Alternatives for Improving Physical, Chemical, and Sensory Characteristics of Goat Cheeses: The Use of Arid-Land Forages in the Diet

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ABSTRACT

To establish the effect of an alternative diet on the quality of Majorero cheese, the basic physicochemical parameters, fatty acid profile, and sensory characteristics were studied. Two groups of 20 Majorero goats were fed 2 different diets: a forage diet (DF), which had a high ratio of long fiber to concentrates (65:35), and a concentrate diet (DC), with a low ratio of long fiber to concentrates (35:65). The DF dietary fiber was supplied by native forages adapted to arid land. A total of 42 Majorero goat cheeses were used for this study: 21 in the DF group and 21 in the DC group. Seven cheeses from each group were tested after 2, 15, and 60 d of ripening. The milk produced by goats fed the DF diet had a higher fat concentration. No significant differences were observed in the milk fatty acid profile. The diet affected the chemical composition of the cheese in pH and fat content, and fat was significantly higher in cheeses made from DF milk than those from DC milk. Dietary characteristics had important effects on the medium-chain fatty acid composition (C₆ to C₁₄) of the cheese fat, giving DF cheeses the specific goat's milk flavor that is sought after for this type of cheese. The fatty acid composition (%) differed substantially among different ripening times. The DF cheeses were more appreciated by the panelists, as they had a greater variety of odors and flavors than the DC cheeses. The DF hard cheeses were described as having vegetable and fruity tones as well as tones of hay and dried fruit. **Key words:** goat's milk and cheese, fiber-to-concentrate ratio, chemical composition, sensory property

INTRODUCTION

It is empirically accepted that the type of pasture influences the chemical composition and sensory prop-

erties of cheese (Verdier-Metz et al., 1998; Bugaud et al., 2001). However, a reduction in the proportion of forage in the diet can induce a decrease in the milk fat content (Morand-Fehr and Sauvant, 1980; Economides et al., 1989).

Two main dietary factors can clearly modify the fatty acid (FA) composition of goat's milk and cheeses: 1) the supply and nature of fiber sources and 2) the supply and characteristics of lipids in the diet (Morand-Fehr et al., 2000). Lipid composition is one of the most important components of the technological and nutritional quality of goat's milk, and lipids are involved in cheese yield (per kilogram of milk), firmness, and the color and flavor of goat dairy products (Delacroix-Buchet and Lamberet, 2000). In addition to their quantitative contribution to the amount of dietary energy, the different FA are also potentially involved as positive or negative predisposing factors in the health of human consumers (Parodi, 1999; Williams, 2000). Furthermore, the peculiarities of the goat's milk lipolytic system (Chilliard, 1982) and content of medium-chain FA (Ha and Lindsay, 1993) could greatly change the FFA content, playing a major role in the distinctive goat's milk flavor (Chilliard et al., 2003).

Studies related to the influence of ruminants' feeding regimen on the sensory properties of cheese are particularly important when the product has been designated as Protected Designation of Origin (PDO), because the feeding regimen constitutes one of the bases of the PDO relationship with the land where cheeses are produced (Grappin and Coulon, 1996).

This study is part of a project aimed at demonstrating the effects on the characteristics of milk used in Canarian PDO cheese when goats are fed diets with varying ratios of different kinds of forage. Because the goat industry has become more intensive, with higher milk yields, goats have been receiving a diet with 50% less fiber. These diets, which are too rich in energy because of a high percentage of concentrates (more than 50% of DM), significantly decrease the milk fat content, reducing the life expectancy of the animals and causing many

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health problems (Gutiérrez et al., 1999). The Canary Islands, like many other arid areas, have scarce pasture resources, and this problem cannot be solved simply by importing forage because of the high cost of its transport; therefore, the production of native forages or those that are properly adapted to these habitats can help to reduce this problematic situation. Furthermore, this encourages the development of livestock farming, which aids in conservation of the environment by recovering areas of forage production that are now severely deteriorated.

The aim of the present paper was to determine the effect of 2 diets on the physicochemical and sensory characteristics of Majorero cheese: one with a high ratio of long fiber to concentrate (65:35), based on forages adapted to arid conditions (forage diet, **DF**), and the other with a low ratio of long fiber to concentrate (35:65; concentrate diet, **DC**), the latter being the diet most often used by Canarian farmers in these arid zones. The study was undertaken in experimental conditions to determine the effects of diet and ripening on the quality of the cheeses. Goat breed, husbandry, and cheese-making practices were based on the instructions given for PDO Majorero cheese (Boletín Oficial del Estado).

MATERIALS AND METHODS

Experimental Design and Procedure

Forty multiparous Majorero goats were divided into 2 equal groups based on their lactation number, milk production, and type of kidding. These animals had kidded in the traditional season (December), and the trial began in March (midlactation period). From 4 wk before the beginning of the experiment, one group (DF) was fed a diet of vinagrera (*Rumex lunaria*), saltbush (*Atriplex halimus*), and barley (*Hordeum vulgare*) hay, whereas the other group (DC) received only cereal straw as a fiber source. The 2 diets were supplemented with a commercial concentrate for goat's milk production and a mixture of corn, barley grain, and dehydrated alfalfa. The amount of concentrates given was determined for the whole experiment to cover the same maintenance and milk production requirements as INRA recommendations (INRA, 1990). These quantities remained unchanged throughout the experiment, although they differed between one group and the other. The concentrates made up 35% (DF group) and 65% (DC group) of the total DM in the diet. The characteristics of the different feeds are specified in Tables 1 and 2. During the experimental period, the quantities of each diet provided were calculated and controlled to ensure an identical supply of energy and protein.

