Effect of the inclusion of artichoke silage in the ration of lactating ewes on the properties of milk and cheese characteristics during ripening

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ABSTRACT

The effect of including artichoke silage in the rations of dairy ewes on milk characteristics and biochemical changes of ripened cheeses was evaluated. Four groups of lactating ewes were fed rations containing 0, 10, 20, or 30% artichoke silage on a dry matter basis. Bulk milk samples were collected 3 times during the feeding period, and semi-hard cheeses were manufactured and sampled during ripening. Milk composition and cheese yield were not affected by diet. Inclusion of 20 and 30% artichoke silage reduced the firmness of the curds at a level only detected by the Gelograph (Gelograph-NT, Gel-Instrumente, Thalwil, Switzerland) probe. Inclusion of artichoke silage in ewes' diet decreased fat and total free fatty acids content of these cheeses and increased total free amino acids content. Despite the effect of diet on cheese ripening characteristics, the overall sensory scores for cheeses corresponding to artichoke silage diets were statistically higher than those for the control cheeses.

Key words: artichoke silage, dairy ewe, milk coagulation, cheese ripening

INTRODUCTION

Semi-intensive and intensive dairy ruminant production is characterized by a high demand and dependence on mixed cereals, which are expensive and require extensive cropland areas. The use of by-products from the vegetable processing industry can be a less expensive source of nutrients suitable for ruminant feeding because of the ruminant's capacity to digest fiber-rich feedstuffs. Furthermore, the use of these by-products can be an alternative for the food industry to diminish waste discharges and to reduce waste management costs.

Artichoke by-products have been traditionally included in the diet of dairy cows in areas with local availability (Martínez et al., 1998). However, the seasonal nature and high water content of this by-product limit its utilization in animal feeding. To address this concern, an evaluation of the ensiling capacity of the artichoke agro-industrial by-product and the phytosanitary, fermentative, and nutritive characteristics of the silage made from these residues has been conducted (Meneses et al., 2007). According to that study, artichoke by-products are suitable for ensiling and can be used as animal feed without health risks. Silages were reported to have an acceptable composition (88 g/kg of CP on a DM basis and 509 g/kg of NDF) and no presence of phytosanitary residues after 12 d of ensiling. Even though several studies deal with the quality of fermentation, content of volatile fatty acids, and the digestibility of artichoke silage (Megías et al., 1991, 1997; Madrid et al., 1999), the literature reports only a few results about the effect of feeding animals with artichoke residues on the quality and composition of milk or meat (Galvano and Scerra, 1983; Bonomi et al., 2004a,b; Marsico et al., 2005). For instance, substitution of alfalfa meal with artichoke leaf meal did not compromise animal health and increased milk production of dairy goats (Bonomi et al., 2004a), and had no effect on milk production and composition when it was offered to dairy ewes (Bonomi et al., 2004b). In another study, diets based on artichoke bracts given to lambs and kids had an effect on meat composition, so that water and protein content increased and the levels of some fatty acids of meat fat were affected (Marsico et al., 2005). Evaluation of other crop by-products has demonstrated that if diets supplemented with these alternative feed resources are carefully formulated and supply the animal nutritional requirements, their use does not compromise milk quality and production in small ruminants (Vasta et al., 2008). It is well known that animal nutrition determines not only the composition of milk but also its technological properties and the quality of derived products. Furthermore, feeding strategies such as type of forage, conservation method,

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Table 1. Ingredients and composition of the experimental rations with 0, 10, 20, and 30% artichoke silage (AS) fed to dairy ewes

Item	Ration (% AS)			
	0	10	20	30
Ingredients (g of DM per day)				
Artichoke silage	0	250	500	750
Barley grains	600	400	200	0
Corn	240	370	499	629
Soybean meal	275	291	308	324
Alfalfa hay	1,050	800	550	300
Barley straw	330	385	441	496
Molasses	40	40	40	40
Vitamin/mineral mixture	75	75	75	75
Total	2,610	2,611	2,613	2,614
Chemical composition ¹ (% of DM)				
DM (%)	85.98	56.39	42.04	33.54
CP	14.81	15.52	15.5	14.48
Fat	1.36	1.49	1.25	1.76
Crude fiber	24.01	21.62	21.02	22.19
NDF	43.13	43.04	43.39	43.16
ADF	23.70	23.36	22.56	23.49
Acid detergent lignin	3.02	3.02	2.42	2.90
Ash	9.38	9.11	9.60	10.62
Net energy (MJ/kg of DM)	5.73	5.59	5.60	5.61

¹Values represent duplicate assays of 4 samples from each ration.

and grass diversity and quality have an effect on the sensory attributes of different types of cheeses (Coulon et al., 2004). Literature about the effect of including nontraditional feedstuffs in dairy ewes on the technological properties of milk and cheese characteristics is limited. For this reason, the aim of the present work was to evaluate the effect of using artichoke silage (AS) as a substitute for barley grain and alfalfa hay in the mixed rations of dairy ewes, on milk technological properties, ripened cheese characteristics, and cheese overall sensory perception.

