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Original Article

Composition of goat and cow milk produced under similar conditions and analyzed by identical methodology

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ABSTRACT

The aim of this study was to identify, under the best possible conditions, the interspecific differences between the proteins, fat and minerals in goat and cow milk. The protein fractions presented evident differences, especially concerning the amount of α_{S1}-casein, which was lower in the goat milk (62.8%; $P < 0.05$). The amino acid profile of the two proteins revealed certain differences, although the total quantity of essential amino acids did not vary ($P > 0.05$). The composition of fats was well-differentiated, mainly as concerns the content of medium-chain fatty acids (C6–14), which were higher in the goat milk (28.8%; $P < 0.05$). The same was true for *n*-6 polyunsaturated fatty acids (10.0%; $P < 0.05$) and *n*-3 polyunsaturated fatty acids (51.0%; $P < 0.05$), and also the total level of conjugated linoleic acid (33.8%; $P < 0.05$). The quantities of Ca, P, Mg and Cu were greater in the ash derived from goat milk (17.4, 15.6, 16.3 and 66.6%, respectively; $P < 0.05$). Due to the greater quantity of total solids present in goat milk (16.3%; $P < 0.05$), all of the above-mentioned differences would be considerably increased by the fact that they refer to the amounts present in a given volume. The differences detected between cow and goat milk mean that the latter constitutes a food of particular interest, in terms of both health and nutrition.
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1. Introduction

The milk of different ruminant species, either directly or as dairy products, comprises a food of outstanding importance for humans throughout their lives. Milk can be considered a source of macro- and micronutrients, and also contains a number of active compounds that play a significant role in both nutrition and health protection (Boza and Sanz Sampelayo, 1997). Today, goat milk is of particular interest due to its specific composition, which has led to it being considered a high-quality raw material for manufacturing food for infants and the elderly, as well as for certain sectors of the population with particular needs (Haenlein, 1992, 1996, 2004; Boza and Sanz Sampelayo, 1997; Park, 2006). The main characteristics of its composition have been compared with those of milk produced by other species, including humans (Haenlein, 1992; Davis et al., 1994; Boza and Sanz Sampelayo, 1997; Park, 2006).

Of particular interest are the differences between the compositions of goat and cow milk. The special characteristics concerning the composition of goat milk, in terms of its principal nutrients, mean that the nutritional utilization of the latter is markedly higher than is the case with cow milk. Thus, the protein of goat milk is more digestible (Park, 1994; Boza and Sanz Sampelayo, 1997; Haenlein, 2001, 2004; López-Aliaga et al. (2003), and at the same time it is more tolerable (i.e. less allergenic) (Bevilacqua et al., 2001; Lara-Villoslada et al., 2004; Sanz Ceballos, 2007). Similarly, the fat of goat milk is more digestible (Alférez et al., 2001; Haenlein, 2001), and it may be considered an excellent source of energy for use in various metabolic processes (Boza and Sanz Sampelayo, 1997; Sanz Ceballos, 2007) and even for combating metabolic diseases (Babayan, 1981; García Unciti, 1996; Velázquez et al., 1996). With respect to its mineral composition, in general the levels measured of the principal elements, and the nutritional use made of them, show it to be of higher quality than cow milk (Moreno, 1995; Boza and Sanz Sampelayo, 1997; Haenlein, 2001; Campos et al., 2003).

The information currently available on the composition of goat milk with respect to that of cow milk has been published in the form of reviews (Park, 1994, 2006; Haenlein, 1996, 2001, 2004; Boza and Sanz Sampelayo, 1997). The composition of the milk produced by a given species depends on the breed, lactation state,

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feeding and other environmental conditions; moreover, the values recorded may be affected by the methodology adopted. Taking these factors into account, and given the growing interest in comparing the composition of goat and cow milk, as the fundamental material for manufacturing diverse products, we believe it would be useful to compile information concerning the composition of the milk from the two species, obtained from the same geographic zone and from the breeds commonly found in the study area, under the same production system, taking into account the specific nutritional requirements of each species, and using an identical methodology for determining this composition.

Thus, in this paper we present the results obtained concerning the composition of milk from Granadina goats and from Holstein Friesian cows, stabled in the same area of south eastern Spain, the milk in question being produced during two consecutive lactations. We measured the protein composition (protein fractions, amino acid profile), and fat composition (fatty acid profile) and the mineral composition (Ca, P, Mg, Fe, Cu and Zn), in addition to the chemical composition (total solids, protein, fat, ash and lactose) in each type of milk.

2. Materials and methods

2.1. Experimental design and procedure

The milk samples analyzed in this study were obtained from two different farms, one with Granadina goats and the other with Holstein Friesian cows. Both farms are located in the same area of southeastern Spain, at latitude 37°11′ north and longitude 3°35′ west, at 774 m above sea level, with a continental Mediterranean climate, and a total of 474 mm average precipitation per year. The duration of the assay corresponded to that of two consecutive lactations; from the total pool of milk produced, fortnightly samples were taken, from the first month of lactation until one month before lactation concluded. Thus, a total of 15 samples were taken during each lactation.