Table 1. Ingredient composition (g/kg) of the diets¹

Ingredient	Diet	
	DF	DC
Commercial concentrate	110	306
Barley grain	46	102
Corn grain	37	102
Lucerne pellets ²	46	128
Saltbush	92	—
Vinagrera	368	—
Barley hay	294	—
Wheat straw	—	358
Mineral supplement ³	7	4

¹DC = concentrate diet; DF = forage diet.

²Lucerne pellets, Biona, Santa Cruz de Tenerife, Spain.

³With different compositions according to the Ca and P content for each ingredient.

Cheese Samples

For 4 consecutive days during the experimental period, milk produced by each of the 2 experimental groups was processed to make cheese. Overall, 8 cheese-making processes were completed in a semitraditional factory placed in the Animal Production Unit; every day, 2 vats were filled with 50 kg of milk, one with DF milk and the other with DC milk. Cheeses were made according to the specifications of the Majorero Cheese Denomination of Origin Regulatory Board (Orden Ministerial de 16 de febrero de 1996). The cheeses were made on the same day as milking. Milk was not pasteurized and no starter culture was added. After heating to $30 \pm 1^\circ\text{C}$, the animal rennet commonly used by farmers (commercial rennin powder, Marshall rennet power 50% chymosin and 50% pepsin) was added, following the manufacturer's instructions, to obtain clotting within 30 to 35 min. After coagulation, all curds were cut to obtain grains the size of millet. The presses were the same for all cheeses: 4.9 kPa for 5 h. Afterward, salting was achieved by rubbing dry salt onto the surface of the cheeses. A total of 42 Majorero goat cheeses were used for this study: 21 DF and 21 DC. Seven cheeses were analyzed from each group after 2, 15, and

Table 2. Chemical composition and net energy content of the diets¹

Item	Diet	
	DF	DC
DM, %	89.1	60.26
OM, % of DM	94.33	80.38
CP, % of DM	10.37	12.63
NDF, % of DM	41.56	41.40
ADF, % of DM	27.33	23.13
Acid detergent lignin, % of DM	5.56	10.13
Net energy, MJ/kg of DM	5.6	5.73

¹DC = concentrate diet; DF = forage diet.

60 d of ripening. Half of each cheese was used for the physicochemical analysis and the other half was used for the sensory analysis. Cheese samples were coded with a letter representing the respective diet used for feeding the goats and with a number. During ripening, the cheeses were stored in a ripening chamber at 10 to 12°C and 85 to 86% relative humidity.

For each ripening time, cheeses were sent to the laboratory in refrigerated boxes and a basic chemical analysis was performed immediately. Cheeses samples were vacuum-packed and stored at -20°C for FFA analysis. Immediately before analysis, the samples were defrosted overnight at 20°C. For the sensory analysis, all samples were wrapped in aluminum sheets, stored under refrigerated conditions, and placed at room temperature ($20 \pm 1^\circ\text{C}$) for 2 h before testing.

Physicochemical Analysis

Milk. The protein, fat, lactose, and DM contents were measured in a representative sample taken from the vat of each cheese, using a MilkoScan 133B (Foss Electric, Slangerupgård, Denmark). The pH value was determined at room temperature (20°C) using an inoLab pH Level 1 pH meter (inoLab, Weilheim, Germany). Another sample was frozen at -20°C for FFA analysis.

Cheese. Each cheese sample was analyzed 3 times by near-infrared spectroscopy (Instalab 600, Foss Electric), with previous calibrations: total solids by standard FIL-IDF 4A (IDF, 1982), fat by standard FIL-IDF 52 (IDF, 1991), and total nitrogen by standard FIL-IDF 220B (IDF, 1993). Cheese pH was measured at 20°C by introducing a penetrometric electrode into the cheese. The pH value was determined at room temperature (20°C) using an inoLab pH Level 1 pH meter.

FFA. The extraction of total FFA and their qualitative and quantitative determination were performed using a modification of the method of Sukhija and Palmquist (1988). In particular, the FA composition of milk and cheese fat was evaluated by gas chromatography. Fatty acid methyl esters were separated on an Autosystem gas chromatograph (PerkinElmer, Norfolk, CT) fitted with an SP-2560 fused-silica capillary column [100 m $\times$ 0.25 mm (i.d.), 0.20 μm of 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, then increased to 230°C at 5°C/min, and held for 26 min. The carrier gas was N_2 . Injector and detector temperatures were 250 and 300°C, respectively. The peaks for individual FA were identified using pure methyl ester standards (Supelco). Peak areas for individual FA were corrected for recovery using butter oil as a reference standard (CRM

164, Commission of the European Community Bureau of References, Brussels, Belgium).

