Effect of feeding goats with leguminous shrubs (Chamaecytisus proliferus ssp. Palmensis and Bituminaria bituminosa) on milk and cheese properties

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ABSTRACT

Physical-chemical parameters, fatty acid profile and sensorial characteristics of experimental Palmero cheese from 2 equivalent groups of 20 Palmero goats fed 2 diets with different long fibre to concentrate ratio (65/35) or (35/65) with leguminous autochthonous forages (tagasaste and tedera) (DF) or wheat straw (DC) respectively as long fibre part of the ration were compared. A great influence on the milk basic composition from Palmero goats was observed when comparing dietary characteristics. Minimal effect on the fatty acid composition of the milk fat was observed but polyunsaturated fatty acids concentration was higher in DF milk. Cheeses were made on four consecutive days and were tested after 2, 15 and 60 days of ripening. Chemical composition was not significantly influenced by the diet while ripening affected all physicochemical parameters. Regarding fatty acids profile palmitic and linolenic acid concentration was higher in DC cheeses while DF cheeses presented higher linoleic values. The odour and aroma intensity was significantly higher for DF cheeses with the goat, butter and hay descriptors that can be correlated with a higher and better forage inclusion in the diet. DF cheeses were sweeter, with lower values for acidity and pungency stimulations and cause better appreciation by the expert panel.

1. Introduction

Feeding appears to be the most important factor affecting the content of goat milk nutrients, through the changes of the quantity and the nature of feeds ingested (Zervas and Tsiplakou 2011). The level of concentrate in the diet and the nature of the specific foodstuff affect the level of milk production and the characteristics of milk and milk products, and it can be difficult to divide their effects (Goetsch et al. 2011).

The physical form of the forage presentation, dietary fat supplements and/or the forage/concentrate ratio in the diet are aspects for special consideration in determining the fat content of the milk (Sanz Sampelayo et al. 2007).

Lipid composition affects the technological and nutritional quality of goat milk and is involved in cheese yield, firmness, colour and flavour of goat dairy products (Delacroix-Buchet and Lamberet 2000). The studies about the influence of ruminants’ feeding regime on sensorial characteristics are particularly valuable when the cheese has been awarded a Protected Designation of Origin (PDO), as it constitutes an important support of their relationship with the land (Grapin and Coulon 2000).

Diet may modify the sensory profile of dairy products (Martin et al. 2005; Coppa et al. 2011; Valdivielso et al. 2016); these effects can appear at different stages of cheesemaking (from moulding or only during ripening) and their magnitude differs according to the ripening time (Agabriel et al. 2004). The cheese flavour is mainly produced during the maturation of cheese from proteolysis that is, amino acids and peptides, and from lipolysis (Molimard et al. 1997) that is, short-chain and middle size-chain fatty acids.

In La Palma, a Canary island from Spain, a traditional cheese awarded with a PDO since 2002 is manufactured; the milk for making this cheese has to come only from the Palmera goat breed fed with local pasture resources. The Palmera breed is the most outstanding of the Canary goats, these animals are the most related to the pre-conquest goat populations. This type was probably the most isolated in La Palma Island over centuries that support their genetic differentiation (Martínez et al. 2006).

To guarantee their link with the territory, most of the Palmera PDO animals should be in extensive; when is not possible a large part of feed must come from local forages. Nowadays the semi-extensive producing farming system is based on a combination of concentrate with fresh shrub pasture. Tagasaste (Chamaecytisus proliferus ssp. palmensis) and tedera (Bituminaria bituminosa), are two of the main local forage resources, autochthonous legumes that have been used traditionally for feeding goats, but despite the adequate natural climate and soil conditions to be cultivated, these practices have been abandoned in the last decades as a consequence of different socioeconomic features. Besides in the last few years, there is a dangerous trend towards intensification and a notable increase in the use of concentrates in the diet that could reduce the quality of the milk and the cheeses produced.

This experimental trial is part of a Canarian PDO cheese project. The objective of this experiment was to determine...
the effect of two diets, one with a high long fibre to concentrate ratio (65/35), based on forages adapted to humid conditions, and another, with a low long fibre to concentrate ratio (35/65), on the physical-chemical and sensorial characteristics of Palmero cheese. In this sense, tagasaste and tedera have shown to be two of the most interesting species for its chemical composition and in vivo digestibility (Álvarez et al. 2004a, 2004b).

2. Material and methods

2.1. Experimental design and procedure

Two equivalent groups of 20 multiparous Palmero goats each were used. These animals had kidded in the traditional season (December), and the trial began in March (midlactation period). A 4 weeks period was made for goats feed adaptation. DF (forage diet) group was fed a diet of tedera (B. bituminosa) hay and tagasaste (C. proliferus), whereas only cereal straw as fibre source was supplied to the other group (DC, concentrate diet). To complete both diets a commercial concentrate for goat’s milk production and a mixture of maize, barley grain and dehydrated alfalfa was supplemented. The diet ingredients amounts were calculated to cover the maintenance and milk production requirements as INRA recommendations (INRA 1990). The concentrates amounted 35% (group DF) and 65% (group DC) of the total DM in the diet. The characteristics of the different rations are showed in Table 1 and 2. The quantities of each diet provided were calculated and controlled to ensure an identical supply of energy and protein.

