Journal of Dairy Research (2009) **76** 210–215. *© Proprietors of Journal of Dairy Research 2009*
doi:10.1017/S0022029909004002 *Printed in the United Kingdom*

Effect of somatic cell counts on ewes' milk protein profile and cheese-making properties in different sheep breeds reared in Spain

Isabel Revilla[1]*, José M Rodríguez-Nogales[2] and Ana M Vivar-Quintana[1]

[1] Food Technology Area, Universidad de Salamanca. E.P.S. de Zamora. Avda. Requejo 33, 49022, Zamora. Spain
[2] Food Technology Area, University of Valladolid. E.T.S. de Ingenierías Agrarias. Avda. Madrid 57, 34004 Palencia. Spain

Received 6 December 2007; accepted for publication 24 November 2008; first published online 13 March 2009

Bulk tank ewe's milks from Assaf, Castellana and Churra breeds categorized within three different Somatic Cell Count (SCC) groups (LSCC: <500 000; MSCC: 1 000 000 to 1 500 000; and HSCC: 2 500 000 to 3 000 000 cells ml^{-1}) were used to investigate changes in capillary electrophoresis protein profiles and cheese-making properties. The results do not reveal a significant effect of SCC on total casein contents, because the sum of β-caseins decreased as SCC increased; no statistically significant differences were observed for the sum of α-caseins, and the values of κ-casein were higher in the HSCC milk. However, the soluble proteins other than α-lactalbumin and β-lactoglobulin increased with SCC. Regarding the effect of breed, the Assaf breed had the lowest contents of κ-CN, α_{s1}-I-CN, α_{s1}-II-CN $_1$-CN, α_{s1}-III-CN, β_1-CN and β_2-CN. The protein profile was significantly correlated with curd textural properties. α_{s1}-I-CN was the most influential variant because it was positively correlated with a large number of textural parameters. Cheese yield was positively correlated with all casein variants except α_{s1}-III-CN, showing that the milk from local breeds were more suitable for cheese-making due to their higher contents of all the casein variants. Regarding curd texture properties LSCC milk curds showed more cohesiveness, associated with its lower content of α_{s1}-III-CN and Castellana milk curds showed the highest values for firmness owing to their higher content of α_{s1}-I-CN.

Keywords: Capillary electrophoresis, texture, yield, SCC, breed.

The Somatic Cell Counts (SCC) of milk, used as indicators of animal mammary disease and to define milk prices (Kalantzopoulos et al. 2004), may vary widely because of endogenous and exogenous factors. In this sense, mastitis is the most important cause of elevated SC levels in milk but other variables with an important effect on ewe milk SCC are physiological processes such as oestrus or an advanced stage of lactation (Albenzio et al. 2005), the sampling month (El-Saied et al. 1998), breed or flock (González-Rodríguez et al. 1995).

Previous studies have shown that an increase in SCC is related to changes in the composition of milk, although without consensus among the different authors (Duranti & Casoli, 1991; Pirisi et al. 2000; Jaeggi et al. 2003; Bianchi et al. 2004; Albenzio et al. 2005; Revilla et al. 2007). Regarding changes in the protein profile of ewe's milk due to the SCC, much less is known. Increases in the concentration of proteins from blood during mastitis leads to an increase in the concentration of soluble whey proteins (Pirisi et al. 2000; Nudda et al. 2003; Albenzio et al. 2004). However, Duranti & Casoli (1991) have shown that β-lactoglobulin percentages decrease when ewe's milk SCC increase. There are no data concerning α-lactalbumin. With respect to the milk casein composition, several authors have reported the absence of significant differences in total casein associated with SCC (Pirisi et al. 2000; Nudda et al. 2003; Albenzio et al. 2005), whereas others have found a significant decrease in casein (Duranti & Casoli, 1991; Jaeggi et al. 2003), or even an increase (Bianchi et al. 2004). There are fewer studies addressing the hydrolysis of casein and these have shown that α-casein and β-casein percentages decrease when SCC increase (Duranti & Casoli, 1991). In this sense, some authors have suggested that if ewes' milk has an elevated SCC, its cheese-making properties will deteriorate, with a

---

*For correspondence; e-mail: irevilla@usal.es

longer coagulation time and low curd firmness (Bencini & Pulina, 1997; Pirisi et al. 2000; Albenzio et al. 2004).