MATERIALS AND METHODS

Animals and Experimental Rations

Forty-eight lactating Guirra ewes were used and previously managed to have one parturition and concentrate lambing within 2 to 3 wk. Six weeks after parturition (weaning period) ewes were mechanically milked twice a day (morning and evening) until the end of lactation. To balance experimental groups for milk production and composition, animals were fed the same ration during a 2-wk preexperimental period (wk 9 and 10) and recorded for daily milk production and milk composition. Animals were then divided into 4 homogeneous groups of equal size and assigned randomly to 1 of 4 experimental rations containing AS at 0 (control), 10, 20, and 30% in substitution of barley grain and alfalfa hay. Ingredients and chemical composition

of experimental rations are shown in Table 1. Rations were formulated to be isoenergetic and isoprotein and were given twice daily to animals. After 2 wk for diet adaptation bulk milk sampling was performed from wk 13 to 16 of lactation.

Artichoke residues were obtained from the canning industry and consisted mainly of the bracts and stems of the inflorescence before being scalded. One month before milking, 25 t of artichoke residues was compacted in a bunker silo and ensiled until use. No additives were used and silage had a final pH of approximately 4.0. Silage was preserved by covering it with plastic sheeting during the experimental period. Silage presented final protein, ether extract, and NDF contents of 15.6, 2, and 49% (on a DM basis), respectively.

Milk Sampling and Analysis

Bulk milk samples were collected 3 times during the experimental period from each animal group (total milk samples: 12). Samples comprised a morning and afternoon milking mixture. Milk for physicochemical analyses and SCC was stored at 4°C until analysis (2–4 h), and bulk samples for cheese production were held at 6 to 8°C and processed approximately 15 h later at the pilot plant. Three cheese batches were obtained from each experimental group and further ripened for 60 d.

Milk samples were analyzed for fat, total protein, casein, lactose, and TS, by infrared analysis (Milko Scan FT-120; Foss Electric, Hillerød, Denmark; IDF, 1996).

The pH was measured using a pH meter (Crison Micro-pH, 2001, Barcelona, Spain), and SCC were performed by a Fossomatic 5000 cell counter (Foss Electric).

Cheese Making

Cheeses were manufactured 3 times during the study with bulk milk corresponding to each animal group. On the day of manufacturing, 4 cheeses from each animal group were obtained by following the protocol described by Trujillo et al. (1999) with some modifications. After milk pasteurization (65°C for 30 min), milk was heated to 32°C, then 2% lactic starter containing $>10^7$ cfu/mL (*Lactococcus lactis* ssp. *lactis* and *Lactococcus lactis* ssp. *cremoris*; AM Larbus S.A., Barcelona, Spain) and 0.35% (wt/vol) of CaCl_2 were added. Twenty minutes later, 0.0375% (vol/vol) of liquid chymosin (Maxiren 180, DSM Food Specialties, Barcelona, Spain) was added and coagulation was carried out at 32°C for 30 min. The resultant coagulum was cut into 8- to 10-mm cubes and the curd was heated to 37°C for 15 min before whey drainage. The curd was then molded into pieces of approximately 400 g and pressed in a pneumatic press at 1.2 kPa for 1 h, followed by 2.4 kPa for 3 h. Cheeses were salted by immersion in brine (19% NaCl) for 2 h and ripened in a room at 14°C and 85% relative humidity for 60 d. Fresh cheese yield (**CHY**) was expressed in kilograms of cheese per 100 kilograms of milk. Samples from each cheese batch were collected as follows: next day after manufacturing, half of the cheese was removed for chemical analysis (d 1), and the remaining piece was wax-coated for further ripening and sampled after 15 d. Whole cheeses were then removed for chemical analysis after 30 and 60 d of ripening, and a whole cheese at the end of ripening (60 d) was used for sensory evaluation.