From the start of lactation, both species were kept under intensive feeding conditions, i.e. they were indoor-fed ad libitum, with a concentrate and a forage. Water was available at all times. They were kept under identical environmental conditions except as concerns the nature and composition of the diet, which in each case was designed in accordance with the nutritional requirements and productive capacity of the species (ARC, 1980; Aguilera et al., 1990; NRC, 2007), and of their particular nutritional behaviour (Morand-Fehr et al., 1991; Boza, 2005). The health condition of the animals was supervised continuously, and any animal presenting any sign of disease was removed from the study. As concerns their feeding, the forage fraction of the diets was constituted of alfalfa hay (for the goats) and corn silage + alfalfa hay (for the cows).

2.2. Milk samples and chemical analysis

The samples of milk, without added preservatives, were stored at −30 °C until analysis (within 1 week). Analyses were carried out in triplicate.

The total solids content was determined by lyophilization. The N content was measured using the Kjeldahl method (AOAC, 2005). Protein N content was calculated as the difference between total N and non-protein N; total N was determined from whole milk samples, and non-protein N from a filtrate of whole milk after precipitation with 12% (w/v) trichloroacetic acid (Martín-Hernández et al., 1988). Casein N content was calculated as the difference between total N and non-casein N, the latter being determined from a filtrate of whole milk after precipitation with 10% (w/v) acetic acid at pH 4.1 for goat milk (Recio et al., 1997) and at pH 4.6 for cow milk (Van Hekken and Thompson, 1992). Finally, whey-protein N content was calculated as the difference between protein N and casein N. Protein, casein and whey-protein N values were converted to protein, casein and whey-protein by multiplying by a factor of 6.38. The fat content was measured by the Gerber method (Pearson, 1976). Milk lactose was calculated as the difference between the amount of total solids and protein + fat + total ash. The ash content was determined by incineration in an electric muffle furnace at 550 °C.

Milk protein contents of α_{S1}-casein and α_{S2}-casein were established by the NIRS methodology (Burns and Ciurczak, 1992, 2001). A continuous-spectrum monochromator spectrophotometer (Foss-NIRSystem 6500, Inc., Silver Spring, MD), fitted with a gyro mechanism, scanning from 400 to 2500 nm, was used to obtain the spectra of the milk samples. The spectra were compiled using the program ISI NIRS3 version 2.05 (Infrasoft International, Port Matilda, PA). Chemometric processing of the spectroscopic data was performed using the program Winisi II, version 1.04 Foss-NIRSystem/Tecator (Infrasoft International LLC, PA). The preparation of the milk samples for analysis consisted of prior heating to 40 °C, and the introduction of a fibreglass filter (Millipore AP 40) soaked in milk. Milk protein content of β- and κ-casein was calculated as the difference between the amount of total casein and α_{S1}-casein + α_{S2}-casein.

Milk protein amino acid composition was determined by high-performance liquid chromatography using the Waters® Pico-Tag method (Cohen et al., 1989) with the modifications proposed by Pérez Martínez (1995), which involves precolumn derivatization with phenylisothiocyanate. Protein hydrolysis was performed in 6N HCl using sealed and evacuated tubes at 100 °C for 24 h. Cysteine and methionine were determined as cysteic acid and methionine sulfone, respectively, which were obtained by oxidation with performic acid before 6 M HCl hydrolysis. Tryptophan was not determined.

The fatty acid profile was determined using lyophilized milk samples, which were subjected to a process of extraction and esterification with hexane and a methanol/acetic chloride (10:1, v/v) mixture, following the methodology proposed by Sukhija and Palmquist (1988). The internal standard used was nonadecanoic acid (C19:0). The sample was maintained in b.m. at 70 °C and shaken continuously for 1 h; 6% potassium carbonate and hexane were then added and the mixture was centrifuged at 3500 rpm for 10 min. The organic phase was transferred to a test tube, anhydrous sodium sulphate was added, and after being allowed to settle briefly, it was centrifuged at 3500 rpm for 10 min. Finally, the supernatant was transferred to a flask ready to be injected onto the chromatograph.

Fatty acid methyl esters were separated in an Autosystem Gas Chromatograph (Perkin-Elmer, Norfolk, CT) fitted with an SP-2560 fused silica capillary column (100 m × 0.25 mm (i.d.), 0.20 μm film; Supelco Bellefonte, PA) equipped with a flame ionization detector. The temperature was programmed from 150 to 185 °C at 5 °C/min held for 30 min and then to 230 at 5 °C/min held for 26 min. The carrier gas was N2. Injector and detector temperatures were 250 and 300 °C, respectively. Peaks for individual fatty acids were identified using pure methyl ester standards (Supelco, Bellefonte, PA). Standards for CLA isomers were obtained from Matreya Inc., PA. Peak areas for individual fatty acids were corrected for recovery using a butter-oil reference standard (CRM 164; Commission of the European Community Bureau of Reference, Brussels, Belgium).