Sensory Analysis

Sensory analyses were carried out after 2, 15, and 60 d of ripening. Samples, coded with random 3-digit codes (Meilgaard et al., 1991), were presented in a balanced way (Suriyaphan et al., 2001) to avoid the effect of the presentation order. Cheeses were served without any identification of the origin of the milk used (DF vs. DC). The methodology used was described previously; odor and flavor attributes were in accordance with those described by Berdier et al. (1996) and texture followed the guidelines published by Lavanchy et al. (1999). The group of 7 judges were highly experienced and had been formally trained over 10 yr; this panel works in collaboration with the PDO Majorero cheese sensory panel. Before beginning this experiment, 5 extra training sessions were performed with Majorero PDO cheeses.

The cheese samples presented were 1.5 cm thick $\times$ 1.5 cm wide $\times$ 5 to 8 cm long with the rinds cut away. The size and shape of all pieces were identical. Two portions per sample were served, one to evaluate texture and the other to evaluate odor and flavor (Lavanchy et al., 1999). Serving temperature was $20 \pm 1^\circ\text{C}$ (Engel et al., 2000). Judges rinsed their mouths between the 2 samples using unsalted crackers, Granny Smith apples, and water with a very low level of mineralization to remove any aftertaste. The sensory analysis was conducted in a special room of the ICIA following the instructions given by the UNE 87-004 norm (IRANOR, 1979).

Seventeen sensory attributes, 7 for texture (roughness, moisture, elasticity, firmness, friability, adhesiveness, and solubility) and 10 for odor and flavor (saltiness, sweetness, bitterness, acidity, pungent, astringent, residual taste, taste persistence, odor, and flavor intensity) were scored on a structured scale from 0 to 7. Roughness and moisture were scored from 0 to 4 and from 0 to 5, respectively. In addition, each assessor was allowed to describe the odor and flavor of each sample by selecting descriptors from the following main family list: milky, vegetable, fruity, toasted, animal, floral, spiced, and others (soap, rancid, and pungent in the nose). Despite all these descriptive characteristics, the panelists also evaluated (on a scale from 0 to 7) their preferences on the cut aspect, texture, odor, flavor, and taste of the cheeses.

Statistical Analysis

The software package SPSS version 11.0 (SPSS Inc., Chicago, IL) was used for statistical processing of the

Table 3. Milk composition for Majorero goats fed different diets (DC, DF)¹

Item	Diet, LSM		RSD	Level of significance ²
	DF	DC		
pH	6.69	6.70	0.08	0.517
Fat, g/kg	43.9	39.2	0.74	0.009
CP, g/kg	37.1	36.8	0.22	0.475
Lactose, g/kg	44.4	45.3	0.19	0.049
DM, g/kg	13.26	12.99	0.94	0.269
Nonfat solids, g/kg	8.85	8.89	0.16	0.279

¹DC = concentrate diet; DF = forage diet; RSD = residual standard deviation.

²Values in bold are significant.

results. A GLM was used to establish statistical differences between the physicochemical parameter values and sensory analysis scores according to the type of diet, ripening time, and the interaction between these 2 factors. Posthoc multiple analyses by Tukey's test were used for the ripening time factor.

RESULTS AND DISCUSSION

Physicochemical Characteristics

Milk. Table 3 contains the mean values for analytical characteristics of the goat's milk used. As expected, all the parameters considered fell within the range of values expected for this type of milk. As may be noted, a greater amount of fat ($P < 0.01$) was found in the DF milk (43.9 g/kg) than in the DC milk (39.2 g/kg). This seemed to indicate an adequate proportion of large fiber in the DF diet and an excessive percentage of concentrates in the DC diet (Letorneau et al., 2000). This fact could be explained by the decrease in the forage-to-concentrate ratio of the diet and the decrease in particle size of the fiber. The fat content of the milk produced tended to be lower in the DC milk, perhaps because of a reduction in the acetic acid produced, which is a principal precursor of the FA synthesized in the mammary gland (Dils, 1986; Vermorel, 1990).

These results, which showed an increase in fat ($P < 0.01$) and protein (nonsignificant) in DF milk, can be used by PDO technicians as an economical argument to urge farmers to change their animal feeding management. Because all Majorero milk is transformed into cheese, better DF cheese yield results (data not shown) could support this proposal.

Other authors (Verdier-Metz et al., 2000; Bugaud et al., 2001) have demonstrated a milk fat increment when comparing different pastures and hays; however, no significant differences were found in similar studies (Buchin et al., 1999; Pirisi et al., 2001). Sanz Sampelayo

Table 4. Fatty acid composition (%) of milk fat for Majorero goats fed different diets (DC, DF)¹

Fatty acid	Diet, LSM		RSD	Level of significance
	DF	DC		
4:0	0.44	0.60	0.06	0.200
6:0	2.07	1.98	0.05	0.528
8:0	2.88	2.82	0.02	0.283
10:0	12.14	12.15	0.20	0.986
10:1	0.43	0.43	0.01	1.000
12:0	6.20	6.40	0.20	0.708
14:0	11.17	11.56	0.20	0.442
15:0	0.93	1.29	0.14	0.233
16:0	34.08	32.60	0.48	0.115
16:1	1.16	1.25	0.05	0.454
18:0	5.95	5.34	0.45	0.613
18:1	17.65	18.90	0.45	0.194
18:2	3.56	3.51	0.07	0.817
18:3	0.44	0.42	0.01	0.515
CLA ²	0.77	0.80	0.01	0.168
20:0	0.02	0.00	0.01	0.423
20:4	0.15	0.08	0.04	0.457

¹DC = concentrate diet; DF = forage diet; RSD = residual standard deviation.

