase (TGase), or microbial transglutaminase (MTGase) (Farnsworth *et al.* 2006). Results presented by Mehaia and El-Khadragy (1998) showed that the concentrations of fat and protein in caprine milk increased proportionally with the volume concentration ratios during ultrafiltration treatment. All these experiments resulted in better textural properties of fermented caprine milk products, but most of their results are not incorporated in the global dairy industry yet. As opposed to gel firmness, some positive properties of the curd of fermented caprine milk products were determined. Vargas *et al.* (2008) showed that, in yoghurt produced from mixtures of caprine and bovine milk, the addition of caprine milk significantly decreased syneresis of the curd. Novaković *et al.* (1998) emphasised the better stability of caprine acidophilus milk curd during storage in a refrigerator than that of bovine acidophilus milk. In addition to the sensory characteristics, in some studies, the nutritional value of fermented caprine milk needed to be improved. As was mentioned in the text above, one of the basic nutritive limitations of caprine milk is a lack of folic acid. Apart from direct addition of folic acid to caprine milk products (Jenness 1980), some other treatments of caprine milk have been suggested. The addition of folate-producing bacteria during fermentation may be one of them (Sanna *et al.* 2005).

From the nutritional as well as from the therapeutic point of view, the development of fermented caprine milk containing probiotic bacteria has been recommended as a great possibility for the production of therapeutic fermented dairy food (Martin-Diana *et al.* 2003). As in bovine fermented milk, in many recent studies researchers want to enhance the functionality of fermented caprine milk products by promoting the growth of probiotic bacteria in caprine milk (Martin-Diana *et al.* 2003; Farnsworth *et al.* 2006; Kongo *et al.* 2006; Tratnik *et al.* 2006; Kehagias *et al.* 2008). In general, the high nutritional and therapeutic potential of fermented caprine milk with probiotics has been emphasised.

Fermentation of caprine milk with different starters

In spite of the absence of fermented caprine milk products on the national market, in the last 15 years many scientific studies of fermented caprine milk have been performed in Croatia. The results presented by Božanić and Tratnik (2001) showed that commercial yoghurt starter grew better, as well as producing faster fermentation of caprine milk than bovine milk. In subsequent experiments with yoghurt DVS starters (YC350 and YC180), caprine milk and bovine milk were aromatised with fruity aromas as well as enriched with sucrose, SMP and WPC (Božanić *et al.* 2003a, 2004). Aromatisation as well as the addition of SMP improved the sensory characteristics of caprine yoghurt, while the addition of WPC had a negative effect on caprine yoghurt quality, especially on its textural properties. Contrary to caprine milk, the addition of WPC to bovine milk improved the fermentation rate as well as the sensory quality of the fermented products from bovine milk. Based on experimental results, the optimal amounts of SMP and WPC to be added were determined: 1% of WPC and SMP for bovine milk and 2% of SMP for caprine milk (Božanić *et al.* 2001b). The positive effect of SMP addition on the texture of caprine fermented milk was also proved by the results of Hardi *et al.* (2000). Additives stimulated lactobacilli growth during fermentation in both types of milk (Božanić *et al.* 1998) and improved the sensory properties of the fermented products. Božanić and Tratnik (2001) analysed the quality of caprine and bovine bifido milk during storage at refrigerator temperature. On the basis of instrumental and sensory examinations, the authors reported a higher overall quality of caprine bifido milk in comparison with bovine bifido milk, during all storage periods. The results of Božanić *et al.* (2002a) showed that probiotic ABT-4 culture fermented bovine milk faster than caprine milk when both types of milk were enriched with 1.5% of inulin. Opposite to these results, in studies with *L. acidophilus* La-5, the addition of inulin improved the curd firmness of fermented caprine and bovine milk, but had no influence on the fermentation activity and viability of *L. acidophilus* La-5 during storage at refrigerator temperature (Božanić *et al.* 2001a). Contrary to fermentation with ABT-4 culture, Božanić *et al.* (2004) found faster growth of *L. acidophilus* La-5 in caprine milk than in bovine milk. Similar results have been reported by Slačanac (2004) and Slačanac *et al.* (2005a). Their results showed higher fermentation activity of ABT-2 culture in caprine milk than in bovine milk, as well as higher numbers of probiotic lactobacilli and bifidobacteria in caprine milk in all fermentation phases (Figure 1). In a report by Slačanac *et al.* (2005a), alteration of the FAs content during fermentation of caprine and bovine milk with ABT-2 culture was presented. In another study, the production of antibacterial organic acids during the fermentation of caprine and bovine milk with *Bifidobacterium longum* Bb-46 was also reported by Slačanac *et al.* (2005b) (Table 11). The results of the both these studies show that higher contents of SCFA and MCFA developed during fermentation of caprine milk (Table 11). In addition, higher contents of lactic and acetic acids developed during fermentation with *Bifidobacterium longum* Bb-46 of caprine milk compared with bovine milk. This is interesting data because the positive physiological function of SCFA and MCFA has been well known and investigated (Park 1994b; Mehaia 1995). Božanić and Tratnik (2001) fermented caprine and bovine milk with *Bifidobacterium animalis* ssp. *lactis* Bb-12. Caprine milk did not coagulate at the isoelectric point of casein (pH = 4.6) but at significantly lower acidity, at pH values of 5.0–5.5. Further fermentation of caprine milk caused an increase in syneresis, as well as a degeneration in overall sensory properties. Božanić *et al.* (2003b), as well as Tratnik *et al.* (2006), reported significantly poorer sensory characteristics of caprine kefir in comparison with those of bovine kefir.