The concentrations of Ca, Mg, Fe, Cu and Zn in the milk samples were determined by atomic absorption spectrophotometry (Perkin-Elmer 1100 B; Perkin-Elmer, Shelton, CT). The samples were previously mineralized by a wet method in a sand bath, placed in a resistant flask and dissolved using nitric acid, followed by mixing with $HNO_3/HClO_4$ (1:4, v/v) until the total elimination of organic

matter. Finally, the samples were diluted with Milli-Q water and filtered through a Whatman No. 41 filter. The concentrations of P were analysed by visible spectrophotometry (Perkin-Elmer UV/VIS spectrometer lambda 16) using the Fiske–Subbarow technique (Fiske and Subbarow, 1925). Samples of skimmed milk powder and lyophilized bovine liver (certified reference material CRM 063 R and CBR 185; Commission of the European Community Bureau of Reference, Brussels, Belgium), were simultaneously used to test the Ca, P and Mg recovery (skimmed milk powder) and Fe, Cu and Zn recovery (bovine liver) (Ca value = 13.89 ± 0.10 mg/g; P value = 10.99 ± 0.12 mg/g; Mg value = 1.19 ± 0.08 mg/g; Fe value = 210 ± 3 μg/g; Cu value = 181 ± 2 μg/g; Zn value = 139 ± 2 mg/kg; mean ± SEM of five determinations. Certified values: Ca = 13.49 ± 0.10 mg/g; P = 11.10 ± 0.13 mg/g; Mg = 1.26 ± 0.02 mg/g; Fe = 214 ± 5 μg/g; Cu = 189 ± 4 μg/g; Zn = 143 ± 4 mg/kg).

2.3. Statistical analysis

One-way ANOVA was applied to the different parameters in accordance with the general linear model procedure (Steel and Torrie, 1984). Statistical analyses were performed using the Statgraphics statistical package (Statgraphics, 2001). The model accounts for variation caused by the species. The tables describe the mean values, residual standard deviations (square root of the mean square errors) and the level of significance of the effects.

3. Results and discussion

3.1. Chemical composition

Table 1 shows the chemical composition of the two types of milk. All the values presented are statistically different ($P < 0.05$), with the higher values corresponding to the goat milk.

The basic composition of goat and cow milk is fairly similar, with certain differences, to a greater or lesser extent, depending on the productive capacity of the breed in question. The Granadina breed of goats is a hardy one, adapted to survival in extreme environmental conditions, and which given appropriate feeding is capable of producing large amounts of milk (Boza, 2005), generally characterized by a high level of nutrients. As reported by Haenlein (1996), goat milk normally provides a higher proportion of total solids than does cow milk, as well as of protein, fats and minerals, although when the latter are expressed as dry matter content, the differences tend to disappear. The goat milk examined in the present study, in comparison with the cow milk, had a higher content of total solids, protein, fats and minerals. When these quantities are expressed as dry matter, they continue to surpass those of cow milk, especially as regards the fat and mineral content.

Table 1
Chemical composition (%) of goat milk ($n = 30$) and cow milk ($n = 30$). Effect of the species.

	Goat milk	Cow milk	R.S.D.[a]	Level of significance	Difference (%) for goat milk[b]
Total solids	13.57	11.36	0.57	***	+16.3
Protein	3.48	2.82	0.17	***	+19.0
Fat	5.23	3.42	0.64	***	+34.6
Ash	0.75	0.65	0.06	***	+13.3
Lactose[c]	4.11	4.47	0.47	*	−8.8

[a] R.S.D. = residual standard deviation.
[b] Difference (%) for goat milk = [(goat milk value − cow milk value)/goat milk value] × 100.
[c] Values derived by difference (lactose = total solids − (protein + fat + ash)).
* $P < 0.05$.
*** $P < 0.001$.

Table 2
Protein fraction (g/100 g protein) of goat milk ($n = 30$) and cow milk ($n = 30$). Effect of species.

	Goat milk	Cow milk	R.S.D.[a]	Level of significance	Difference (%) for goat milk[b]
Casein (Cn)	82.70	82.65	0.76	NS[c]	
α_{S1}-Cn	18.92	30.80	1.71	***	−62.8
α_{S2}-Cn	8.52	7.50	1.83	NS	
β + κ-Cn	55.26	44.35	2.79	***	+19.7
Whey proteins	17.30	17.35	0.76	NS	

[a] R.S.D. = residual standard deviation.
[b] Difference (%) for goat milk = [(goat milk value − cow milk value)/goat milk value] × 100.
[c] NS = $P > 0.05$.
*** $P < 0.001$.

3.2. Protein composition

3.2.1. Protein fractions

Table 2 shows the protein fraction composition of the two types of milk. The levels of α_{S1}-casein and β-casein + κ-casein varied ($P < 0.05$), with cow milk providing higher values in the first case, and goat milk, in the second.