²CLA = conjugated linoleic acid.

et al. (1998), comparing forages of different physical forms, found that goats appeared to be more sensitive to energy intake than to the characteristics of the diet. The other contents of the milk analyzed were very similar for both types of diet, except lactose, which was higher in the DC group ($P < 0.05$). The pH value did not differ substantially in either diet. These pH values could result in similar coagulation properties for cheese making (Pirisi et al., 2001).

Table 4 shows the FA composition of the milk fat from goats fed each diet. The most abundant FA in both types of milk were capric, myristic, palmitic, and oleic acids. Other authors have reported similar findings in different goat's milks (Fontecha et al., 1990; Sanz Sampelayo et al., 1998). Medium-chain FA containing between 6 and 14 carbons represented 34.9 and 35.3% of the total FA for the milk fat from goats consuming diets DF and DC, respectively.

No effect on the FA composition of the milk fat was observed when comparing different dietary characteristics. When the milk fat content of ruminants decreases because of alterations in the diet, the FA composition of the milk also changes. The proportion of unsaturated FA increases and the proportion of saturated FA decreases (Rook, 1976). Such changes were not observed in the present study, in accordance with the findings of Sanz Sampelayo et al. (1998). As described by Bas et al. (1998), the synthesis of microbial lipids in the rumen is very active in goats. The proportion and type of roughage in the diet modify the composition of microbial lipids, more specifically the ratio of 18:0 to 18:1 and the

Table 5. Cheese composition for Majorero goats fed different diets (DC, DF)¹

Item	LSM					RSD	Level of significance		
	Diet		Ripening time				Diet effect (D)	Ripening time effect (R)	D × R
	DF	DC	2 d	15 d	60 d				
pH	5.96	6.14	6.58 ^a	4.99 ^b	6.57 ^a	0.09	0.001	0.001	0.001
Moisture, %	44.88	45.55	47.72 ^a	45.65 ^b	42.27 ^c	0.34	0.145	0.001	0.751
Fat, %	24.56	22.91	19.73 ^a	23.23 ^b	28.24 ^c	0.47	0.001	0.001	0.551
Protein, %	20.74	20.71	19.50 ^a	20.85 ^b	21.83 ^c	0.14	0.909	0.001	0.723
Fat, % of TS	44.32	41.84	37.65 ^a	42.72 ^b	48.86 ^c	0.61	0.001	0.001	0.274
Protein, % of TS	37.65	38.07	37.33	38.38	37.87	0.24	0.409	0.324	0.738

^{a-c}Within a row, means marked with different superscripts differ ($P < 0.05$). Values in bold are significant.

¹DC = concentrate diet; DF = forage diet; RSD = residual standard deviation.

percentage of minor FA. This ratio was different for the experimental milks (lower in DC milk: 0.28 vs. 0.34), but there were no changes in the percentage of short-chain FA.

Cheese. Table 5 presents the mean values for pH, moisture, fat, protein, and fat in DM over ripening (at 2, 15, and 60 d) for the types of cheese considered. The chemical composition was affected by the diet in pH and fat content. Fat was significantly higher in cheeses made from DF milk than those from DC milk ($P < 0.001$). This could be due to the high fat content of the DF milk, which significantly influenced cheese composition. However, similar results were not always observed when ruminants were fed different diets (concentrate vs. pasture; Pirisi et al., 2001).

Ripening time affected nearly all physicochemical parameters. Fat and protein contents rose significantly over the ripening period, whereas moisture decreased. The moisture values were similar to those reported by Martín-Hernández et al. (1992) but were considerably lower than those determined by Fontecha et al. (1990) for artisanal Majorero cheese, in which ripening takes place at ambient temperature and low relative humidity. Significant differences were observed in pH because of the diet and ripening. Cheese pH decreased up to 15 d and increased considerably between 15 and 60 d, attaining values similar to those of fresh cheeses, thus confirming the important metabolic activity of lactic acid bacteria in this period.

Table 6 shows the mean profile for the main FA in the experimental cheeses. Dietary characteristics had important effects on the medium-chain FA composition (C_6 to C_{14}) of the cheese fat. Within long-chain FA, only the stearic acid concentration differed between the 2 groups. Saturated FA constituted 76.08 and 76.25% of the cheese fat from goats fed the DF and DC diets, respectively.

According to the type of diet, the FA profile of the cheeses showed differences ($P < 0.05$); in spite of that and in accordance with their respective values, these

results cannot be considered relevant. In this respect, the most important aspect was the different concentrations of milk fat according to the type of diet; DF milk presented 43.9 g/kg of fat, whereas the value for DC milk was 39.2 g/kg. In addition to medium-chain FA (C_6 to C_{14}), conjugated linoleic acid and polyunsaturated FA are important because of their aromatic and health aspects (McGuire and McGuire, 2000; Haenlein, 2004); and the changes in these acids as an effect of the DF and DC diets were 16.2, 0.22, and 1.61 g and 14.52, 0.22, and 1.39 g, respectively.