2.2. Cheese samples

Milk produced by each of the two experimental groups was processed to make cheese. Eight cheesemaking productions in 4 consecutive days were processed in an experimental cheese factory placed in the Animal Production Unit; two 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 Palmero Cheese Designation of Origin Regulatory Board (European Union Regulation 1241/2002). The cheeses were made with raw milk on the same day as milking. After heating to 30 ± 1°C, animal rennet (commercial rennin powder, Marshall rennet power 50% quimosin and 50% pepsin) was added, following the manufacturer’s instructions, to obtain a 35 min clotting time. After coagulation, curds were cut to obtain grains the size of millet. Press process was the same for all cheeses: 4.9 kPa for 5 h. Subsequently, salting was achieved by rubbing dry salt onto the surface of the cheeses. Forty-two Palmero goat cheeses were used for this study: 21 DF and 21 DC. Seven cheeses were analysed from each group after 2, 15, and 60 days of ripening. Half of each cheese was used for the physico-chemical analysis and the other half was used for the sensory analysis. Cheese samples were coded with a letter and with a number. The cheeses were stored in a ripening chamber at 10–12°C and 85–86% relative humidity. For each ripening time, cheeses were sent to the laboratory in refrigerated boxes and a basic chemical analysis was performed immediately. Cheese samples were vacuum-packed and stored at −20°C for free fatty acids (FFA) analysis. Immediately before analysis, the samples were defrosted overnight at 20°C. For the sensory analysis, all samples were wrapped in aluminium sheets, stored under refrigerated conditions, and placed at room temperature (20 ± 1°C) for 2 h before testing.

2.3. Physicochemical analysis

2.3.1. Milk

The protein, fat, lactose and dry matter contents were measured in a representative sample taken from the vat of each cheese-making using a Milko-Scan 133B (Foss Electric, Slangerupgaard, Denmark). The pH value was determined using a pH meter InoLab Level 1 from WTW (Weilheim, Germany) at room temperature (20°C) by introducing a penetrometric electrode into the cheese. The pH value was determined at room temperature (20°C) using a pH meter InoLab Level 1 from WTW (Weilheim, Germany).

2.3.2. Cheese

Basic chemical composition analysis of cheeses was performed in triplicate using a near-infrared spectroscopy (Instalab 600, Foss Electric, Slangerupgaard, Denmark). 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 a pH meter InoLab Level 1 from WTW (Weilheim, Germany).

2.3.3. Free fatty acids

The extraction of total FFA and their qualitative and quantitative determination was performed using a modification of the method of Sukhiya and Palmquist (Sukhiya and Palmquist 1988). In particular, the fatty acid composition of milk and cheese fat was evaluated by gas chromatography. Fatty acid methyl esters were separated on an Autosystem gas chromatograph (Perkin-Elmer, Norfolk, CT, USA) fitted with an SP-2560 graph (Perkin-Elmer, Norfolk, CT, USA) and a 30 m DB-225 column (J&W Scientific, Folsom, CA, USA).

Table 1. Ingredient composition (g/kg) of the diets (DC, DF).

| Ingredient            | Diet<sup>a</sup> |       |       |
|-----------------------|------------------|-------|-------|
|                       | DF               | DC    |       |
| Commercial concentrate<sup>b</sup> | 161             | 304   |       |
| Barley grain          | 48               | 63    |       |
| Corn grain            | 48               | 51    |       |
| Lucerne pellets<sup>b</sup> | –               | 304   |       |
| Tagasaste             | 582              | –     | –     |
| Tedera                | 161              | –     | –     |
| Wheat straw           | –                | 278   |       |

<sup>a</sup> Diet: DC = concentrate diet and DF = forage diet.
<sup>b</sup> Commercial concentrate and lucerne pellets, Biona, Santa Cruz de Tenerife, Spain.

Table 2. Chemical composition and net energy content of the diets (DC, DF).

|                   | Diet<sup>a</sup> |       |       |
|-------------------|------------------|-------|-------|
|                   | DF               | DC    |       |
| DM, %             | 59.2             | 89.2  |       |
| OM, % of DM       | 89.1             | 92.8  |       |
| CP, % of DM       | 16.2             | 15.8  |       |
| NDF, % of DM      | 40.6             | 43.2  |       |
| ADF, % of DM      | 25.4             | 28.7  |       |
| ADL, % of DM      | 12.7             | 5.8   |       |
| Metabolic energy, MJ/kg of DM | 9.9 | 10.4 |       |

<sup>a</sup> Diet: DC = concentrate diet and DF = forage diet.
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°C 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 N2. Injector and detector temperatures were 250°C and 300°C, respectively. The peaks for individual fatty acids (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).