On the other hand in Spain, despite the lower quality of foreign-breed milk due to its lower total protein and fat content (Rodríguez-Nogales et al. 2007) a progressive replacement of local breeds by more productive foreign breeds, such as Assaf, has been implemented because farmers usually obtain higher incomes by producing more milk. Foreign breeds tend to adapt to local environments less well than the Churra and Castellana breeds and, since they require more time for milking and more careful management, a higher incidence of mastitis tends to be observed (Gonzalo et al. 2005).

Taking into account that cheese-making properties depend on the type and amount of intact casein, the main aim of the present study was to determine the effect of breed (Churra, Castellana or Assaf) and the level of SCC (low, medium or high) on capillary electrophoretic protein profiles, cheese-making properties, and curd textural parameters. The correlations between protein composition and cheese-making properties were studied in order to establish the effect of specific protein variation on the cheese quality.

Materials and Methods

Milk and cheese-making procedure

Milk samples were taken from bulk milk with three somatic cell counts (LSCC: less than 500 000 cells ml^{-1}; MSCC: between 1 000 000 and 1 500 000 cells ml^{-1}; HSCC: between 2 500 000 and 3 000 000 cells ml^{-1}). The upper and lower limits were set according to the highest and lowest SCC values found in the region throughout the year. Following this, the groups were made up according to the recommendations of the veterinary services of the Sheep Improvement Consortium and previous works (Pirisi et al. 2000), reporting significant differences in milk quality and technological properties among these groups.

Raw ewes' milk was collected from three herds of Assaf breed sheep, three herds of the Churra breed, and two herds of the Castellana breed because it was not possible to find herds with SCC higher than 2 500 000 cells ml^{-1} owing to their higher resistance to mastitis (Gonzalo et al. 2005). All the herds were bred in Zamora (Spain) under identical husbandry systems and feeding regimes. During the autumn and winter, the herds were kept in stables, fed with concentrates composed of beetroot pulp, alfalfa, barley, corn, soy and cotton and were machine-milked. The herds were selected on the basis of the milk SCC recorded during the previous months, choosing herds that always showed SCC within the limits of each group.

Two samples were taken from each herd and trial and these samples were collected in the same week and transported to the pilot plant of Food Technology. Milk samples (16) for the first trial were collected from the first week of November until the first week of December (2006) and milk samples (16) of the second trial were collected in the same period of 2007. Month within herd is a relevant factor of variation in SCC; however month as a variation factor not within herd is of little importance (Gonzalo et al. 2005). A sample was submitted for SCC analyses (Fossomatic Foss Analytical Denmark) at the certified laboratory of the Junta de Castilla y León (Spain) (LILCYL).

Cheeses of each milk type were manufactured in accordance with the Regulatory Board of the *Zamorano* Cheese Denomination of Origin (B.O.E., 1993) as previously described (Revilla et al. 2007). Cheese yield was calculated as the ratio between the weight of the cheese after pressing and the weight of milk used for cheese-making.

Milk capillary electrophoresis

Ewe's milk was skimmed by low-speed centrifugation (3000 ***g*** for 20 min) (4K15 Sigma, Osterode, Germany). The sample solutions were easily prepared dissolving 300 μl skim milk in 1 ml sample buffer. The sample solutions were filtered through 0·20 μm filters (Millex-GV_{13}, Millipore, Molsheim, France) before analysis by capillary electrophoresis. Capillary electrophoresis was carried out according to the method previously reported (Revilla et al. 2007). Each sample was analysed three times ($n=3$) by capillary electrophoresis and the average of the relative area of each peak was calculated.

Texture analyses of curds

For each trial three samples of 100 ml milk were taken after calf rennet addition and coagulation was allowed to take place in a 125 ml cup. When the curd developed the desired firmness, analysis of texture was carried out using a TX-T2i*plus* (Stable Microsistems, Surrey, England) as follows: A 50 mm diameter cilindrical probe was inserted into the curd cap (diameter 70 mm) to a depth of 5 mm at a speed of 1 mm s^{-1}. The resulting force-time curves were analysed using texture profile analysis (Bourne, 1978). Hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness were calculated.