The more elevated amount of fat in the DF milk implied higher concentrations of nearly all FFA in the DF cheeses. Furthermore, medium-chain FA play a major role in the characteristic goat flavor of these types of cheese (Chilliard et al., 2003), and the content of the FA was higher, but not significant, in the DF milk.

The fatty acid composition differed substantially among the different ripening times. The C_4 to C_{12} FA had similar concentrations at 2 and 15 d of ripening, and increased their values until 60 d of maturity. On the other hand, the concentrations of stearic, oleic, linoleic, and conjugated linoleic acids decreased after d 15 of ripening. These FA are potentially involved as positive or negative predisposing factors in the health of human consumers (Williams, 2000). The C_4 to C_{10} FA concentration provides a specific goat's milk flavor that is sought after in this type of cheese. Of the FFA, octanoic acid is known to be the one from the lipid fraction principally responsible for the goat's milk flavor, because it is perceived even at low proportions and is present at levels higher than the perceptual threshold (Le Queré et al., 1998). This acid was significantly higher ($P < 0.001$) in the DF cheeses and also in cheeses ripened for 60 d ($P < 0.001$).

As described by some authors (Dils, 1986; Vermorel, 1990), it is possible to understand that diets richer in fiber produce more VFA in the rumen, and for this reason, the synthesis of FA with less than 18 carbons increases. The proportion of short-chain FA in the 3

Table 6. Fatty acid composition (percentage) of cheese fat from Majorero goats fed different diets (DC, DF)¹

Item	LSM					RSD	Level of significance		
	Diet		Ripening time				Diet effect (D)	Ripening time effect (R)	D × R
	DF	DC	2 d	15 d	60 d				
C ₄	0.64	0.64	0.55 ^a	0.56 ^a	0.80 ^b	0.03	0.893	0.001	0.112
C ₆	2.48	2.34	2.26 ^a	2.31 ^a	2.66 ^b	0.04	0.011	0.001	0.298
C ₈	3.43	3.19	3.20 ^a	3.15 ^a	3.58 ^b	0.05	0.001	0.001	0.869
C ₁₀	13.36	12.94	12.72 ^a	12.68 ^a	14.04 ^b	0.15	0.030	0.001	0.961
10:1	0.43	0.45	0.40 ^a	0.43 ^{ab}	0.49 ^b	0.01	0.244	0.003	0.586
C ₁₂	6.26	6.55	6.11 ^a	6.36 ^{ab}	6.75 ^b	0.09	0.040	0.003	0.264
C ₁₄	10.96	11.56	11.18	11.32	11.28	0.08	0.001	0.673	0.213
C ₁₅	0.79	1.10	0.93 ^{ab}	0.99 ^a	0.91 ^b	0.03	0.001	0.028	0.045
C ₁₆	32.16	32.72	32.22	32.17	32.93	0.29	0.352	0.508	0.419
16:1	1.17	1.17	1.09	1.10	1.32	0.04	0.988	0.071	0.860
C ₁₈	5.98	5.19	6.16 ^a	5.87 ^a	4.73 ^b	0.20	0.023	0.004	0.952
18:1	18.16	18.03	18.69 ^a	18.76 ^a	16.83 ^b	0.23	0.673	0.001	0.041
18:2	3.04	3.11	3.31 ^a	3.22 ^a	2.70 ^b	0.09	0.625	0.009	0.966
18:3	0.54	0.36	0.41	0.36	0.58	0.08	0.238	0.475	0.320
CLA ²	0.51	0.57	0.65 ^a	0.62 ^a	0.36 ^b	0.03	0.114	0.001	0.969
C ₂₀	0.02	0.02	0.04	0.01	0.08	0.01	0.967	0.128	0.508
20:4	0.09	0.08	0.01	0.09	0.05	0.02	0.745	0.486	0.696

^{a,b}Within a row, means marked with different superscripts differ ($P < 0.05$). Values in bold are significant.

¹DC = concentrate diet; DF = forage diet; RSD = residual standard deviation.

²CLA = conjugated linoleic acid.

ripening stages was considerably lower, not only than that recorded for artisanal Majorero cheese using unpurified rennet pastes obtained by macerating kids' stomachs (Fontecha et al., 1990), but also compared with data from industrial Majorero cheeses using commercial rennet (Martín-Hernández et al., 1992).

Sensory Analysis. Results of the sensory evaluation of the DF and DC cheeses are shown in Table 7 for texture, odor and flavor descriptors, and preference attributes. Diet affected 4 of the 7 texture attributes. The DF cheeses were less firm and friable ($P < 0.001$), characterized by a higher moisture and solubility value. On the other hand, roughness, elasticity, and adhesiveness were very similar for both types of cheeses. Verdier Metz et al. (2000, 2002), comparing diets with different botanical species, found different values for firmness and solubility in the experimental cheeses.

The odor and aroma intensity were significantly higher for DF cheeses, with lactic and grass descriptors that could be correlated with the higher composition of medium-chain FA in the DF cheeses. These differences could be due to the presence in the milk of some chemical elements that came directly from the forage, which played a direct role in the odor and aroma or an indirect role in the ripening process (Martin and Coulon, 1995).