2.4. Texture analysis

The textural analysis was performed in a texturometer TA-Xt2i (Stable Micro Systems, Surrey, UK), with a load cell of 5 kg, by carrying out a texture profile analysis (TPA). Prior to TPA, a 0.5-cm layer was removed from the upper surface of the cheese to obtain a regular surface for probe compression, analyses were performed at 20 ± 2°C under lubricated conditions to eliminate frictional effects. Six representative samples of each cheese were cut into cylinders with a 40-mm diameter and a 60-mm height and used for a compression test. This test was performed at 20 ± 2°C using a 50-mm diameter cylindrical flat probe; a compression of 75% and a crosshead speed of 2 mm/s. From the force vs. time texturomgrams, six parameters were obtained for compression: hardness (N), fracturability (N), adhesiveness (N.s), cohesiveness, elasticity and gumminess. The interpretation of these texture parameters was made in accordance with the methods advocated by Bara-Herczegh et al. (2002).

2.5. Colour measurement

Internal colour was recorded using a portable MINOLTA spectro-colourimeter (Minolta CR-400, Osaka, Japan). The L* (lightness), Croma and Hue Angle colour measurements were determined according to the CIELCH colour space, where L* corresponds to light/dark chromaticity (changing from 0% dark to 100% light), colour intensity was recorded using the Croma value and Hue angle was used as a measure of colour tone. The instrument was calibrated with a white tile prior to measuring. Each colour test was performed on 10 replicates inside the cheese.

2.6. Sensory analysis

Sensory analyses were carried out at 2, 15, and 60 days of ripening. Samples, coded with random three-digit codes, were presented in a balanced way 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 sensory methodology used has been described previously (Álvarez et al. 2007a; Fresno and Álvarez 2012); odour and flavour attributes were in accordance with those described by Beródier et al. (1996) and texture followed the guidelines published by Lanchchey et al. (1999). This methodology has been adapted to goat cheeses by Fresno and Álvarez (2007).

2.7. Statistical analysis

The software package SPSS version 15.0 (SPSS Inc., Chicago, IL, USA) was used for statistical processing of the results. A general linear model (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 two factors. Post hoc multiple analyses by Tukey’s test were used for the ripening time factor.

3. Results and discussion

3.1. Physicochemical characteristics

3.1.1. Milk

Milk basic composition for Palmero goats fed different diets (DC, DF) is showed in Table 3. All the parameters considered fall within the range of values to be expected for Palmero goat milk. A great effect on the milk basic composition from Palmero goats was observed when comparing dietary characteristics. Only fat content, presenting high values, was similar between diets. No significant differences were found in similar studies (Pirisi et al. 2001).

Contrary to the results reported by Álvarez et al. (2007a) in a similar experiment for Majorera goat, and in others with Alpine goats where different quantity and composition of concentrate was given to the goats (Min et al. 2005), an increase of fat content in DF group was not observed. This fact could be explained from a greater influence of genetic factors in this type of rustic goats (Martinez et al. 2006). Besides in literature, it is described that inadequate rations could derive in minor milk yields, as occurred in this experiment (Álvarez et al. 2007b), without substantially changing the content thereof (Ramos and Juárez 1981) so that females tend to produce milk of uniform composition (Sachdeva et al. 1974).

Furthermore, physicochemical characteristics of diets (e.g. particle size and non-extreme concentrate : forage levels) have only indirect effects on milk fat concentration via energy intake as influencing milk yield and dilution (Goetsch et al. 2011). On the other hand, in intensive indoor systems, the farmer tends to improve milk yield by modifying the ratio of forage to concentrate (F/C) of the diets, more often by increasing concentrate supply. Usually, in these cases, milk fat content tends to decrease when the amount of ingested concentrates increases (Morand-Fehr et al. 2007).

According to previous results, even as relatively low CP values for both diets were determined, a significant difference between both types of milk was observed (P < .001). Although
as in other ruminants, nutritional factors in goats minimally change the relative proportions of the different proteins and amino acids in milk (Min et al. 2005), in this case it appears that the inclusion in the diet of rich forage shrubs (tagasaste and tedera), with a significant proportion of digestible protein (Álvarez et al. 2004a, 2004b), were able to induce a higher protein content in DF milk group.

Lactose, DM and non-fat solids parameters presented higher values for DF milk (P < .001). These results that showed an increase of CP content and DM content in DF milk can be used by PDO technicians to advise farmers not to increase the percentage of concentrates in the ration above the recommended values. As all Palmero goat milk is transformed in artisanal cheese, better DF cheese yield results (S. Álvarez, unpublished data) could support this proposal. The pH represents the parameter that most influences the behaviour in milk coagulation (Pirisi et al. 2001). The pH value differed substantially between diets (P < .001).