In this respect, the first observation to be made is that, in general, goat milk contains a somewhat lower amount of caseins and so its proportion of serum proteins is higher (Park, 2006). This aspect is the first reason normally given to explain the greater digestive utilization made of goat milk protein than of cow milk protein (Boza and Sanz Sampelayo, 1997; López-Aliaga et al., 2003). Recently, however, it seems to have been shown that the above-mentioned difference does not, in fact, exist. In general, in the case of caseins, what are studied are the protein fractions of the milk that precipitate at a pH of 4.6, and the analysis is performed on this basis (Martín-Hernández et al., 1988). Nevertheless, it is now considered that the minimum solubility of the caseins in goat milk is achieved at a pH of 4.1, rather than 4.6 (Recio et al., 1997), and that the latter value is more appropriate for the precipitation of bovine caseins (Van Hekken and Thompson, 1992). This aspect, among others, is indicative of the different nature of the proteins in the two types of milk. When this factor is taken into account, the total casein content in the two types of milk is found to be similar, as we show.

With respect to the nutritive value of goat milk protein versus that of cow milk, it has long been suggested that goat milk is more digestible, as a softer, more easily broken down coagulate is formed in the stomach, and thus the protease in the stomach can act more readily, thus favouring digestibility (Park, 1994, 2006; Haenlein, 2004). This differing behaviour of the proteins in goat and cow milk seems to be due to the diverse composition as concerns their casein fractions; thus, cow milk protein contains a higher proportion of α_{S1}-casein (Park, 1994, 2006; Haenlein, 2004). The identification of a high degree of genetic polymorphism among goats, related to the levels of α_{S1}-casein in the milk, explains the different behaviour of casein fractions in the stomach (Boulanger et al., 1984; Haenlein, 2001, 2004). The results obtained in this study, concerning the casein fraction composition of the two types of milk, are in total agreement with the above considerations. It is also noticeable that in assays carried out to establish the quality of the milk from Granadina goats, with respect to that from Holstein Friesian cows, the former were found to produce a better nutritional utilization, especially in terms of digestion (Sanz Ceballos, 2007).

3.2.2. Amino acid composition

Table 3 shows the amino acid composition of the protein in the two types of milk, while Table 4 shows the amino acid content per

Table 3
Amino acid composition (g/100 g amino acids) of goat milk ($n = 30$) and cow milk ($n = 30$). Effect of species.

	Goat milk	Cow milk	R.S.D.[a]	Level of significance	Difference (%) for goat milk[b]
Essential amino acids					
Thr	3.98	4.11	0.32	NS[c]	
Ileu	4.61	4.54	0.33	NS	
Leu	9.80	9.44	0.20	**	+3.7
Lys	9.85	8.96	0.65	*	+9.0
Met	2.24	2.48	0.13	**	−10.7
Cys	0.88	0.82	0.07	NS	
Phe	5.04	4.73	0.13	***	+6.2
Tyr	4.67	5.67	0.77	*	−21.4
Val	6.04	5.24	0.55	*	+13.2
Total	47.11	45.99	1.95	NS	
Nonessential amino acids					
Arg	3.90	4.06	0.14	*	−4.1
His	3.53	3.30	0.47	NS	
Ala	3.39	3.41	0.03	NS	
Asp	7.19	7.60	0.19	**	−5.7
Glu	19.96	19.66	1.04	NS	
Gly	1.60	1.75	0.11	*	−9.4
Pro	8.93	8.99	1.11	NS	
Ser	4.39	5.24	0.38	**	−19.4
Total	52.89	54.01	1.95	NS	

[a] R.S.D. = residual standard deviation.
[b] Difference (%) for goat milk = [(goat milk value − cow milk value)/goat milk value] × 100.
[c] NS = $P > 0.05$.
* $P < 0.05$.
** $P < 0.05$.
*** $P < 0.001$.

100 g of each type. In the first case (Table 3), the levels of Leu, Lys, Phe and Val were significantly higher ($P < 0.05$) in goat milk, while they were lower ($P < 0.05$) for Met, Tyr, Arg, Asp, Gly and Ser. There were no significant differences ($P > 0.05$) in the total levels of essential amino acids. Concerning the contents of each amino acid per 100 g of milk (Table 4), we concluded that except for the quantities of Tyr and Ser, in which cases the differences were not statistically significant ($P > 0.05$), those of all the other amino acids were higher in goat milk than in cow milk ($P < 0.05$).

Table 4
Amino acid composition (mg/100 g milk) of goat milk ($n = 30$) and cow milk ($n = 30$). Effect of species.