The DF cheeses were sweeter, with lower values for bitterness, acidity, pungency, and astringency characteristics. The DF cheeses were more appreciated by the expert panel, presenting higher values for texture, odor, flavor, and taste attributes.

The evaluation of expert judges was in agreement with a consumer panel (100 to 150 people, data not shown). Texture hedonic results could be related to the higher fat content in DF cheeses, with more solubility but less firmness and friability. Preference in taste could be related to less acidity and bitterness and also to lower trigeminal sensation values. Both judges and consumers preferred the DF cheeses in their odor and flavor evaluations because of the higher intensity and more complex descriptors (vegetable, fruity, and hay descriptors).

Ripening time affected all the sensory parameters analyzed. The odor and aroma intensity increased during ripening for both the DF and DC cheeses. This increase is associated with a progressive reduction of lactic family descriptors (Muir et al., 1997). As the cheeses matured and became drier, they became firmer and more crumbly. Trigeminal stimulation increased with the ripening process. Lemieux and Simard (1994) referred to a frequent correlation between bitterness and astringency; this started to appear slightly in the cheeses after 15 d and became stronger tasting at 60 d. The DF cheeses had a greater variety of odors and flavors than did the DC cheeses. The DF cheeses at 60 d of ripening presented vegetable and fruity characteristics as well as those of hay and dried fruit.

CONCLUSIONS

The use of a diet (DF) with a long fiber-to-concentrate ratio (65:35) based on forage adapted to arid conditions

Table 7. Influence of experimental diets (DC, DF) on cheese sensory properties¹

Item	LSM					RSD	Level of significance		
	Diet		Ripening time				Diet effect (D)	Ripening time effect (R)	D × R
	DF	DC	2 d	15 d	60 d				
Texture									
Roughness	1.75	1.68	1.52 ^a	1.88 ^b	1.74 ^c	0.02	0.072	0.001	0.019
Moisture	2.88	2.69	4.51 ^a	2.27 ^b	1.57 ^c	0.08	0.003	0.001	0.001
Elasticity	2.67	2.70	5.01 ^a	1.77 ^b	1.28 ^c	0.11	0.587	0.001	0.001
Firmness	3.03	3.70	3.09 ^a	1.88 ^b	5.13 ^c	0.09	0.001	0.001	0.013
Friability	2.94	3.31	2.32 ^a	1.88 ^b	5.13 ^c	0.11	0.001	0.001	0.001
Adhesivity	2.93	2.87	2.26 ^a	2.64 ^b	3.80 ^c	0.05	0.355	0.001	0.001
Solubility	4.58	4.14	1.76 ^a	5.77 ^b	5.57 ^c	0.12	0.001	0.001	0.001
Odor and flavor									
Saltiness	4.11	4.14	4.02 ^a	4.21 ^b	4.16 ^{ab}	0.03	0.579	0.001	0.081
Sweetness	0.88	0.17	0.91 ^a	0.00 ^b	0.66 ^c	0.05	0.001	0.001	0.001
Bitterness	0.71	1.46	0.00 ^a	1.04 ^b	2.21 ^c	0.07	0.001	0.001	0.001
Acidity	1.92	2.70	1.89 ^a	2.72 ^b	2.32 ^c	0.05	0.001	0.001	0.586
Pungent	0.50	1.46	0.00 ^a	0.52 ^b	2.42 ^c	0.08	0.001	0.001	0.001
Astringent	0.17	0.68	0.00 ^a	0.52 ^b	2.42 ^c	0.03	0.001	0.001	0.001
Residual taste	3.44	3.71	1.15 ^a	4.82 ^b	4.76 ^b	0.12	0.001	0.001	0.001
Taste persistence	3.99	3.74	2.26 ^a	4.64 ^b	4.70 ^b	0.09	0.011	0.001	0.001
Odor intensity	4.56	3.79	2.63 ^a	4.92 ^b	5.02 ^b	0.08	0.001	0.001	0.001
Flavor intensity	4.58	4.00	2.64 ^a	4.72 ^b	5.51 ^c	0.09	0.001	0.001	0.079
Preference									
Cut aspect	5.53	6.44	6.66 ^a	5.24 ^b	6.03 ^c	0.07	0.001	0.001	0.001
Texture	6.52	6.44	6.79 ^a	6.51 ^b	6.14 ^c	0.04	0.216	0.001	0.270
Odor	6.23	5.86	6.38 ^a	6.02 ^b	5.74 ^c	0.04	0.001	0.001	0.001
Flavor	6.25	5.17	6.38 ^a	5.43 ^b	5.32 ^b	0.06	0.001	0.001	0.001
Taste	6.05	5.32	6.41 ^a	5.73 ^b	4.91 ^c	0.06	0.001	0.001	0.018

^{a-c}Within a row, means marked with different superscripts differ ($P < 0.05$). Values in bold are significant.