Table 4 shows the fatty acid composition of the milk fat from goats fed each diet. In the same way as other authors reports for goat milk (Álvarez et al. 2007a) the most abundant fatty acids in both groups were capric, myristic, palmitic and oleic acids. Medium-chain fatty acids (6–14 carbons) amounted 35.4% and 35.7% of the total milk fatty acids from the DF and DC groups respectively. Goat milk is specifically rich in C6:0, C8:0 and C10:0 fatty acids, termed as caproic, caprylic and capric because of the milk in which they are preferentially found; these three fatty acids form up to 15–18% of goat milk, but only 5–9% of cow milk (Sanz Sampelayo et al. 2007). These acids are of special interest from a medicinal point of view, because of their particular metabolism and hence their application to certain cases of metabolic illness (Haenlein 2004).

Furthermore, the concentration in free FA with less than 11 atoms of carbon plays a significant role in the development of specific organoleptic characteristics as goaty flavour (Zervas and Tsiplakou 2011).

Table 4. Fatty acid composition (percentage) of milk fat for Palmero goats fed different diets (DC, DF).

|       | DF       | DC       | RSD | Level of significance |
|-------|----------|----------|-----|-----------------------|
| C4:0  | 0.54     | 2.07     | 0.03| 0.977                 |
| C6:0  | 2.21     | 3.05     | 0.04| 0.150                 |
| C8:0  | 12.34    | 11.61    | 0.11| 0.786                 |
| C10:0 | 0.43     | 0.44     | 0.01| 0.759                 |
| C12:0 | 5.97     | 6.12     | 0.07| 0.298                 |
| C14:0 | 11.25    | 11.61    | 0.88| 0.036                 |
| C15:0 | 0.89     | 0.98     | 0.35| 0.222                 |
| C16:0 | 31.86    | 33.11    | 0.42| 0.146                 |
| C16:1 | 1.27     | 1.21     | 0.03| 0.388                 |
| C18:0 | 7.63     | 6.31     | 0.27| 0.005                 |
| C18:1 | 18.57    | 18.23    | 0.29| 0.578                 |
| C18:2 | 2.84     | 2.84     | 0.09| 0.984                 |
| C18:3 | 0.36     | 0.26     | 0.02| 0.011                 |
| CLA   | 0.60     | 0.57     | 0.04| 0.747                 |
| C20:0 | 0.07     | 0.03     | 0.01| 0.189                 |
| C20:4 | 0.10     | 0.09     | 0.02| 0.702                 |

Note: LSM = least square mean; RSD = residual standard deviation; values in bold are significant.

As in other ruminants, nutritional factors in goats minimally change the relative proportions of the different proteins and amino acids in milk (Min et al. 2005), in this case it appears that the inclusion in the diet of rich forage shrubs (tagasaste and tedera), with a significant proportion of digestible protein (Álvarez et al. 2004a, 2004b), were able to induce a higher protein content in DF milk group.

Minimal effect on the milk fatty acid composition was observed when comparing different diets. The milk fat content of both milks (DF vs. DC) did not change because of modifications in the diet, so minimum fatty acid composition changes were expected. Other authors (Álvarez et al. 2007a) have observed these minimal changes in similar studies with experimental diets.

Other studies have shown that milk from sheep and goats in pasture is naturally enriched in fat-soluble vitamins, terpenes, unsaturated FA and CLA, in addition to being naturally high in medium-chain FA in comparison to those fed conventional concentrate-forage diets (Chilliard et al. 2006; Lucous et al. 2008). Unsaturated fatty acids proportion was higher in DF milk maybe due to the inclusion of natural rich forages as tagasaste and tedera.

C14:0 presented higher values for DC diet (P < .05) while C18:0 and C18:3 contents were favourable for DF diet (P < .01). Polyunsaturated fatty acids (PUFAs) are not synthesized by tissues in ruminants, and therefore their concentration in milk is closely related to the quantities absorbed in the intestine (Chilliard et al. 2006). PUFAs concentration was higher in DF milk. These quantities may be increased by dietary PUFA intake and by factors which affect rumen hydrogenation, such as high forage/concentrate ratio.

Goat microbial population synthesizes significant concentrations of lipids. These lipids contain high levels of medium-chain fatty acids. The proportion and type of forage may determine the composition of these microbial lipids, especially that of the C18:0/C18:1 ratio, higher in DF milk (0.41 vs. 0.34). Rations higher in fibre cause specific rumen bacterial populations, as measured by a higher content of branched-chain fatty acids in milk fat (Elgersma et al. 2006).

### 3.1.2 Cheese

Table 5 shows the basic cheese composition (pH, moisture, fat, protein and fat in dry matter) for Palmero goats fed different diets (DC, DF) at 2, 15 and 60 days of ripening. Chemical composition was not significantly affected by the diet. Both fat and fat, % of TS, contents were similar between different types of diets. This result may be due to the similar content in fat for DC and DF milk composition. Comparable results were observed by Pirisi et al. (2001) when ruminants fed different diets (concentrate vs. pasture).