Coagulation Properties

During cheese manufacturing, coagulation was monitored with a Gelograph probe (Gelograph-NT, Gel-Instrumente, Thalwil, Switzerland) and values for rennet clotting time (**RCT**), rate of curd aggregation (**RCA**), and gel firmness at 30 min (**F₃₀**) were obtained. Rennet clotting time is the time elapsed between the addition of rennet and the formation of the first aggregates detected by the instrument, measured in minutes; RCA is the rate at which micelles aggregate, which corresponds to the slope value obtained by linear regression, reported as percentage of transmission (**T**) per minute ($\Delta\%T/\text{min}$); and **F₃₀** ($\Delta\%T$) is the curd firmness after 30 min of coagulation.

Cheese Composition

Cheeses were analyzed at 60 d of ripening in triplicate for TS (ISO, 2004), fat by using the Van Gulik method (ISO, 2008), and total nitrogen (**TN**; IDF, 2002); pH was measured in duplicate with a pH meter (Crison Micro-pH, Barcelona, España) on a cheese/distilled water slurry (1:1).

Water-Soluble Nitrogen and Total Free AA Analysis

Water-soluble nitrogen at pH 4.6 (**WSN**) was performed following the procedure described by Kuchroo and Fox (1982) and expressed as percentage of TN; total free AA were determined according to the method described by Folkertsma and Fox (1992). These 2 measurements were used as an index of proteolysis and were determined in triplicate at 1, 15, 30, and 60 d of ripening.

FFA Analysis

Sample cheeses for FFA determinations were stored at -70°C and then thawed for 24 h at 4°C before analysis. Determinations of FFA were carried out at 15, 30, and 60 d of ripening. Extraction was performed twice for each sample according to the procedure proposed by De-Jong and Badings (1990) as modified by Juan et al. (2007). Briefly, lipid extraction was performed by adding diethyl ether-heptane (1:1 vol/vol) to a mixture of 1.0 g of cheese, 3 g of Na_2SO_4 , 0.3 mL of H_2SO_4 (2.5 M), and 30 μL of internal standard solution (36.4 mg/mL). The mixture was vortexed (3 min) and the supernatant transferred to a glass tube with fresh Na_2SO_4 (1 g). After repeating this procedure 3 times, the lipid extract was loaded to an aminopropyl column (Spe-ed NH_2 500 mg/mL, Applied Separations, Allentown, PA) conditioned with 10 mL of heptane. Glycerides were removed with hexane/2-propanol (3:2 vol/vol), and FFA were eluted with 5 mL of diethyl ether containing 2% formic acid. A direct injection of the solution (1 μL) into the gas chromatograph (GC System HP 6890 Series, Hewlett-Packard Inc., Wilmington, DE) was made by an automatic on-column injector (HP 6890). A flame-ionization detector was used, and separation occurred in a fused-silica capillary column (30 m $\times$ 0.25 mm $\times$ 0.25 μm ; TRB-5TR, Teknocruma, Barcelona, Spain). High-purity helium (0.9 mL/min) was used as carrier gas, and the column oven temperature was programmed from 50 to 240°C at a rate of $5^\circ\text{C}/\text{min}$ with a 20-min hold. Individual FFA were identified by their retention times compared with those of the commercial standards (Sigma Chemical Company, St. Louis, MO). Different

Table 2. Physicochemical characteristics and SCC of milk samples corresponding to experimental rations with 0, 10, 20, and 30% artichoke silage (AS)¹

Parameter	Ration (% AS)			
	0	10	20	30
Fat (%)	7.23 ± 0.44	7.34 ± 0.29	7.57 ± 0.17	7.45 ± 0.48
Protein (%)	6.55 ± 0.10	6.47 ± 0.04	6.75 ± 0.17	6.79 ± 0.14
Casein (%)	5.12 ± 0.04	5.07 ± 0.05	5.26 ± 0.15	5.32 ± 0.13
Lactose (%)	4.53 ± 0.02	4.65 ± 0.10	4.58 ± 0.10	4.46 ± 0.10
Total solids (%)	19.26 ± 0.52	19.39 ± 0.21	19.86 ± 0.19	19.69 ± 0.56
pH	6.46 ± 0.02	6.49 ± 0.06	6.56 ± 0.05	6.53 ± 0.03
Log (SCC)	5.71 ^{ab} ± 0.23	5.55 ^{bc} ± 0.11	5.33 ^c ± 0.14	5.94 ^a ± 0.25

^{a-c}Means with different superscript letters within the same row indicate significant differences between rations ($P < 0.05$).