	Goat milk	Cow milk	R.S.D.[a]	Level of significance	Difference (%) for goat milk[b]
Essential amino acids					
Thr	138.67	115.81	9.38	***	+16.5
Ileu	160.54	128.04	10.17	***	+20.2
Leu	341.01	266.23	7.03	***	+21.9
Lys	342.86	252.59	21.29	***	+26.3
Met	77.95	71.15	2.58	***	+8.7
Cys	30.62	23.20	2.23	***	+24.2
Phe	175.45	133.51	4.40	***	+23.9
Tyr	162.51	159.99	22.02	NS[c]	
Val	210.23	147.84	17.29	***	+29.7
Total	1639.84	1298.36	62.14	***	+20.8
Nonessential amino acids					
Arg	135.65	114.44	4.86	***	+15.6
His	122.73	93.06	14.28	**	+24.2
Ala	117.95	96.09	2.53	***	+18.5
Asp	250.15	214.22	5.32	***	+14.4
Glu	694.58	554.30	34.87	***	+20.2
Gly	55.83	49.24	3.16	**	+11.8
Pro	310.61	253.38	33.24	**	+18.4
Ser	152.65	147.85	11.73	NS	
Total	1840.15	1522.58	61.83	***	+17.3

[a] R.S.D. = residual standard deviation.
[b] Difference (%) for goat milk = [(goat milk value − cow milk value)/goat milk value] × 100.
[c] NS = $P > 0.05$.
** $P < 0.05$.
*** $P < 0.001$.

Although the amino acid composition of each protein fraction in the milk depends on the producer species (Marchalonis and Weltman, 1971), in general, it is possible to identify certain similarities in this composition according to the corresponding protein fraction. Thus, Park (2006) reported that α-caseins present higher levels of Asp, Lys and Tyr than do β-caseins, but lower ones of Leu, Pro and Val. The results obtained in the present study broadly coincide with the latter, with the exception of the Lys content, which in our case was higher in the goat milk protein, despite its lower content, especially, of α_{S1}-casein. Irrespective of the composition in milk protein fractions and of the corresponding amino acid profile, reports have been published concerning amino acid composition in milk, and these results vary according to the source and, above all, on the way in which the values in question are expressed. Park (2006) in reviewing this question, examined the information given by Davis et al. (1994) on the milk composition of various mammal species, and observed that there seemed to be certain similarities related to the model of amino acid composition for their proteins. Thus, and coinciding with the values obtained in the present study, it was stated that the most abundant amino acids were Glu, Leu, Lys, Pro and Asp, with the sum of essential amino acids exceeding 40% of the total. On comparing the composition reported by Davis et al. (1994) for the protein in goat and cow milk with our results, some differences may be pointed out. According to the data of the above-cited authors, the protein in goat milk presents higher quantities of Asp, His, Thr, Ala, Pro and Val than does cow milk. In our study, and in agreement with the above, the quantities of His and Val were indeed higher in the goat milk protein, while the opposite was true for the levels of Asp, and no marked differences were recorded among the quantities of Thr, Ala and Pro. From the data published by Davis et al. (1994), we also deduce that the levels of Ser, Arg, Tyr, Met, Leu, Phe and Lys would be lower in goat milk protein than in that of cows. On comparing the earlier data with those obtained in the present study, there is agreement as concerns the quantities of Ser, Arg, Tyr and Met, but on the contrary, the levels of Leu, Phe and Lys were higher.

Together with the information on the protein composition in each type of milk, the bibliography also contains data on the quantities of the various amino acids in a given volume of milk. In these cases, the composition in question should be examined without overlooking the fact that, in general, and as we too have found, the amount of total solids in goat milk is normally higher than that in cow milk. Posati and Orr (1976) analyzed the content of the different amino acids in 100 g of milk, and concluded that goat milk, with respect to cow milk, contains larger amounts of 6 of the 10 essential amino acids. In the present study, the quantity of any given amino acid in 100 g of goat milk was found to be greater than the corresponding quantity in the same amount of cow milk. This effect was mainly due to the greater content of total solids in goat milk, together with the greater quantity of protein in the dry extract (25.64% vs. 24.82%).

3.3. Fat composition and fatty acid profile

Table 5 shows the fatty acid profile of goat and cow milk fat (g/100 g total fatty acids), while Table 6 shows the quantities of the fatty acids present in 100 g of milk. In the first of these cases, and except for the values for C11:0, C15:1, C16:2 *n*-4, C17:0, C17:1, C18:0, C18:1 *n*-9, *cis*, CLA *n*-7, *cis*-9, *trans*-11, C20:0, C20:1 *n*-9, C20:2, *n*-6, C21:0, C22:0, C23:0 and C24:0, and the total quantity of

Table 5
Fatty acid composition (g/100 g total fatty acids) of goat milk fat ($n = 30$) and cow milk fat ($n = 30$). Effect of species.