Although the other contents of the milk analysed were different for both types of diet, these contents did not affect cheese composition. Ripening time affected all physicochemical parameters. Fat and protein contents rose significantly over the ripening period, while moisture decreases. The pH decreased up to 15 days and increased considerably till then to the end of the ripening period. The moisture and protein values were considerably higher than those determined by Fresno and Álvarez (2012) for Palmero cheese from PDO factories, while the fat content was lower.

Table 6 shows the fatty acid composition (percentage) of cheese fat from DF and DC groups. Goats feeding had limited effects on C6–C14 (medium-chain) fatty acid composition. Only the concentration of miristic acid differed between the two groups. The cheese from goats fed DC diet (P < .05) had lower percentages than did the cheese from goats fed DF...
diet. Contrary to the results described by Álvarez et al. (2007a) in a similar study with Majorero goats comparing diets with high and low ratios of long fibre to concentrates significant differences in short and medium-chain fatty acid composition were not detected. The characteristic flavour of goat cheese is particularly affected by milk content of short-chain fatty acids (C6–C10) and of branched-chain fatty acids with less than 11 atoms of carbon, mainly when these fatty acids are in free form (Chilliard et al. 2003).

Within long chain fatty acids, diet effect was higher, palmitic and linolenic acid concentration was higher in DC cheeses (P < .001) while DF cheeses presented higher linoleic values (P < .05). Unsaturated fatty acids amounted 22.78% and 22.17% (P < .001) while DF cheeses presented higher linoleic values (P < .001) while DF cheeses presented higher linoleic values (P < .001). Values in bold are significant.

As has been described by other authors in goat cheeses (Álvarez et al. 2007a) fatty acid composition differed substantially between different ripening times. C6–C14 fatty acids had similar concentrations at 2 and 60 days ripening time, decreasing their values at the middle stage of maturity (15 days) and increasing thereafter till the end of ripening. An opposite fluctuation was recorded for stearic, oleic and linolenic acids, increasing their values till 15 days and decreasing later to 2 months of ripening, reaching similar values to the beginning of maturation. Oleic and linoleic acids have beneficial cardiovascular and anti-inflammatory properties for human health (Williams 2000).

Among the many origins of the specific goat milk flavour and taste are the C6–C10 fatty acid concentration, being caprylic acid (C8) the one mainly responsible, which provides a sought-after flavour for this type of cheeses, not detected in cow milk products (Salles et al. 2002). The intensity of aavour depends on the proportion of these acids in the milk lipids but also on the intensity of lipolysis during cheesemaking and ripening process. Medium-chain fatty acids had significantly higher levels at 60 days ripening cheeses (P < .005). The proportion of short-chain fatty acids in the three ripening stages was considerably higher than that recorded for other Canarian experimental goat cheeses (Álvarez et al. 2007a). In opposition, PUFA proportion was lower.

### 3.2. Texture

The mean values obtained for texture attributes of TPA during ripening for the two diets evaluated are presented in Table 7. Ripening period revealed significant changes for most of the textural parameters analysed (P < .001) except cohesiveness (P = .058). Hardness, adhesiveness and gumminess increased from 2 to 60 days of ripening, while fracturability decreased till 15 days and the increased again till 60 days and elasticity

### Table 5. Cheese composition for Palmero goats fed different diets (DC, DF). (P < .001) except cohesiveness (P = .058). Hardness, adhesiveness and gumminess increased from 2 to 60 days of ripening, while fracturability decreased till 15 days and the increased again till 60 days and elasticity

| Diet | DC | 2 days | 15 days | 60 days | RSD | Diet effect (D) | Ripening time effect (R) | D × R |
|------|----|--------|---------|---------|-----|-----------|----------------|--------|
| Moisture (%) | 42.25 | 42.32 | 46.80 | 42.14 | 37.91 | .04 | .868 | .001 | .239 |
| Protein (%) | 21.92 | 21.94 | 20.14 | 22.97 | 22.69 | .20 | .938 | .001 | .288 |
| Fat (%) | 26.56 | 26.88 | 20.99 | 27.84 | 31.33 | .51 | .454 | .001 | .379 |
| Fat (% TS) | 45.63 | 46.31 | 39.44 | 48.03 | 50.39 | .56 | .129 | .001 | .434 |
| Protein (% TS) | 38.09 | 38.09 | 37.87 | 39.73 | 36.58 | .30 | .917 | .001 | .065 |
| pH | 5.86 | 5.78 | 6.54 | 5.41 | 5.51 | .06 | .108 | .001 | .094 |