¹Data presented as means ± SD of 3 individual bulk milk samples.

standard mixtures with increasing concentrations of individual FFA and fixed concentrations of internal standard (C7: 0.7 µg/mL) were used for the calculation of calibration curves. Results were expressed as short-, medium-, and long-chain free fatty acids grouped according to chain length.

Sensory Analysis

The aim of the sensory analysis was to evaluate if the inclusion of AS in the diet had an effect on the overall perception of the ripened cheeses. Sensory evaluation of 60-d-old cheeses was carried out by a group of 8 panelists from the Centre Especial de Recerca Planta de Tecnologia dels Aliments (CERPTA, Bellaterra, Spain). All panelists were experienced in the assessment of sensory analysis of similar ewe milk cheeses. From each animal group and cheese batch, 1 cheese was sampled and tested in duplicate in 2 different sessions. A triangular wedge (1 cm thick) from each cheese was cut and the outer rind was removed before assessment. The 4 samples were presented simultaneously to the panelist on white plates at room temperature (~22°C). A random 3-digit number was assigned to each sample so that panelists were unable to recognize the treatment. Water and unsalted biscuits were provided to neutralize taste between cheese samples. Panelists were asked to give an overall quality impression of each sample on a 7-point scale (1 = defective; 3 = acceptable; 5 = good; 7 = excellent). Intensity and quality of overall aroma was scored by panelists on a 7-point scale (1 = low; 4 = medium; 7 = high).

Statistical Analysis

Data analysis was carried out by using the SAS statistical program (version 9.1, SAS Institute Inc., Cary, NC). The SCC values were converted into logarithms

to perform the statistical analysis. Differences between diets were tested by an ANOVA performing a PROC GLM for each ripening time. Cheese production and diet were considered the main factors and the evaluations were based on a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Milk Composition

Physicochemical composition and SCC of milk used for cheese making are shown in Table 2. No differences in terms of milk composition were observed between diets ($P > 0.05$) except for SCC. Contributions about the effect of AS inclusion in ewes' rations on milk composition are limited; however, the use of artichoke by-products seems to have no detrimental effects on milk composition from dairy cows (Galvano and Scerra, 1983). In contrast, other industry by-products such as ensiled crude olive cake offered to dairy ruminants increased milk fat content from dairy ewes and goats (Hadjipanayiotou, 1999). Milk SCC differed significantly ($P < 0.05$) between rations but no correlation with AS level could be observed so these differences may be attributed to other environmental factors.

Coagulation Parameters and Cheese Composition

Milk coagulation parameters and CHY are described in Table 3. Inclusion of AS in the diet of lactating ewes did not have a significant effect on RCT, RCA, or CHY ($P > 0.05$). Curd firmness was the only technological characteristic influenced by diet ($P < 0.05$). The Gelo-graph probe registered lower F_{30} values for 20 and 30% AS milk samples; however, ewe milk tends to form firm curds (i.e., firmer than cow's milk), so these differences were revealed by the equipment but were not visually detected by researchers during manufacturing.

Table 3. Coagulation parameters and cheese yield obtained during cheese manufacture corresponding to experimental rations with 0, 10, 20, and 30% artichoke silage (AS)¹

Parameter ²	Rations (% AS)			
	0	10	20	30
RCT (min)	11.69 ± 0.05	11.49 ± 0.50	11.75 ± 0.66	10.03 ± 1.77
F ₃₀ (Δ%T)	3.57 ^a ± 0.10	3.35 ^{ab} ± 0.24	3.18 ^b ± 0.09	2.73 ^c ± 0.04
RCA (Δ%T/min)	0.50 ± 0.05	0.51 ± 0.06	0.48 ± 0.00	0.40 ± 0.05
CHY (%)	28.19 ± 1.71	26.58 ± 0.86	27.89 ± 0.77	28.16 ± 1.01

^{a-c}Means with different superscript letters within the same row indicate significant differences between rations ($P < 0.05$).

¹Data presented as means ± SD of 3 individual cheese productions.

²RCT = rennet clotting time; F₃₀ = gel firmness at 30 min; RCA = rate of curd aggregation; T = transmission; CHY = cheese yield.