Statistical analyses

Outliers were detected by means of the Box and Whisker plot. Then, the significance of factor (breed and SCC) was obtained using General Linear Model procedures. The LSD Fisher test was employed to test for statistically significant differences among samples; differences were considered significant at the $P\leqslant 0{\cdot}05$ level. The correlation matrix and the rest of statistical analyses were carried out using the Statgraphic Plus for Windows Computer Package (1995 Manugistics, Inc., Rockville MD).

Results and Discussion

Milk protein profile

Table 1 summarizes the areas of milk protein fractions for the three breeds and the different levels of SC. Regarding the effects of SCC on protein profiles, lactoalbumin underwent a significant decrease ($P<0{\cdot}01$) as SCC increased. Thus, for all three breeds a significant decrease was observed between LSCC and MSCC milk. In the case of β-lactoglobulin, no relationship was observed between the variations in the levels of this serum protein and SCC. These findings differ from those of Duranti & Casoli (1991), who reported that β-lactoglobulin percentages decrease when ewe's milk SCC increases, contrary to seroalbumin and immunoglobulin.

Regarding α-caseins, a significant effect of SCC ($P<0{\cdot}01$) was observed for the three variants studied, the highest levels of α_{s1}-I-CN corresponding to LSCC milks, while in the case of α_{s1}-II-CN and α_{s1}-III-CN the HSCC milks had the highest values. This behaviour was also observed for κ-casein; statistically significant effects of SCC on this protein were observed, the highest values corresponding to the HSCC milk.

Finally, the group of β-caseins includes three genetic variants: β-CN, β_2-CN and β_1-CN, according to the order of elution of the electropherogram. For these three caseins, a significant effect of SCC was seen for β-CN, β_2-CN ($P<0{\cdot}01$) and β_1-CN ($P<0{\cdot}1$), this last variant being the most abundant and the least affected by SCC. The levels of all three variants underwent a decrease with increasing SCC, possibly due to increased proteolysis. This is consistent with previous results (Verdi et al. 1987; Leitner et al. 2003). The phenomenon could be due to the increase in plasmin activity reported for HSCC milks (Bianchi et al. 2004; Albenzio et al. 2004, 2005). The primary cleavage substrate of plasmin is β-CN, yielding different γ-CNs. However, other studies have stressed the relevance of other enzymes such as cathepsin D, cathepsin G, elastase or cathepsin B, which come from the lysosomes of somatic cells. These enzymes also act on β-caseins and some of the cleavage sites are identical to those cleaved by plasmin (Marino et al. 2005; Considine et al. 2000, 2002, 2004).

These results thus coincide with the findings of Bianchi et al. (2004), who reported a decrease in the sum of β-caseins, together with the absence of statistical differences for the sum of α-caseins, although contrary to the present study those authors failed to find a significant effect of SCC for κ-casein.

Finally, these results suggest that the increase in the percentage of total protein observed in milk with SCC (LSCC=5·53, MSCC=6·31, HSCC=6·51; significant effect $P<0{\cdot}01$) may be due to the fact that the increase in the level of soluble proteins other than α-lactalbumin and β-lactoglobulin was more pronounced as SCC increased, owing to the entry of proteins from blood (Duranti & Casoli, 1991; Pirisi et al. 2000; Nudda et al. 2003;

Table 1. Protein composition of the milks expressed as peak area per 0·1 ml of milk injected of each compound