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

### Table 6. Fatty acid composition (percentage) of cheese fat from Palmero goats fed different diets (DC, DF). (P < .001) except cohesiveness (P = .058). Hardness, adhesiveness and gumminess increased from 2 to 60 days of ripening, while fracturability decreased till 15 days and the increased again till 60 days and elasticity

| Fatty acid | C6 | C8 | C10 | C12 | C14 | C16 | C18 | C20 | CLA | C22 | C24 |
|-----------|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| C6:0 | 0.71 | 0.74 | 0.75 | 0.63 | 0.79 | 0.04 | 0.06 | 0.71 | 0.60 | 0.02 | 0.06 |
| C8:0 | 2.66 | 2.59 | 2.65 | 2.38 | 2.83 | 0.07 | .493 | .023 | .599 |
| C10:0 | 3.71 | 3.60 | 3.76 | 3.34 | 3.85 | 0.07 | .341 | .002 | .725 |
| C12:0 | 13.65 | 13.58 | 13.96 | 12.55 | 14.34 | 0.21 | .827 | .001 | .486 |
| C14:0 | 0.46 | 0.46 | 0.47 | 0.44 | 0.47 | 0.01 | .842 | .276 | .453 |
| C16:0 | 6.08 | 6.10 | 6.06 | 5.79 | 6.41 | 0.08 | .894 | .005 | .567 |
| C18:0 | 11.29 | 11.57 | 11.39 | 11.21 | 11.67 | 0.08 | .043 | .028 | .190 |
| C20:0 | 0.78 | 0.79 | 0.75 | 0.83 | 0.77 | 0.01 | .691 | .091 | .145 |
| C22:0 | 31.78 | 32.85 | 32.42 | 32.35 | 32.18 | 0.15 | .001 | .712 | .157 |
| C24:0 | 1.29 | 1.20 | 1.29 | 1.24 | 1.21 | 0.02 | .060 | .411 | .178 |
| C18:1 | 6.56 | 6.02 | 6.03 | 6.92 | 5.92 | 0.19 | .128 | .048 | .286 |
| C18:2 | 17.85 | 17.54 | 17.36 | 19.03 | 16.70 | 0.26 | .420 | .001 | .138 |
| C18:3 | 2.51 | 2.27 | 2.38 | 2.30 | 2.28 | 0.06 | .049 | .314 | .069 |
| CLA | 0.23 | 0.30 | 0.27 | 0.31 | 0.21 | 0.03 | .218 | .190 | .527 |
| C20:3 | 0.40 | 0.35 | 0.42 | 0.40 | 0.31 | 0.02 | .087 | .005 | .069 |
| C20:4 | 0.02 | 0.02 | 0.02 | 0.04 | 0.01 | 0.01 | .891 | .388 | .981 |
| C20:5 | 0.04 | 0.05 | 0.04 | 0.05 | 0.04 | 0.01 | .757 | .937 | .376 |

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

"- Within a row, means marked with different superscripts differ significantly (P < .001). Values in bold are significant.
decreased at a level of 30% at the end of the ripening period. These results are partially in accordance with those reported by Fresno et al. (2006) and Fresno and Álvarez (2012) studying another Canarian cheese, Majorero PDO where fracturability also increased and elasticity decreased just 10%. Pinho et al. (2004) analysing Terrincho cheese observed an increase in fracturability, hardness, adhesiveness and gumminess up to 30 days and afterwards a decrease to the end of maturation. Diet did not affect instrumental texture characteristics.

### 3.3. Colour

Results of diet and ripening effect on internal cheese colour are shown in Table 7.

As was described for texture parameters diet did not affect colour characteristics either. Ripening affected all colour parameters. Internal lightness decreased along maturation as has been described by Fresno and Álvarez (2012) for other Canarian cheese. Croma, representing the colour intensity, increased till 15 days and then become constant till 60 days ripening.

Colour intensity increase could be related to higher proteolysis and also an indirect correlation can be evidenced between moisture and colour (Tejada et al. 2007). These Palmero cheeses were lighter and had a higher tone value but presented a lower chroma value than other experimental Palmero cheeses (Fresno et al. 2006).

### 3.4. Sensorial analysis

Table 8 shows the least square means and the ANOVA results for the sensory attributes of cheeses from DF and DC diets ripened for 2, 15 and 60 days.

#### 3.4.1. Diet effect

Diet affected three of the nine texture attributes. This low diet effect on texture properties could be related to the null level of significance found in basic cheese composition. DF cheeses were less firm than DC cheeses (P < .01), characterized by a

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### Table 7. Instrumental texture and colour of Palmero cheese made from goats fed different diets (DC, DF)1.