	Goat milk	Cow milk	R.S.D.[a]	Level of significance	Difference (%) for goat milk[b]
C4:0	1.27	3.84	1.25	**	−202.4
C6:0	3.28	2.28	0.34	***	+30.5
C8:0	3.68	1.69	0.31	***	+54.1
C10:0	11.07	3.36	0.62	***	+69.6
C11:0	0.14	0.21	0.12	NS[c]	
C12:0	4.45	3.83	0.53	*	+13.9
C14:0	9.92	11.24	0.93	*	−13.3
C14:1	0.14	0.49	0.19	**	−250.0
C15:0	0.54	1.03	0.26	**	−90.7
C15:1	0.06	0.08	0.11	NS	
C16:0	25.64	32.24	1.31	***	−25.7
C16:1	0.99	1.53	0.19	***	−54.5
C16:2 *n*-4	0.03	0.02	0.05	NS	
C17:0	0.35	0.18	0.25	NS	
C17:1	0.08	0.08	0.13	NS	
C18:0	9.92	11.06	1.14	NS	
C18:1 *n*-9, *trans*	0.37	1.63	0.30	***	-340.5
C18:1 *n*-9, *cis*	23.80	21.72	2.21	NS	
C18:2 *n*-6	2.72	2.41	0.55	**	+11.4
CLA *n*-7, *cis*-9, *trans*-11	0.36	0.40	0.07	NS	
CLA *n*-6, *trans*-10, *cis*-12	0.07	0.05	0.01	**	+28.6
CLA *n*-7, *cis*-9, *cis*-11	0.02	-	0.01	***	
CLA *n*-5, *cis*-11, *trans*-13	0.24	-	0.07	***	
CLA total	0.68	0.45	0.07	***	+33.8
C18:3 *n*-3	0.53	0.25	0.05	***	+52.8
C20:0	0.05	0.11	0.07	NS	
C20:1 *n*-9	0.03	0.03	0.04	NS	
C20:2 *n*-6	0.11	0.04	0.12	NS	
C20:3 *n*-6	–	0.02	0.02	*	
C21:0	0.03	0.01	0.02	NS	
C22:0	0.08	0.12	0.07	NS	
C23:0	0.01	0.03	0.02	NS	
C24:0	0.01	0.02	0.02	NS	
C24:1 *n*-9	0.02	–	0.01	**	
C6-14	32.42	23.10	1.91	***	+28.7
SFA	70.42	71.24	2.59	NS	
MUFA	25.67	25.56	2.76	NS	
PUFA	4.08	3.20	0.22	***	+21.6
PUFA *n*-6	2.81	2.53	0.20	*	+10.0
PUFA *n*-3	0.51	0.25	0.04	***	+51.0
PUFA *n*-6/*n*-3	5.49	10.49	1.24	***	−91.1

[a] R.S.D. = residual standard deviation.
[b] Difference (%) for goat milk = [(goat milk value − cow milk value)/goat milk value] × 100.
[c] NS = $P > 0.05$.
* $P < 0.05$.
** $P < 0.05$.
*** $P < 0.001$.

saturated and monounsaturated fatty acids, all the others were significantly affected ($P < 0.05$) by the species. Thus, in the goat milk fat, the levels of C6:0, C8:0, C10:0, C12:0, C18:2 *n*-6, CLA *n*-6, *trans*-10, *cis*-12, CLA *n*-7, *cis*-9, *cis*-11, CLA *n*-5, *cis*-11, *trans*-13, CLA total, C18:3 *n*-3, C24:1 *n*-9 and C6-14, as well as the quantities of polyunsaturated fatty acids (both total and of the *n*-6 and *n*-3 series) were higher than in the cow milk fat. On the contrary, the levels of C4:0, C14:0, C14:1, C15:0, C16:0, C16:1, C18:1 *n*-9, *trans* and C20:3 *n*-6, as well as the ratio of *n*-6:*n*-3 polyunsaturated fatty acids were higher ($P < 0.05$) in the cow milk fat. When the quantities of the different fatty acids were expressed as mg/100 g of milk, except in the case of C11:0, C15:0, C15:1, C16:1, C16:2 *n*-4, C17:0, C17:1, C20:0, C20:1 *n*-9, C20:2 *n*-6, C21:0, C22:0, C23:0 and C24:0, all were significantly affected ($P < 0.05$) by the species, the quantities being greater in goat milk ($P < 0.05$) for the fatty acids C6:0, C8:0, C10:0, C12:0, C14:0, C16:0, C18:0, C18:1 *n*-9, *cis*, C18:2 *n*-6, CLA *n*-7, *cis*-9, *trans*-11, CLA *n*-6, *trans*-10, *cis*-12, CLA *n*-7, *cis*-9, *cis*-11, CLA *n*-5, *cis*-11, *trans*-13, total CLA, C18:3 *n*-3, C24:1 *n*-9, C6-14, saturated, monounsaturated and total polyunsaturated fatty acids, as well as the *n*-6 and *n*-3 series polyunsaturated fatty acids. On the contrary, the quantities corresponding to the fatty acids C4:0, C14:1, C18:1 *n*-9, *trans* and C20:3 *n*-6 were higher in the cow milk as was the ratio of *n*-6 to *n*-3 polyunsaturated fatty acids ($P < 0.05$).