Inhibitory effect of fermented caprine milk

A wide range of investigations in our laboratory has focused on the inhibitory effect of fermented caprine and bovine milk on some intestinal and urogenital pathogens. All these studies are based on the results of some previous work over the past two decades regarding the antagonistic action of probiotics against many pathogens (Mitsuoka 1990; Salminen *et al.* 1998; Niku-Paavola *et al.* 1999; Reid *et al.* 2001). The inhibitory effect of a mixed ABT culture (containing bacteria *L. acidophilus* La-5*, Bifidobacterium animalis* subsp. *lactis* Bb-12 and *Streptococcus thermophilus*)

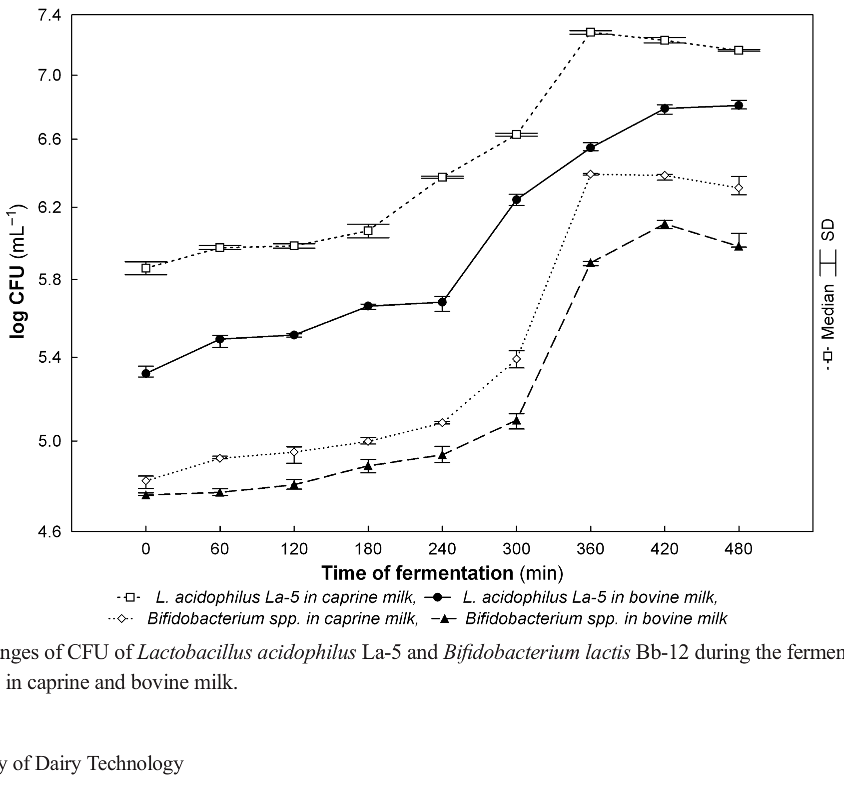

Figure 1 Changes of CFU of *Lactobacillus acidophilus* La-5 and *Bifidobacterium lactis* Bb-12 during the fermentation of ABT-2 culture in caprine and bovine milk.

Table 11 Changes of short chain (SCFA) and medium chain (MCFA) fatty acids contents (mol/100 mol of total fatty acids) during fermentation of caprine and bovine milk with *Bifidobacterium longum* Bb-46 (Slačanac *et al.* 2005)

		Fermentation time/hours		
Milk	*Fatty acid*	*0*	*12*	*24*
Caprine	Butyric	3.44[a] ± 0.18b[b]	3.46 ± 0.06b	3.86 ± 0.35c
Bovine		2.90 ± 0.04a	3.27 ± 0.12b	3.78 ± 0.14c
Caprine	Caproic	2.32 ± 0.03b	2.39 ± 0.2b	3.27 ± 0.22c
Bovine		1.09 ± 0.1a	1.15 ± 0.0a	1.05 ± 0.06a
Caprine	Caprylic	3.47 ± 0.05b	3.76 ± 0.29b	6.95 ± 0.22c
Bovine		0.67 ± 0.16a	0.85 ± 0.08a	0.75 ± 0.14a
Caprine	Capric	9.03 ± 0.38b	9.65 ± 0.04c	11.21 ± 0.31d
Bovine		2.31 ± 0.02a	2.36 ± 0.14a	2.32 ± 0.07a
Caprine	Lauric	6.77 ± 0.15b	7.01 ± 0.07b	8.31 ± 0.38c
Bovine		2.46 ± 0.25a	2.54 ± 0.25a	2.42 ± 0.07a
Caprine	Myristic	12.57 ± 0.04d	12.18 ± 0.28cd	21.20 ± 0.35e
Bovine		10.15 ± 0.27a	11.76 ± 0.35bc	11.33 ± 0.16b

[a]Mean ± standard deviation, $n = 5$.