	Assaf			Churra			Castellana		Significance	
SCC ml^{-1}	<500 000	10^6–$1{\cdot}5{\cdot}10^6$	$2{\cdot}5$–$3{\cdot}0{\cdot}10^6$	<500 000	10^6–$1{\cdot}5{\cdot}10^6$	$2{\cdot}5$–$3{\cdot}0{\cdot}10^6$	<500 000	10^6–$1{\cdot}5{\cdot}10^6$	Breed	SCC
α-La	$68{\cdot}62^{bxy}$ (36·13)	$24{\cdot}11^{a}$ (21·50)	$49{\cdot}77^{aby}$ (6·19)	$52{\cdot}23^{bx}$ (21·47)	$28{\cdot}41^{a}$ (3·86)	$26{\cdot}67^{ax}$ (8·32)	$81{\cdot}55^{by}$ (15·59)	$29{\cdot}05^{a}$ (17·70)	**	***
β-Lg	$53{\cdot}75^{by}$ (24·46)	$21{\cdot}77^{ax}$ (15·02)	$51{\cdot}69^{by}$ (5·35)	$26{\cdot}64^{ax}$ (9·16)	$41{\cdot}32^{bxy}$ (5·12)	$26{\cdot}92^{ax}$ (5·15)	$67{\cdot}06^{y}$ (1·93)	$58{\cdot}78^{y}$ (32·56)	***	ns
α_{s1}-I-CN	$83{\cdot}54^{bx}$ (4·089)	$67{\cdot}54^{ax}$ (8·64)	$107{\cdot}14^{cy}$ (7·81)	$112{\cdot}14^{cy}$ (9·63)	$66{\cdot}00^{ax}$ (2·11)	$83{\cdot}64^{bx}$ (7·64)	$123{\cdot}24^{by}$ (11·05)	$101{\cdot}43^{ay}$ (38·11)	***	***
α_{s1}-II-CN	$96{\cdot}64^{ax}$ (19·59)	$55{\cdot}58^{ax}$ (14·23)	$150{\cdot}41^{by}$ (5·16)	$154{\cdot}34^{y}$ (15·04)	$144{\cdot}89^{y}$ (16·19)	$135{\cdot}18^{x}$ (9·03)	$147{\cdot}37^{y}$ (21·67)	$124{\cdot}94^{y}$ (12·47)	***	***
α_{s1}-III-CN	$43{\cdot}89^{bx}$ (7·84)	$37{\cdot}44^{ax}$ (4·06)	$61{\cdot}90^{c}$ (5·41)	$63{\cdot}14^{ay}$ (11·58)	$86{\cdot}81^{bz}$ (12·96)	$67{\cdot}86^{a}$ (3·73)	$51{\cdot}41^{xy}$ (5·32)	$66{\cdot}58^{y}$ (3·85)	***	***
κ-CN	$79{\cdot}38^{bx}$ (2·60)	$66{\cdot}30^{ax}$ (11·78)	$109{\cdot}76^{c}$ (4·73)	$118{\cdot}65^{y}$ (19·12)	$100{\cdot}54^{y}$ (10·02)	102·54 (10·75)	$99{\cdot}25^{xy}$ (3·82)	$100{\cdot}21^{y}$ (12·49)	***	***
β_1-CN	$281{\cdot}79^{ax}$ (45·80)	$242{\cdot}16^{ax}$ (36·98)	$362{\cdot}94^{b}$ (23·92)	$465{\cdot}68^{by}$ (66·43)	$355{\cdot}096^{ay}$ (66·54)	$317{\cdot}16^{a}$ (23·65)	$330{\cdot}25^{x}$ (12·59)	$289{\cdot}97^{xy}$ (51·03)	***	*
β_2-CN	$166{\cdot}42^{ax}$ (7·42)	$155{\cdot}54^{ax}$ (17·04)	$241{\cdot}61^{b}$ (39·27)	$299{\cdot}66^{bz}$ (31·77)	$171{\cdot}54^{ax}$ (16·23)	$194{\cdot}81^{a}$ (13·42)	$231{\cdot}99^{y}$ (6·52)	$213{\cdot}04^{y}$ (41·05)	*	***
β-CN	$37{\cdot}07^{ax}$ (6·92)	$32{\cdot}14^{ay}$ (4·76)	$43{\cdot}42^{b}$ (4·48)	$69{\cdot}31^{by}$ (25·01)	$21{\cdot}75^{ax}$ (4·57)	$36{\cdot}78^{a}$ (4·08)	$44{\cdot}76^{bxy}$ (3·57)	$37{\cdot}30^{ax}$ (6·04)	ns	***

^{a,b,c} Different letter means statistically significant differences at $P<0{\cdot}05$ due to the SCC within the breed

^{x,y} Different letter means statistically significant differences at $P<0{\cdot}05$ due to the breed within for the same SCC level

ns: not significant effect, * $P<0{\cdot}1$, ** $P<0{\cdot}05$, *** $P<0{\cdot}01$

Albenzio et al. 2004), while the total casein content showed no clear trend with SCC (LSCC=1158, MSCC=924, HSCC=1092), the MSCC milks having the statistically lowest casein content.