| Diet | Fracturability | Hardness | Cohesiveness | Adhesiveness | Elasticity | Gumminess | Lightness | Hue Angle |
|------|----------------|----------|--------------|--------------|------------|-----------|-----------|-----------|
| DC   | 32.17          | 0.16     | 0.57         | 53.11        | 352.4      | 406.8     | 86.01     | 15.11     |
| DF   | 27.66          | 0.15     | 0.61         | 52.47        | 352.4      | 358.75    | 85.42     | 14.93     |
| 2 days | 32.17          | 0.16     | 0.57         | 53.11        | 352.4      | 406.8     | 86.01     | 15.11     |
| 15 days | 16.99          | 0.16     | 0.29         | 42.29        | 352.4      | 358.75    | 85.42     | 14.93     |
| 60 days | 32.63          | 0.15     | 0.57         | 42.29        | 352.4      | 358.75    | 85.42     | 14.93     |
| RSD  | 1.30           | 0.70     | 0.26         | 1.26         | 1.26       | 2.70      | 0.38      | 0.38      |

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

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### Table 8. Influence of ripening (2, 15 and 60 days) and experimental diets (DC, DF) on cheese sensory properties1.

| Diet | Texture | Ripening time | Level of significance |
|------|---------|---------------|-----------------------|
|      |         | 2 days | 15 days | 60 days | RSD | Diet effect (D) | Ripening time effect (R) | D × R |
|      |         | DF     | DC     | DF     | DC     | 0.05 | .615 | .001 | .615 |
|      |         | 1.48   | 1.67   | 1.00a  | 2.00b  | 1.98b | .05  | .615 | .001 |
|      |         | 3.44   | 3.02   | 4.75c  | 4.75c  | 3.00b | 2.31a | .05  | .615 |
|      |         | 5.07   | 3.85   | 6.00a  | 2.42a  | 2.42a | .28  | .708 | .001 |
|      |         | 2.47   | 2.94   | 2.25a  | 2.25a  | 2.42a | .32  | .708 | .001 |
|      |         | 3.00   | 2.86   | 2.50a  | 2.50a  | 2.33a | .36  | .708 | .001 |
|      |         | 2.39   | 2.22   | 1.90a  | 1.90a  | 2.17a | .33  | .708 | .001 |
|      |         | 4.13   | 4.17   | 6.00a  | 5.50a  | 5.50a | .33  | .708 | .001 |
|      |         | 3.80   | 3.96   | 4.33a  | 5.00i  | 5.00i | .33  | .708 | .001 |
|      |         | 1.69   | 1.44   | 1.56b  | 1.13a  | 1.73b | .33  | .708 | .001 |

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

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Within a row, means marked with different superscripts differ significantly (P < .01). Values in bold are significant.
higher superficial and mouth moisture. Álvarez et al. (2007a) in a similar study found comparable results for firmness although they described significant diet influence also in friability and solubility parameters.

Moreover roughness, elasticity, friability, adhesivity, solubility and granularity were very similar for both types of cheeses. In terms of texture, both DF and DC cheeses were observed to be quite elastic, adhesive and soluble but presenting low granularity level. Other authors have recorded different texture results when comparing different diets. Thereby Verdier-Metz et al. (2005) found more gritty Saint Nectaire cheeses but less melting and mellow Cantal cheeses comparing grass silage vs. hay. As well, Carpino et al. (2004), in Ragusano cheese using total mixed rations with or without pasture complement determined less oily but higher fracturability in the latter.

Analysing odour and flavour descriptors, the type of diet used for feeding the goats only affected significantly \((P < .05)\) sweetness, bitterness and odour and flavour intensity. The other trigeminal stimulations values were similar for both types of cheeses. This moderate influence of diet was not totally shared in other goat cheeses (Álvarez et al. 2007a) where nearly all descriptors were affected. The origin of flavour differences is generally difficult to interpret. They could result from differences in the fatty acid composition according to diets consumed (Martin et al. 2005). Certain fatty acids, unsaturated ones in particular, may be degraded by microbial enzymes in the rumen and produce compounds responsible for cheese and other dairy products aromas (Urbach 1990).

The odour and aroma intensity was significantly higher for DF cheeses with lactic and grass descriptors that can be correlated with a higher and better forage inclusion in the diet. Carpino et al. (2004) have found that cow pasture cheeses were much more rich in odour-active aldehyde, ester, and sulphur compounds than cheeses from cows fed only total mixed ration. As already pointed out in advance by Martin and Coulon (1995) the differences in odour and aroma can be due to the presence in the milk of some chemical elements which come directly from the forage. In the same way, Gaborit et al. (2002) contrasting maize silage with lucerne hay diets in fresh and ripened goat cheeses found different intense flavour with oxidized, fermented and bitter descriptors.

Cheeses made from autochthonous forage diet had a greater variety of odours and flavours due to the odouriferous presence of tagasaste and teda forages in the diet. The DF cheeses presented more complex odour and aroma descriptors (Table 9). Higher scores were recorded for hay, butter and goaty characteristics while lactic acid odour and rancid flavour were appreciated in higher proportions in DC cheeses. The odour and flavour profile is a crucial aspect, it could be considered as a cheese fingerprint and is directly responsible for consumer’s acceptance (Niimi et al. 2016, Rincón et al. 2016).