The effect of changes in animal diet on the technological characteristics of milk has been evaluated. In this sense, Verdier-Metz et al. (2005) compared coagulation properties of cow's milk when animals were fed pasture preserved either as silage or as hay, without observing significant differences. No effect of diet on technological parameters was observed by Masucci et al. (2006) who evaluated the inclusion of *Lupinus albus* in the ration of dairy ewes, replacing soybean meal as protein source. In contrast, Kreuzer et al. (1996) observed that the improvement in diet quality with respect to dietary energy of dairy cows through the use of better forage and concentrate enhanced the technological properties of milk, which showed shorter coagulation times and moderate increases in curd firmness.

Physicochemical composition of 60-d cheeses is summarized in Table 4. All cheeses at the end of ripening showed TS content close to 61%. Total N content was significantly lower for 20% AS cheeses compared with 10 and 30% AS cheeses, but none of these showed a significant difference compared with the control cheese. Cheeses corresponding to 10, 20, and 30% AS rations tended to show a lower fat content compared with 0% AS cheese. This trend is not explained by the original composition of AS milks (Table 2), but may be associ-

ated with their coagulation properties (Table 3). Milks with faster coagulation rates and firmer gels produce lower loss of fat in the whey (Ng Kwai Hang et al., 1989); these characteristics were observed in 0% AS milk and may explain the higher fat content of these cheeses compared with those observed for the cheeses corresponding to 10, 20, and 30% AS.

Finally, the pH values of cheeses at the end of ripening differed significantly ($P < 0.05$) between rations: the pH values for 10 and 20% AS cheeses were higher compared with the 0 and 30% AS samples; however, these differences did not show a specific trend related to the increased amount of AS in the diet.

Proteolysis: WSN and AA Content

The parameters used for the evaluation of cheese proteolysis were highly influenced by ripening time (Figure 1). Amino acids increased from approximately 0.3 mg Eq of Leu/g of cheese to a maximum of 6.8 mg Eq of Leu/g of cheese at 60 d of ripening, whereas WSN increased from approximately 7 to 20%. Similar values have been described for ewe milk cheeses (Pavia et al., 2000).

Table 4. Physicochemical composition of 60-d cheeses corresponding to experimental rations with 0, 10, 20, and 30% artichoke silage (AS)¹

Parameter	Ration (% AS)			
	0	10	20	30
Total solids (%)	61.24 ^{bc} ± 1.73	60.92 ^c ± 0.46	62.72 ^a ± 0.87	61.76 ^b ± 0.43
Total nitrogen ² (%)	6.44 ^{ab} ± 0.06	6.54 ^a ± 0.08	6.34 ^b ± 0.20	6.54 ^a ± 0.09
Fat ² (%)	53.32 ^a ± 1.27	50.87 ^b ± 2.34	50.22 ^{bc} ± 1.30	48.30 ^c ± 1.37
pH	4.80 ^d ± 0.03	4.84 ^b ± 0.02	4.89 ^a ± 0.03	4.82 ^c ± 0.04

^{a-d}Means with different superscript letters within the same row indicate significant differences between rations ($P < 0.05$).

¹Data presented as means ± SD of 3 individual cheese batches.

²Total nitrogen and fat are expressed as percentage of total solids.

Inclusion of AS in the ration increased total AA especially in 60-d-old cheeses ($P < 0.05$) irrespective of inclusion level. During secondary proteolysis, enzymes from lactic acid (starter) bacteria and remaining non-starter bacteria are largely responsible for the formation of free AA (McSweeney, 2004). The results suggest that cheeses corresponding to experimental rations, despite AS concentration, presented more favorable conditions for the development of lactic acid bacteria or their enzyme activity compared with control cheeses. According to Coulon et al. (2004), differences in terms of cheese proteolysis and lipolysis could be related to variations in the microbial ecosystem attributed to the animal diet and the transport of particular compounds from feed to milk and thus to cheese. Furthermore, Fallico et al. (2006) showed that the feeding strategy of cows (native pasture vs. TMR) had no influence on primary proteolysis of Ragusano cheese but described a qualitative effect on the peptide profile of pasture cheeses attributed to the possible presence of proteases from particular microflora derived from local pasture.

On the other hand, the WSN fraction of 60-d cheeses was not influenced by the inclusion of AS in the diet ($P > 0.05$). The similar extent of proteolysis observed for all cheeses at the end of ripening suggests that the enzymatic activity of the residual coagulant, milk proteases, or enzymes from SCC were little influenced by the incorporation of AS in the diet.