Regarding the effect of breed, a significant effect was observed for almost all the proteins studied. In the case of lactoserum proteins, a significant effect was observed for α-lactalbumin ($P<0{\cdot}05$) and β-lactoglobulin ($P<0{\cdot}01$), the Churra breed showing the lowest values. The α-caseins studied revealed a significant effect of breed ($P<0{\cdot}01$) for the three genetic variants. The Assaf breed had significantly lower values of α_{s1}-I-CN and α_{s1}-II-CN proteins; the Castellana breed showed the highest levels of α_{s1}-I-CN, and the local breeds showed the highest and statistically equal values of α_{s1}-II-CN. Regarding α_{s1}-III-CN, the Castellana breed had the highest values while Churra and Assaf had significantly lower values. This means that the Assaf breed had the lowest values for the sum of α-caseins (Assaf=249·58, Churra=305·99, Castellana=302·79; $P<0{\cdot}01$).

Scrutiny of the behaviour of β-caseins revealed a statistically significant effect of breed for β_1-CN and β_2-CN ($P<0{\cdot}01$) and the Assaf breed also had the lowest values, although not for β-CN. The sum of β-caseins revealed that the Churra breed had the highest levels of this group of proteins (Assaf=527·40, Churra=654·00, Castellana=559·36; $P<0{\cdot}01$). Finally, the κ-CN was also significantly affected by breed ($P<0{\cdot}01$) and the lowest value was observed for the Assaf breed.

Cheese-making properties

In the case of dairy sheep, almost all the milk is processed to make cheese and hence any changes in the casein concentrations will strongly affect the final product (Leitner et al. 2003). Table 2 shows the curding properties of the milks analysed and the textural parameters of the resulting curds. Previous results have shown that the rennet clotting time is affected by high SC levels (Duranti & Casoli, 1991; Pirisi et al. 2000; Albenzio et al. 2004, 2005). However, in the present work no statistically significant differences in the clotting time due to the SCC were observed. This is in agreement with the findings of Pirisi et al. (2000), who indicated that when the pH of all the samples is around 6.50 no significant differences in the clotting time are observed. Cheese yield did not show significant differences due to SCC, in agreement with previous work carried out with soft cheeses (Galina et al. 1996).

Regarding curd textural parameters, SCC affected adhesiveness ($P<0{\cdot}05$), cohesiveness ($P<0{\cdot}05$), gumminess ($P<0{\cdot}01$) and chewiness ($P<0{\cdot}01$) to a significant extent, and in agreement with other studies there was no a statistically significant effect of SCC on firmness (Jaubert et al. 1996). The HSCC milk curds showed high adhesiveness while the LSCC milks had the lowest values of chewiness and gumminess and the highest values of cohesiveness.

Table 2. Renneting properties, cheese yield and curds textural parameters

	Assaf			Churra			Castellana		Significance	
SCC ml^{-1}	<500 000	10^6–1·5·10^6	2·5–3·0·10^6	<500 000	10^6–1·5·10^6	2·5–3·0·10^6	<500 000	10^6–1·5·10^6	Breed	SCC
Clotting time (min)	36·7^{y} (8·42)	37·7 (10·5)	33·5 (14·14)	24·2^{ax} (5·5)	31·5^{b} (5·4)	32·5^{b} (4·9)	29·2^{xy} (4·6)	27·5 (8·8)	ns	ns
Cheese yield %	20·0 (2·8)	19·7 (2·2)	20·8 (1·1)	22·5 (3·3)	20·9 (2·3)	22·0 (1·2)	22·7 (2·1)	21·8 (3·4)	ns	ns
Hardness (g)	749·4^{ax} (200·2)	1072·2^{abx} (397·4)	1241·2^{b} (219·9)	1111·5^{by} (113·4)	875·8^{abx} (173·6)	1115·1^{ab} (159·9)	1525·9^{az} (247·2)	1578·5^{ay} (100·3)	***	ns
Adhesiveness (g·mm)	215·2^{ax} (54·5)	179·1^{ax} (41·8)	371·3^{bx} (77·2)	375·0^{bx} (86·6)	241·3^{ay} (16·6)	285·8^{bx} (66·3)	235·5^{ax} (131·5)	400·3^{bz} (77·7)	**	**
Springiness (mm)	0·960 (0·04)	0·930 (0·05)	0·982 (0·01)	0·969 (0·04)	0·971 (0·04)	0·994 (0·05)	0·958 (0·02)	0·976 (0·02)	ns	ns
Cohesiveness	0·339 (0·01)	0·332 (0·08)	0·297^{x} (0·04)	0·332^{b} (0·02)	0·300^{b} (0·02)	0·332^{by} (0·01)	0·329 (0·05)	0·291 (0·01)	ns	**
Gumminess (g)	267·6^{ax} (29·8)	287·5^{ax} (24·2)	417·0^{by} (30·3)	370·9^{cy} (23·7)	288·0^{ax} (16·3)	342·8^{bx} (33·1)	435·1^{az} (37·2)	506·2^{by} (17·9)	***	***
Chewiness (g·mm)	277·4^{ax} (47·2)	314·7^{ax} (45·2)	412·8^{by} (38·3)	360·2^{by} (25·2)	280·1^{ax} (16·0)	337·5^{bx} (33·6)	415·46^{ay} (19·6)	580·1^{ay} (12·6)	***	***