[b]Mean values followed by the same letter in the same column and in the same row are not significantly different ($P < 0.05$) – for all fatty acids separately.

against *E. coli*, isolated directly from the cervixes of 50 women with acute bacterial vaginosis or urinary tract infection, was analysed by *in vitro* experiments (Slačanac *et al.* 2004a). There were no significant differences in inhibitory effect between fermented caprine and bovine milk. However, the results of all of the *in vitro* trials showed that semi-fermented ABT-2 culture of caprine and bovine milk (pH = 5.3–5.6) more strongly inhibited the growth of the uropathogenic *E. coli* strain than fully fermented samples (pH = 4.6–4.8). In another two studies with uropathogenic microorganisms, the antagonistic activity of caprine and bovine milk fermented with *B. longum* Bb-46 (Slačanac *et al.* 2004b), as well as with ABT-2 culture (Slačanac 2004), against *Candida albicans* was determined by *in vitro* trials (Hardi *et al.* 2006). As in the case of *E. coli*, *C. albicans* were isolated directly from the cervixes of women with diagnosed yeast vaginitis. The results obtained have shown a considerably higher inhibitory effect of caprine milk fermented with *B. longum* Bb-46 on the growth of *C. albicans* compared with that of fermented bovine milk. Similarly, ABT-2 culture of caprine milk inhibited the growth of *C. albicans* to a significantly greater extent than that of bovine milk. In all of these studies, there was no significant correlation between changes of pH or CFU of the analysed probiotic strain during fermentation and the inhibitory effect of fermented caprine and bovine milk. Pavlović *et al.* (2006) analysed the antagonistic action of caprine and bovine milk fermented with *B. longum* Bb-46 on the pathogenic organisms *Serratia marscenses* and *Campylobacter jejuni*. Their results showed that the inhibitory effect of *B. longum* Bb-46 fermented caprine milk increased with the fermentation time. In contrast, the largest inhibitory effect of fermented bovine milk was obtained from samples taken in the middle of the fermentation period. All samples of fermented caprine and bovine milk exhibited an inhibitory effect on the growth of *C. jejuni*. From all the *in vitro* experiments done in our laboratory, the greatest differences between fermented caprine and bovine milk were noted for the case of *Salmonella enteritidis* D growth (Slačanac *et al.* 2007a). In a number of *in vitro* experiments, *S. enteritidis* D bacteria, which were isolated directly from the faeces of an infant diagnosed with salmonellosis, were inhibited by caprine and bovine milk fermented with *B. longum* Bb-46. The results obtained showed a considerably larger inhibitory effect of fermented caprine milk on the growth of *S. enteritidis* D compared with that of fermented bovine milk. Finally, inhibition of the growth of *Staphylococcus aureus* by caprine and bovine milk fermented with *B. longum* Bb-46 was examined (Slačanac *et al.* 2007b). The results showed a significantly larger inhibitory effect of fermented caprine milk on the growth of *S. aureus,* compared with that of fermented bovine milk. Fermented caprine milk inhibited the growth of *S. aureus* during the whole fermentation period. In contrast to fermented caprine milk, the weaker inhibitory effect of fermented bovine milk was observed only during the first phase of fermentation (incompletely fermented samples at higher pH values and lower numbers of viable cells of *B. longum* Bb-46).

All these results demonstrate the diversity in microbiological interaction. In many cases, neither the acidity of the fermented milk nor the number of probiotic viable cells was a critical factor in determining the degree of inhibition.

Current investigations in our laboratories are focused on ways to ferment caprine sweet whey using different lactic acid starters, as well as reconstituting with different additives, in order to produce fermented products with good sensory properties and high nutritional value. The most recent experiments in our laboratories include the addition of honey, as a strong antimicrobial substance, to fermented caprine and bovine milk.

CONCLUSION

The unique characteristics of caprine milk have been investigated and reported in many studies during the last two decades. Caprine milk products other than cheese and heat treated milk are considered to be the dairy products with the greatest marketing potential and, therefore, several characteristics of caprine milk are currently the focus of increased research interest. Fermented caprine milks incorporating live probiotic cells represent a group of products with great prospects in the future with regard to their functional and therapeutic properties. As in other Mediterranean countries, the rise in the number of goat farms in Croatia has pointed to the requirement for production of some other products from caprine milk. The results of scientific studies conducted on fermented caprine milk have been a great support to the production sector, but further investigations are necessary.

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