¹DC = concentrate diet; DF = forage diet; RSD = residual standard deviation.

compared with another diet (DC) with a low fiber-to-concentrate ratio affected the quality of the cheese. Fat composition was higher in the DF cheeses, and this fact had an important effect on the medium-chain FA composition (C₆ to C₁₄). These chemical results could be related to particular sensory properties such as odor and flavor descriptors. Expert judges found differences in texture, odor, flavor, and taste. The DF cheeses were more appreciated by the expert panel and also by a consumer test. This fact could be due to less acidity and trigeminal sensation and more solubility, taste persistence, and odor and flavor intensity as well as the presence of vegetable, fruity, and dried fruit descriptors. This study demonstrates the importance of including long fiber from local forages in the diet of goat breeds in arid zones, especially when milk is transformed into PDO cheeses.

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REFERENCES

- Bas, P., H. Archimède, A. Rouzeau, and D. Sauvant. 1998. Influence of forage type and concentrate proportion, given to dry goats, on the duodenal microbial fatty acid composition. *Cahiers Options Méditerranéennes* 52:111–114.
- Berodier, F., P. Lavanchy, M. Zannoni, J. Cassals, L. Herrero, and C. Adamo. 1996. Guía para la evaluación olfato-gustativa de los quesos de pasta dura o semidura. AIR Project 2039. AIR, Poligny, France.
- Boletín Oficial Estado. 1996. Reglamento de la denominación de Origen Queso Majorera y de su Consejo Regulador. *Boletín Oficial Estado* 223:27883–27890.
- Buchin, S., B. Martin, D. Dupont, A. Bornard, and C. Achilleos. 1999. Influence of the composition of Alpine highland pasture on the chemical, rheological and sensory properties of cheese. *J. Dairy Res.* 66:579–588.
- Bugaud, C., S. Buchin, J. B. Coulon, A. Hauwuy, and D. Dupont. 2001. Influence of the nature of alpine pastures on plasmin activity, fatty acid and volatile compound composition of milk. *Lait* 81:401–414.
- Chilliard, T. 1982. Variations physiologiques des activités lipasiques et de la liopolysse spontanée s les laits de vache, de chèvre et de femme: Revue bibliographique. *Lait* 62:1–31, 126–154.
- Chilliard, Y., A. Ferlay, J. Rouel, and G. Lamberet. 2003. A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis. *J. Dairy Sci.* 86:1751–1770.
- Delacroix-Buchet, A., and G. Lamberet. 2000. Sensorial properties and typicity of goat dairy products. Pages 559–563 in *Proc. 7th Int. Conf. on Goats*. Int. Goat Association, Tours, France.