^{a,b,c} Different letter means statistically significant differences at $P<0{\cdot}05$ due to the SCC within the breed

^{x,y,z} Different letter means statistically significant differences at $P<0{\cdot}05$ due to the breed within for the same SCC level

ns: not significant effect, * $P<0{\cdot}1$, ** $P<0{\cdot}05$, *** $P<0{\cdot}01$

Table 3. Coefficients of the correlation matrix between renneting properties, cheese yield and curds textural parameters with protein composition of the milk. Loadings less than an absolute value of 0·300 are not shown

	Clotting time	Cheese yield	α-La	β-Lg	α_{s1}-I-CN	α_{s1}-II-CN	α_{s1}-III-CN	κ-CN	β_1-CN	β_2-CN	β-CN
Clotting time	—				−0·6842**	−0·7204**	−0·4815	−0·8010***	−0·7736**	−0·8156***	−0·6507*
Cheese yield	−0·8654***	—			0·7158**	0·8090***	0·3666	0·7747**	0·6390*	0·7316**	0·6256*
Hardness	−0·5166	0·5585		0·5021	0·7253**	0·4354		0·3244		0·4697	0·3665
Adhesiveness	−0·6937**	0·5009			0·7061**	0·5308	0·4554	0·7887**	0·6384*	0·7779**	0·5304
Springiness	−0·4227	0·5002			0·3600	0·6092	0·7205**	0·8048***	0·5248	0·4135	
Cohesiveness			0·3530	−0·3366		−0·3669	−0·6645*	−0·3853			0·3054
Gumminess	−0·6235*	0·6308*		0·5416	0·8295***	0·5396		0·5605		0·6031	0·4228
Chewiness	−0·5225	0·4604		0·5264	0·7032**	0·3054		0·3853		0·4485	

* $P<0·1$, ** $P<0·05$, *** $P<0·01$

These result point to the better quality of LSCC curds because the protein losses in the LSCC drained whey were lower (LSCC=1·63%, MSCC 1·88%; HSCC 1·77%; $P<0·05$), probably due to higher curd cohesiveness.

Regarding the effect of breed, this factor exerted a statistically significant effect on hardness ($P<0·01$), adhesiveness ($P<0·05$), gumminess ($P<0·01$) and chewiness ($P<0·01$). In this case, the Castellana milk curds had the best textural properties, due to the higher values of hardness, adhesiveness, gumminess and chewiness, with no differences as regards springiness and cohesiveness, which were unaffected by breed.

Correlations between the protein profile and cheese-making properties

Previous works have reported that curd firmness tends to decrease when a decrease in the casein content occurs (Raynal-Ljutovac et al. 2007). In the present study, the Castellana milk curds showed the highest firmness but the Churra breed had the highest total casein content. Table 3 shows the correlation matrix between proteins and textural properties, and it may be observed that the result obtained is due to the fact that hardness was only correlated positively with α_{s1}-I-CN and the Castellana breed showed the highest contents of this variant.

Adhesiveness was positively correlated with α_{s1}-I-CN but also with κ-CN, β_1-CN and β_2-CN. It is noteworthy that this was the only textural parameter correlated with β-caseins. Springiness was positively correlated with κ-CN and α_{s1}-III-CN, and this latter variant was negatively correlated with cohesiveness. Finally, gumminess and chewiness were positively correlated only with α_{s1}-I-CN. These results show that α_{s1}-I-CN is the most influential variant in curd texture and the previous results regarding protein composition (Table 1) showed that LSCC milk and the local breeds had the highest values of this protein.

