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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