- Dils, R. R. 1986. Comparative aspects of milk fat synthesis. *J. Dairy Sci.* 69:404–410.
- Economides, S., E. Georgiades, A. Koumas, and M. Hadjipanayotou. 1989. The effect of cereal processing on the lactating performance of Chios sheep and Damascus goats and the pre-weaning growth of their offspring. *Anim. Feed Sci. Technol.* 26:93–104.
- Engel, E., S. Nicklaus, A. Gareu, C. Septier, C. Salles, and J. L. Le Quére. 2000. Taste active compounds in a goat cheese water-soluble extract. 1. Development and sensory validation of a model water-soluble extract. *J. Agric. Food Chem.* 48:4252–4259.
- Fontecha, J., C. Peláez, M. Juárez, T. Requena, C. Gómez, and M. Ramos. 1990. Biochemical and microbiological characteristics of artisanal hard goat's cheese. *J. Dairy Sci.* 73:1150–1157.
- Grappin, R., and J. B. Coulon. 1996. Terroir, lait et fromage: Éléments de réflexion. Pages 21–28 in *Proc. 3rd Rencontres Recherches Ruminants*, Paris, France. INRA, Paris, France.
- Gutiérrez, C., J. L. Rodríguez, and A. Fernández. 1999. Situación sanitaria de la Agrupación Caprina Canaria. *Ovis* 62:75–83.
- Ha, J. K., and R. C. Lindsay. 1993. Release of volatile branched-chain and other fatty acids from ruminal milk fats by various lipases. *J. Dairy Sci.* 76:677–690.
- Haenlein, G. F. W. 2004. Goat milk in human nutrition. *Small Rumin. Res.* 51:155–163.
- IDF (International Dairy Federation). 1982. Cheese and processed cheese—Total solids content (reference method). Standard FIL-IDF 4A. International Dairy Federation, Brussels, Belgium.
- IDF (International Dairy Federation). 1991. Milk and milk products. Fat content. General guidance on the use of butyrometric methods. Standard FIL-IDF 52. International Dairy Federation, Brussels, Belgium.
- IDF (International Dairy Federation). 1993. Milk nitrogen content. Standard FIL-IDF 220B. International Dairy Federation, Brussels, Belgium.
- INRA (Institut National de la Recherche Agronomique). 1990. Alimentación de bovinos, ovinos, y caprinos. Mundi-Prensa, Madrid, Spain.
- IRANOR (Instituto Nacional de Racionalización y Normalización). 1979. UNE 87-004; Análisis sensorial. Guía para la instalación de una sala de cata. IRANOR, Madrid, Spain.
- Lavanchy, P., J. Mège, F. Pérez Elortondo, L. Bivar, M. Scintu, P. Torre, P. Bárcenas, and S. Loygorri. 1999. Guía para la evaluación sensorial de la textura de quesos de pasta dura o semidura de leche de oveja. COST 95, EUR 18829. European Communities, Brussels, Belgium.
- Lemieux, L., and R. L. Simard. 1994. Astringency, a textural defect in dairy products. *Lait* 74:217–240.
- Le Queré, J. L., A. Pierre, A. Riaubanc, and D. Demaizieres. 1998. Characterization of aroma compounds in the volatile fraction of soft goat cheese during ripening. *Lait* 3:279–290.
- Letorneau, P., N. Bossis, J. Cherbonnier, C. Fouillard, M. Guillon, F. Jenot, A. Lauret, B. Poupin, and A. Reveau. 2000. Dossier: Les taux du lait de chèvre et leurs variations. *L'Éleveur de Chèvres* 7:1–7.
- Martin, B., and J. B. Coulon. 1995. Facteurs de production du lait et caractéristiques des fromages. II. Influence des caractéristiques des laits de troupeaux et des pratiques fromagères sur les caractéristiques du Reblochon de Savoie fermier. *Lait* 75:133–149.
- Martín-Hernández, M. C., M. Juárez, and M. Ramos. 1992. Biochemical characteristics of three types of goat cheese. *J. Dairy Sci.* 75:1747–1752.
- McGuire, M. A., and M. K. McGuire. 2000. Conjugated linoleic acid (CLA): A ruminant fatty acid with beneficial effects on human health. *Proc. Am. Soc. Anim. Sci. Annu. Mtg.* 1999. Available: <http://www.asas.org/jas/symposia/proceedings/0938> Accessed July 15, 2006.
- Meilgaard, M., G. Civille, and B. Carr. 1991. Selection and training of panel members. Pages 174–176 in *Sensory Evaluation Techniques*. 2nd ed. CRC Press, Boca Raton, FL.
- Morand-Fehr, P., and D. Sauvant. 1980. Composition and yield of goat milk as affected by nutritional manipulation. *J. Dairy Sci.* 63:1671–1680.
- Morand-Fehr, P., M. R. Sanz Sampelayo, Y. V. Fedele, Y. Le Frileux, M. Eknaes, P. H. Schmidely, S. Giger Reverdin, P. Bas, R. Rubino, O. Havrevoll, and D. Sauvant. 2000. Effects of feeding on the quality of goats milk and cheeses. Pages 53–58 in *Proc. 7th Int. Conf. on Goats*. International Goat Association, Poitiers, France.
- Muir, D. D., J. M. Banks, and E. A. Hunter. 1997. A comparison of the flavour and texture of Cheddar cheese of factory or farmhouse origin. *Int. Dairy J.* 7:479–485.
- Parodi, P. W. 1999. Conjugated linoleic acid and other anticarcinogenic agents of bovine milk fat. *J. Dairy Sci.* 82:1339–1349.
- Pirisi, A., G. Piredda, M. F. Scintu, and N. Fois. 2001. Effect of feeding diets on quality characteristics of milk and cheese produced from Sarda dairy ewes. *Options Méditerranéennes A* 46:115–119.
- Rook, J. A. 1976. Nutritional influence on milk quality. Pages 216–232 in *Principles of Cattle Production*. 1st ed. H. Swan and W. H. Broster, ed. Butterworths, London, UK.
- Sanz Sampelayo, M. R., L. Pérez, J. Boza, and L. Amigo. 1998. Forage of different physical forms in the diets of lactating Granadina goats: Nutrient digestibility and milk production and composition. *J. Dairy Sci.* 81:492–498.
- Sukhija, P. S., and D. L. Palmquist. 1988. Rapid method for determination of total fatty acid content and composition of feedstuffs and feces. *J. Agric. Food Chem.* 36:1202–1206.
- Suriyaphan, O., M. Drake, X. Chen, and K. Cadwallader. 2001. Characteristic aroma components of British farmhouse Cheddar cheese. *J. Agric. Food Chem.* 49:1382–1387.
- Verdier-Metz, I., J. B. Coulon, P. Pradel, C. Viallon, H. Albouy, and J. L. Berdagué. 2000. Effect of the botanical composition of hay and casein genetic variants on the chemical and sensory characteristics of ripened Saint-Nectaire type cheeses. *Lait* 80:361–370.
- Verdier-Metz, I., J. B. Coulon, P. Pradel, C. Viallon, and J. L. Berdagué. 1998. Effect of forage conservation (hay or silage) and cow breed on the coagulation properties of milks and on the characteristics of ripened cheeses. *J. Dairy Res.* 65:9–21.
- Verdier-Metz, I., P. Pradel, and J. B. Coulon. 2002. Influence of the forage type and conservation on the cheese sensory properties. Pages 606–607 in *Multi-function Grasslands: Quality Forages, Animal Products and Landscapes*. Vol. 7. J. L. Durand, J. C. Emile, C. Huygue, and G. Lemaire, ed. European Grassland Federation, Poitiers, France.
- Vermorel, M. 1990. Nutrición energética. Pages 55–69 in *Alimentación de Bovinos, Ovinos y Caprinos*. Mundi-Prensa, Madrid, Spain.
- Williams, C. M. 2000. Dietary fatty acids and human health. *Ann. Zootech.* 49:165–180.