Regarding technological parameters, the results revealed that clotting time was negatively correlated with cheese yield, which was positively correlated with all casein variants except α_{s1}-III-CN. This shows that although no significant differences were detected due to the higher variability of some samples, the local breeds are more suitable for the cheese-making process because they have significantly higher casein contents. Moreover, the increase in SCC did not produce significantly lower casein contents and this explains why the clotting time and cheese yield did not decrease.

Conclusions

The results of the present study do not reveal a significant effect of SCC on total casein contents, because the sum of β-caseins decreased as SCC increased; no statistically significant differences were observed for the sum of α-caseins, and the values of κ-casein were higher in the

HSCC milk. However, the soluble proteins other than α-lactalbumin and β-lactoglobulin increased with SCC. Regarding the effect of breed, the Assaf breed had the lowest contents of all the casein variants affected significantly by breed (κ-CN, α_{s1}-I-CN, α_{s1}-II-CN $_1$-CN, α_{s1}-III-CN, β_1-CN and β_2-CN).

The protein profile was significantly correlated with curd textural properties. α_{s1}-I-CN was the most influential variant because it was positively correlated with a large number of textural parameters, while α_{s1}-III-CN was the only variant found to be correlated with cohesiveness, and the β-caseins only affected adhesiveness. Indeed, the correlation matrix showed that cheese yield was positively correlated with all casein variants except α_{s1}-III-CN, showing that the milk from local breeds were more suitable for cheese-making due to their higher contents of all the casein variants.

The significant differences in the rheological properties of the curds were due to the different protein profiles. The LSCC curds showed more cohesiveness, associated with its lower content of α_{s1}-III-CN, but no differences in firmness were detected despite their higher α_{s1}-I-CN levels. Regarding breed effect, the Castellana milk curds showed the highest values for firmness owing to their higher content of α_{s1}-I-CN.

Authors are grateful to Spanish Junta de Castilla y León (SA066/04) for financial support.

References

Albenzio M, Caroprese M, Santillo A, Marino R, Muscio A & Sevi A 2005 Proteolytic patterns and plasmin activity in ewes' milk as affected by somatic cell count and stage of lactation. *Journal of Dairy Research* **72** 86–92

Albenzio M, Caroprese M, Santillo A, Marino R, Taibi L & Sevi A 2004 Effects of somatic cell count and stage of lactatin on the plasmin activity and cheese-making properties of ewe milk. *Journal of Dairy Science* **87** 533–542

Barron LJR, Redondo Y, Flanagan CE, Pérez-Elortondo FJ, Albisu M, Nájera AI, de Renobales M & Fernández-García E 2005 Comparison of the volatile composition and sensory characteristics of Spanish PDO cheeses manufactures from ewes' raw milk and animal rennet. *International Dairy Journal* **15** 371–382

B.O.E. (Boletin Oficial del Estado) [State Official Bulletin] 1993 Order of 6-05-1993 of Ministry of Agriculture, Fish and Food that approves the Regulation board of Queso Zamorano Quality Appellation of Origin and the Regulation Council

Bencini R & Pulina G 1997 The quality of sheep milk: A review. *Australian Journal of Experimental Agriculture* **37** 485–504

Bianchi L, Bolla A, Budelli E, Caroli A, Casoli C, Pauselli M & Duranti E 2004 Effect of udder health and lactation phase on the characteristics of Sardinian ewe milk. *Journal of Dairy Science* **87** 2401–2408

Bourne MC 1978 Texture profile analysis. *Food Technology* **32**(**7**) 62–66

Considine T, Geary S, Kelly AL & McSweeney PLH 2002 Proteolytic specificity of cathepsin G on bovine α_{s1}- and β-caseins. *Food Chemistry* **76** 59–67

Considine T, Healy A, Kelly AL & McSweeney PLH 2000 Proteolytic specificity of elastase on bovine α_{s1}-casein. *Food Chemistry* **69** 19–26

Considine T, Healy A, Kelly AL & McSweeney PLH 2004 Hydrolysis of bovine caseins by cathepsin B, a cysteine proteinase indigenous to milk. *International Dairy Journal* **14** 117–124