DF cheeses were sweeter, with lower values for acidity and pungency stimulations. These characteristics, joint to the higher odour and flavour intensity, induce a better appreciation by the expert panel, with higher values for cut aspect and flavour attributes. Although no significant differences were detected, odour and taste preferences were also better for DF cheeses.

### 3.4.2 Ripening effect

Ripening time affected all the sensory parameters analysed (Table 8). The sensorial properties of ripened cheeses are more strongly related to the ripening parameters than to the sensorial properties of the raw material (Morgan and Gaborit 2001). Regarding texture attributes, superficial moisture, adhesivity and solubility decreased during ripening while firmness, friability and mouth moisture, with similar values in 2- and 15-day cheeses, increased till the end of the ripening period. Similar results were recorded by Rincón et al. (2017) in goat cheeses ripening when comparing different ratios of banana silage in the diet.

Elasticity and granulosity presented an irregular fluctuation, decreasing till 15 days and increasing moderately thereafter. The trigeminal stimulation increased with the ripening process although acidity values increased till 15 days, decreasing till 2 months of maturation.

The milk lipolysis in the ripening of cheeses produces free fatty acids, among other compounds, which directly or

### Table 9. Influence of ripening (2, 15 and 60 days) and experimental diets (DC, DF) on cheese odour and flavour specific descriptors\(^1\).

|     | Diet | Ripening time | LSM | Level of significance | RSD | Diet effect (D) | Ripening time effect (R) | D × R |
|-----|------|---------------|-----|-----------------------|-----|-----------------|--------------------------|-------|
|     |      | 2 days | 15 days | 60 days |     |     |     |     |
| Odour |      |       |       |       |     |     |     |     |
| Goaty | 1.12 | 0.56   | 0.00   | 2.52   | 0.00 | 0.24 | .001 | .001 |
| Lactic acid | 0.00 | 1.5    | 1.08   | 0.17   | 0.00 | 0.18 | .001 | .001 |
| Butter | 2.39 | 1.43   | 1.63   | 0.00   | 4.1  | 0.38 | .001 | .001 |
| Hay | 2.71 | 0.00   | 1.13   | 1.69   | 1.26 | 0.27 | .001 | .001 |
| Dry fruits | 0.72 | 0.86   | 0.00   | 0.00   | 2.37 | 0.24 | .001 | .088 |
| Rancid | 0.22 | 0.00   | 0.00   | 0.00   | 3.33 | 0.08 | .150 | .088 |
| Flavour |      |       |       |       |     |     |     |     |
| Goaty | 1.08 | 0.61   | 0.00   | 2.54   | 0.00 | 0.24 | .001 | .001 |
| Rennet | 0.75 | 0.72   | 2.21   | 0.00   | 0.00 | 0.19 | .631 | .001 |
| Lactic acid | 1.46 | 1.69   | 1.13   | 2.31   | 1.29 | 0.23 | .154 | .001 |
| Butter | 2.09 | 1.41   | 1.53   | 0.00   | 4.11 | 0.37 | .001 | .001 |
| Hay | 2.68 | 0.00   | 1.12   | 1.56   | 1.33 | 0.27 | .001 | .069 |
| Dry fruits | 0.72 | 0.79   | 0.00   | 0.00   | 2.26 | 0.22 | .397 | .415 |
| Rancid | 0.22 | 0.00   | 0.00   | 0.00   | 0.50 | 0.10 | .066 | .001 |

\(^1\) Diet: DC = concentrate diet and DF = forage diet; RSD: residual standard deviation.

Within a row, means marked with different superscripts differ significantly \((P < .05)\). Values in bold are significant.
indirectly contribute to the final flavour characteristics (Delgado et al. 2011; Kalit et al. 2014). Goaty odour and aroma characterized 15-day cheeses. The taste persistence joint to the odour and aroma intensity increased during ripening, reaching the highest values at 2 months cheeses. Sixty days DF cheeses presented butter and dried fruits characteristics. Lactic descriptors, as milk, whey and yogurt, relevant in 2- and 15-day cheeses, diminished its importance at the end of the ripening time.

4. Conclusions

When using a diet (DF) with long fibre to concentrate ratio (65/35) based on autochthonous rich forages compared with another (DC), with a low fibre to concentrate ratio with imported wheat straw the quality of milk and cheese is affected.

Although milk and cheese composition was not highly influenced, the sensorial profile of the cheeses was different. Expert judges had found differences in texture, odour, flavour and taste. DF cheeses were more appreciated by the expert panel. This result can be due to a less bitterness and sweeter sensation with higher odour and flavour intensity and the presence of goat, butter and hay descriptors.

For PDO cheeses like Palmero cheese closely linked to natural local forage resources, experimental diet studies are very important for demonstrating influence of feeding the goats.

Funding

This study was supported financially by the INIA RTA-01-092 Project and DOQUECAN (Canarian Government, Spain) Project.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This study was supported financially by the INIA RTA-01-092 Project and DOQUECAN (Canarian Government, Spain) Project.

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