With respect to the fatty acid profile of the fat from both types of milk, the first noteworthy aspect concerns the medium-chain fatty acid content (C6–14); as was to be expected, these were present in considerably higher quantities in the goat milk fat. It has long been known that one of the most noteworthy aspects of consuming goat milk, concerning both its nutritional value and the benefits to health thus obtained, results from the specific composition of its fat (Velázquez et al., 1996; Boza and Sanz Sampelayo, 1997; Alférez et al., 2001; Haenlein, 2001, 2004; Sanz Ceballos, 2007). Triglycerides with medium-chain fatty acids are metabolized in a different way from those containing long-chain fatty acids, being readily hydrolyzed in the digestive tract, a process that begins in the stomach with the action of salivary pregastric lipase, and thus they can be absorbed without needing any reesterification. Fast and efficient digestion is followed by equally fast oxidative metabolism and these compounds are, consequently, excellent sources of energy (Leyton et al., 1987; Aurousseau et al., 1989; Velázquez et al., 1996; Matsuo and Takeuchi, 2004). Therefore, together with the high degree of digestibility (Alférez et al., 2001; Sanz Ceballos, 2007), the fast and substantial energy supply obtained from this

Table 6
Fatty acid composition (mg/100 g milk) of goat milk fat ($n = 30$) and cow milk fat ($n = 30$). Effect of species.

	Goat milk	Cow milk	R.S.D.[a]	Level of significance	Difference (%) for goat milk[b]
C4:0	66.55	116.44	40.47	*	−75.0
C6:0	171.68	77.86	17.06	***	+54.6
C8:0	192.20	57.80	15.55	***	+69.9
C10:0	579.10	114.91	27.75	***	+80.2
C11:0	7.46	7.29	5.06	NS[c]	
C12:0	232.61	130.87	27.67	***	+43.7
C14:0	518.56	384.41	45.71	***	+25.9
C14:1	7.19	16.87	7.21	*	−134.6
C15:0	28.11	35.23	13.65	NS	
C15:1	3.01	2.74	5.06	NS	
C16:0	1340.97	1102.72	62.71	***	+17.8
C16:1	51.58	52.32	9.97	NS	
C16:2 *n*-4	1.57	0.57	2.29	NS	
C17:0	18.44	6.27	10.90	NS	
C17:1	4.32	2.85	5.71	NS	
C18:0	493.56	378.25	51.91	**	+23.4
C18:1 *n*-9, *trans*	19.22	55.75	15.77	***	−190.1
C18:1 *n*-9, *cis*	1245.92	742.71	112.45	***	+40.4
C18:2 *n*-6	142.39	82.31	8.86	***	+42.2
CLA *n*-7, *cis*-9, *trans*-11	18.70	13.79	3.26	**	+26.3
CLA *n*-6, *trans*-10, *cis*-12	3.53	1.82	0.29	***	+48.4
CLA *n*-7, *cis*-9, *cis*-11	1.05	–	0.30	***	
CLA *n*-5, *cis*-11, *trans*-13	12.42	–	3.55	***	
CLA total	35.75	15.62	3.31	***	+56.3
C18:3 *n*-3	27.72	8.55	2.05	***	+69.2
C20:0	2.49	3.76	3.53	NS	
C20:1 *n*-9	1.57	1.03	1.64	NS	
C20:2 *n*-6	5.49	1.48	5.96	NS	
C20:3 *n*-6	–	0.80	0.50	*	
C21:0	1.44	0.23	1.21	NS	
C22:0	4.05	3.99	3.44	NS	
C23:0	0.26	0.91	0.71	NS	
C24:0	0.66	0.68	0.68	NS	
C24:1 *n*-9	0.92	–	0.47	**	
C6-14	1695.70	790.02	87.71	***	+53.4
SFA	3683.10	2436.41	134.36	***	+33.8
MUFA	1342.67	874.27	142.74	***	+34.9
PUFA	213.25	109.32	8.20	***	+48.7
PUFA *n*-6	146.97	86.41	9.85	***	+41.2
PUFA *n*-3	26.81	8.55	1.43	***	+68.1
PUFA *n*-6/*n*-3	5.49	10.49	1.24	***	−91.1

[a] R.S.D. = residual standard deviation.
[b] Difference (%) for goat milk = [(goat milk value − cow milk value)/goat milk value] × 100.
[c] NS = $P > 0.05$.
* $P < 0.05$.
** $P < 0.05$.
*** $P < 0.001$.

source enables, or even leads directly to, a better metabolic utilization of the protein (Sanz Ceballos, 2007). For this reason, it has been employed in treating certain metabolic diseases (Haenlein, 1992, 1996). The results we report show that goat milk has a 40% higher content of medium-chain fatty acids than does cow milk. When the values are expressed as mg/100 g of milk, the difference rises to as much as 115%.