Lipolysis: FFA Content

The evolution of FFA of cheeses during ripening is shown in Figure 2. As has been described for ovine milk cheeses (Poveda et al., 2000; Fernández-García et al., 2006), the amount of FFA increased significantly ($P < 0.05$) with aging. According to the statistical analysis, experimental rations had a significant effect on the concentration of most individual FFA during ripening with few exceptions (C18–C18:2 of 60-d cheeses). Free fatty acids grouped according to chain length were influenced by diet at each ripening stage (Figure 2). Inclusion of AS in the diet decreased the content of short-chain FFA ($P < 0.05$) during ripening, with the exception of 10% AS cheeses, which were similar to the control. A lower content of medium- and long-chain FFA (mainly C16) was observed for 20 and 30% AS cheeses after 60 d of ripening ($P < 0.05$); therefore, these samples presented a significantly ($P < 0.05$) lower content of total FFA at the end of ripening (20% AS: $2,729 \pm 231$; 30% AS: $2,004 \pm 262$ mg/kg of cheese) compared with 0 and 10% AS cheeses ($3,587 \pm 284$ and $3,549 \pm 242$ mg/kg of cheese, respectively). According to the original milk fat composition (data not shown), the inclusion of 30%

Figure 1. Total free AA and water-soluble nitrogen (WSN; expressed as percentage of total nitrogen, TN) of cheeses at each ripening stage, corresponding to rations with 0, 10, 20, and 30% of artichoke silage (AS). Results are presented as means $\pm$ SD of 3 independent cheese batches. Significant differences ($P < 0.05$) between rations within same ripening time are indicated by different letters.

AS in the ration reduced the content of short-chain fatty acids in these milk samples, which explains to some extent the lower short-chain FFA content of these cheeses. On the other hand, the lower total sum of FFA could be partially explained by the lower fat content of 20 and 30% AS cheeses (Table 4). Effect of diet on the lipolytic system and milk fat composition has been reported elsewhere for cow's milk (Ferlay et al., 2006). Furthermore, changes in feeding strategy during different times of the year are partly responsible for the seasonal variation of FFA profiles of ripened ewe milk cheeses (Fernández-García et al., 2006).

Sensory Analysis

Overall impression scores given by panelists based on a 7-point scale (1 = defective; 3 = acceptable; 5 = good; 7 = excellent) were as follows: 2.94 ± 0.96 , 3.53 ± 1.04 , 3.35 ± 1.02 , and 3.07 ± 0.99 for 0, 10, 20, and 30% AS cheeses, respectively. All cheeses were ranked as acceptable in terms of overall impression. However, sensory analysis revealed significant ($P < 0.05$) differences between diets, so that 10% AS cheeses received

Figure 2. Short- (C4 to C8; panel A), medium- (C10 to C14; panel B), and long-chain (C16 to C18:2; panel C) of cheeses at each ripening stage, corresponding to rations with 0, 10, 20, and 30% of artichoke silage (AS). Results are presented as means $\pm$ SD of 3 independent cheese batches. Significant differences ($P < 0.05$) between rations within same ripening time are indicated by different letters.

the highest scores. Intensity and quality of cheese aroma was also evaluated by panelists (1 = low; 4 = medium; 7 = high), with the 10% AS cheeses having higher aroma scores (intensity: 4.19 ± 0.94 ; quality: 3.84 ± 1.09) than control cheeses (intensity: 3.87 ± 1.05 ; quality: 3.52 ± 1.11). These observations may be explained by the greater formation of AA in these cheeses compared with 0% AS cheeses. In fact, flavor development of some ewe cheeses may be more influenced by proteolysis than by other biochemical changes (Fernández-García et al., 1994). Moreover, the higher formation of short-chain FFA in 10% AS cheeses could also contribute to their higher overall sensory quality.

CONCLUSIONS

The inclusion of AS up to levels of 30% as part of the complete ration of dairy ewes had no effect on milk composition or the overall cheese-making properties of milk. Although curd firmness decreased with AS in the ration, cheese yield was not impaired. Cheeses corresponding to AS rations presented a lower fat content; this fact might explain the lower levels of total FFA of these cheeses at the end of ripening. Cheese proteolysis described in terms of AA was influenced by the use of AS. From the overall sensory scores of 60-d cheeses, it can be noted that rations containing AS have a positive effect on the sensory characteristics of cheeses.

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