Duranti E & Casoli C 1991 Variazione della composizione azotata e dei parametri lattodinamografici del late di pecor in funzione del contenuto di cellule somatiche [Variations in the nitrogen composition and in the lactodinamographic parameters of ewe's milk in relation to somatic cell content]. *Zootecnia e Nutrizione Animale* **17** 99–105

El-Saied UM, Carriedo JA & San Primitivo F 1998 Heritability of test day somatic cell counts and its relationship with milk yield and protein percentage in dairy ewes. *Journal of Dairy Science* **81** 2956–2961

Galina MA, Morales R, Lopez B & Carmona MA 1996 Effect of somatic cell count on lactation and soft cheese yield by dairy goats. *Small Ruminant Research* **21** 251–257

González-Rodríguez M, Gonzalo C, San Primitivo F & Cármenes P 1995 Relationship between somatic cell count and intramammary infection of the half udder in dairy ewes. *Journal of Dairy Science* **78** 2753–2759

Gonzalo C, Carriedo JA, Blanco MA, Beneitez E, Juárez MT, De la Fuente LF & San Primitivo F 2005 Factors of variation influencing bulk tank Somatic Cell Count in dairy sheep. *Journal of Dairy Science* **88** 969–974

Jaeggi JJ, Govindasamy-Lucey S, Berger YM, Johnson ME, McKusick BC, Thomas DL & Wendorff WL 2003 Hard ewe's milk cheese manufactured from milk of three different groups of somatic cell counts. *Journal of Dairy Science* **86** 3082–3089

Jaubert G, Gay Jacquin MF & Perrin G 1996 Numérations cellulaires et caractéristiques biochimiques et technologiques du lait de chévre [Somatic cell counts and biochemical and technological characteristics of goat milk]. In *Proceedings of the International Symposium on Somatic Cells and Milk of Small Ruminants*, pp. 263–268 (Ed. R Rubino). EAAP Publication No. 77, Wageningen Press

Kalantzopoulos G, Dubeuf JP, Vallerand F, Pirisi A, Casalta E, Laurte A & Trujillo T 2004 Characteritics of sheep and goat milks: quality and hygienic factors for the sheep and goat dairy sectors. *Bulletin of IDF* **390** 17–28

Leitner G, Chaffer M, Caraso Y, Ezra E, Kababea D, Winkler M, Winkler M, Glickman A & Saran A 2003 Udder infection and milk somatic cell count, NAGase activiy and milk composition-fat, protein and lactose-in Israeli-Assaf and Awassi sheep. *Small Ruminant Research* **49** 157–164

Marino R, Considine T, Sevi A, McSweeney PLH & Kelly AL 2005 Contribution of proteolytic activity associated with somatic cells in milk to cheese ripening. *International Dairy Journal* **15** 1026–1033

Nudda A, Feligini M, Battacone G, Macciota NPP & Pulina G 2003 Effects of lactation stage, parity, β-lactoglobulin genotype and milk SCC on whey protein composition in Sarda dairy ewes. *Italian Journal of Animal Science* **2** 29–39

Pirisi A, Piredda G, Corona M, Pes M, Pintus S & Ledda A 2000 Influence of somatic cell count on ewe's milk composition, cheese yield and cheese quality. In *Proceedings of 6th Great Lakes Dairy Sheep Symposium*, pp. 47–59. Ontario, Canada

Raynal-Ljutovac K, Pirisi A, de Crémoux R & Gonzalo C 2007 Somatic cells of goat and sheep milk: Analytical, sanitary, productive and technological aspects. *Small Ruminant Research* **68** 126–144

Revilla I, Rodríguez-Nogales JM & Vivar-Quintana AM 2007 Proteolysis and texture of hard ewes' milk cheese during ripening as affected by somatic cell counts. *Journal of Dairy Research* **74** 127–136

Rodríguez-Nogales JM, Vivar-Quintana AM & Revilla I 2007 Influence of somatic cell count and breed on capillary electrophoretic protein profiles of ewes' milk: A chemometric study. *Journal of Dairy Science* **90** 3186–3196

Verdi RJ, Barbano DM, DellaValle ME & Senyk GF 1987 Variability in the protein, casein, nonprotein nitrogen, and proteolysis in high and low somatic cell milks. *Journal of Dairy Science* **70** 230–242