Another aspect of the fat content of the two types of milk that should be commented on concerns their content of the different forms of conjugated linoleic acid (CLA), which has been attributed diverse beneficial properties for consumer health, such as anticarcinogenic and antilipogenic effects (McGuire and McGuire, 2000). The total proportion of CLA in goat milk, in our study, was 62% higher than that in the cow milk. On comparing the quantities present in 100 g of milk, the difference in favour of goat milk was 134%. Regarding the global composition of the two fats, in relation to their total proportions of saturated, monounsaturated and polyunsaturated fatty acids, the most noteworthy aspect is that although the contents of saturated and monounsaturated fatty acids were practically identical, that of polyunsaturated fatty acids was higher in the goat milk fat. Among the polyunsaturated fatty acids, and distinguishing the *n*-6 and *n*-3 series among these, we observed that the goat milk fat presented higher quantities of both types of fatty acids, and in this case the *n*-6:*n*-3 ratio was markedly lower, an aspect which reflects a higher level of quality (Valenzuela et al., 1999).

3.4. Mineral composition

Table 7 shows the content of Ca, P, Mg, Fe, Cu and Zn in the ash (g/100 g ash) of goat and cow milk, while Table 8 shows the same elements, but with respect to a given volume (mg/100 g of milk). The levels of Ca, P, Mg, Fe and Cu in the goat milk ash were significantly higher ($P < 0.05$) than those in the cow milk ash. When these values were expressed as mg/100 g of milk, all except that of Zn were also higher ($P < 0.05$) in goat milk. The difference for the quantities of Zn reached a level of statistical significance of $P = 0.13$. The most marked differences between the two types of milk, when the mineral composition is expressed in terms of the quantities present in a given volume of milk, are due to the different amounts of total solids in the two types of milk, as commented previously.

One of the main reasons why milk is considered an exceptionally important food is its rich mineral content. Moreno (1995) remarked how difficult it would be to achieve an adequate

Table 7
Mineral composition (g/100 g ash) of goat milk ($n = 30$) and cow milk ($n = 30$). Effect of species.

	Goat milk	Cow milk	R.S.D.[a]	Level of significance	Difference (%) for goat milk[b]
Ca	21.14	17.47	2.13	*	+17.4
P	15.86	13.39	1.04	**	+15.6
Mg	1.72	1.44	0.20	*	+16.3
Fe	0.02	0.02	0.00	NS[c]	
Cu	0.006	0.002	0.001	***	+66.7
Zn	0.07	0.07	0.01	NS	

[a] R.S.D. = residual standard deviation.
[b] Difference (%) for goat milk = [(goat milk value − cow milk value)/goat milk value] × 100.
[c] NS = $P > 0.05$.
* $P < 0.05$.
** $P < 0.05$.
*** $P < 0.001$.

Table 8
Mineral composition (mg/100 g milk) of goat milk ($n = 30$) and cow milk ($n = 30$). Effect of species.

	Goat milk	Cow milk	R.S.D.[a]	Level of significance	Difference (%) for goat milk[b]
Ca	158.57	113.58	15.80	***	+28.4
P	118.97	87.04	7.68	***	+26.8
Mg	12.92	9.40	1.46	**	+27.2
Fe	0.15	0.09	0.01	***	+40.0
Cu	0.042	0.014	0.009	***	+66.6
Zn	0.528	0.463	0.068	NS[c]	

[a] R.S.D. = residual standard deviation.
[b] Difference (%) for goat milk = [(goat milk value − cow milk value)/goat milk value] × 100.
[c] NS = $P > 0.05$.
** $P < 0.05$.
*** $P < 0.001$.

intake of Ca, both in total quantity and in relation to P, if not for an appreciable consumption of milk or other dairy products. Although the mineral composition of milk may be affected by the animal species in question and by the nutrition provided to it, a comparison of goat and cow milk seems to show there are certain aspects that are characteristic for each species. This fact has enabled the mineral composition of the milk to be used to identify the producer species (Rincón et al., 1994). Park (2006) reviewed this aspect of milk composition for different species and stated that goat milk, in comparison with cow milk, provides higher quantities (mg/100 g of milk) of Ca, P, K, Mg and Cl, and lower ones of Na and sulphur. Haenlein (2001) commented that goat milk presents a mineral composition that is very similar to that of cow milk as concerns its content of Na, Fe, Zn and Mb, but has higher amounts of Ca, K, Mg, P, Cl and Mn.

Nowadays, the better nutritional quality of goat milk compared to cow milk, on the basis of its mineral composition, is considered to result not just from the minerals provided by each, but also from the body's utilization of them, in both digestive and metabolic processes. Thus, using an appropriate animal model, results have been obtained showing this better utilization of the minerals provided in goat milk, an effect accounted for on the basis of the corresponding mineral content and the different composition of both protein and fat in the two types of milk (Park et al., 1986; Barrionuevo et al., 2002; Campos et al., 2003; López-Aliaga et al., 2003; Alférez et al., 2006).

4. Conclusions

Under the conditions in which the present study was carried out, the composition of protein, fat and mineral in the goat milk and cow milk were found to be different, both in qualitative and quantitative terms. The differences that were found would account for those observed in the nutritional utilization of goat milk and cow milk.

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