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Influence of Technology and Ripening on Textural and Sensory Properties of Vacuum Packaged Ewe's Cheese

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Abstract

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The effect of curd cooking temperature (40 and 42°C), pressing, and ripening on textural and sensory properties of vacuum packaged semi-cooked ewe's milk cheese was studied. Chemical and microbiological analyses, colour, texture, and sensory characteristics were determined. Curd cooking temperature and pressing influenced a_w, moisture and salt-in-moisture content. Texture parameters were partially modified by pressing. On the contrary, cooking temperature resulted mainly in changes of cheese colour. Storage time was the most important factor in changing cheese characteristics, including sensory characteristics, whereas an increase of bitter aftertaste was observed during storage, likely due to packaging in a plastic pouch.

Keywords: texture; sensory characteristics; ewe's milk cheese; storage; vacuum packaging

The development of high-quality dairy products requires the evaluation of qualitative parameters like sensory and texture properties, often used for cheese differentiation (Foegeding *et al.* 2003). In particular, the texture is influenced by composition and processing that consists of milk coagulation (Esteves *et al.* 2003; Castillo *et al.* 2006; Madadlou *et al.* 2006), curd cooking (Abdalla & Nusr 2009) and pressing (Tunick *et al.* 2008). At last, ripening conditions (storage temperature, packaging) play an important role in cheese sensory and textural attributes (Tunick *et al.* 2008; Esmer *et al.* 2009; Akalin & Karaman 2010; Del Caro *et al.* 2012; Hayaloglu *et al.* 2012). Instrumental texture measurements and sensory descriptive analysis are very useful tools to discriminate cheeses and to evaluate textural and sensory changes due to technology or storage conditions (Tunick *et al.* 2008; Esmer *et al.* 2009), but very few authors studied the relationship between instrumental texture measurements and sensory texture evaluation in cheeses (Drake & Gerard 1999; Gonzales Vinas *et al.* 2007).

The aim of this study was to apply sensory and instrumental texture analysis to a ewe's milk cheese, which is sold sliced inside film-wrapped trays, produced with some differences in cheese making, to evaluate sensory and instrumental texture changes during a ripening period of 90 days.

MATERIAL AND METHODS

Cheese making and storage. Cheese samples were prepared, in duplicate, in a dairy plant. Pasteurised ewe's milk was inoculated with a thermophilic culture of *Streptococcus salivarius* subsp. *thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* (1 vat unit/100 l), coagulated with liquid calf rennet (7 ml/100 l of rennet 1 : 50 000), rested for 24 min and cut into small grains of 8–12 mm in size. Then

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the curd was washed with water at 65°C, divided into 2 batches, one was cooked up to 40°C and the other up to 42°C, with an increase in temperature of 0.5°C/min, and formed into plastic rectangular moulds (10 × 10 × 20 cm). Only half of the batches were pressed, so we had: 40°C pressed (40P), 40°C not pressed (40NP), 42°C pressed (42P), 42°C not pressed (42NP). Then the cheeses were brined for 3 h (18° Be), dried for 4–5 h at 8–10°C, and after 24 h they were vacuum packaged to avoid the formation of the crust and the development of any aerobic microorganisms on the surface and stored at 4°C for 90 days. Chemical and texture analyses were performed after 24 h, 1, 2, and 3 months on 8 samples, 4 per batch. Colour and sensory analyses were performed after 1 month of storage, which is the minimum ripening period before marketing, and at 2 and 3 months.

Chemical analysis. The cheese was homogenised and subjected to the analysis of pH and water activity (a_w) using routine methods. Fat content was determined following the IDF Standard 5B (1986). Total nitrogen (TN) was determined by the Kjeldahl method (AOAC 1998) to estimate protein content (N × 6.38). Soluble nitrogen (SN) was determined by the Kjeldahl method (Gripon *et al*. 1975). Two indexes, ripening index (SN/TN) and casein N (TN-SN), were also calculated. NaCl% was determined following the IDF Standard 88 A (1988).

Microbiological analysis. On 10 g of cheese sample, homogenised with sterile water and subjected to decimal dilutions, the following microorganisms were enumerated using routine laboratory methods: total microbial count (TMC) on Plate Count Agar (PCA; Oxoid, Milan, Italy) medium; *Salmonella* spp. and *Listeria monocytogenes* using the VIDAS SLM and VIDAS L (bioMérieux, Marcy l'Etoile, France) duo protocols, respectively; coliforms on Violet Red Bile Agar (VRBA; Oxoid, Italy); *Escherichia coli* on Chromogenic EC X-Gluc agar (Biolife Italiana, Milan, Italy); yeasts and moulds on PDA (Oxoid, Italy).

Texture analysis. A puncture test was performed on unpacked cheese using a TA.XT2 testing machine (Stable Microsystems, Surrey, UK), a 4 mm cylindrical probe and a test speed of 1 mm/seconds. The puncture force at 75% of the depth (f_{75}) was measured (Frau *et al*. 1999). Samples were equilibrated to 14°C before the analysis and cut into two cubes of side 10 cm. Ten measurements were performed on the half of each cheese. The following indexes were calculated: force (f_{75}) (N) that is the maximum force at 75% of the depth, gradient, slope of the curve up to the first major peak (N/s), and area under the curve (N·s), all representing the cheese hardness. Texture Profile Analysis (TPA) was also performed using a 75 mm compression plate. The test speed was 0.5 mm/s and 5 s was the time between the two compressions. Cheeses were cut into cubes of side 10 cm and compressed to 40%. Hardness (N), cohesiveness, adhesiveness (N·s), elasticity (mm), and chewiness (N·mm) were evaluated.

Colour analysis. Colour was determined 6 times on each sample using a CR-300 tristimulus colorimeter (Minolta, Osaka, Japan). The Hunter colour space (L, a, b) was used and the coordinates were used to calculate the Z (Yellowness) Index (Frau *et al*. 1999) to check the change in yellowness during ripening.

Sensory analysis. A descriptive test was performed with 14 judges trained for 4 weeks for the following attributes: bitter aftertaste, hardness, solubility, and cohesiveness. Reference standards were used as suggested (Lavanchy *et al*. 1993; Berodier *et al*. 1997). A 1–7 point scale with anchors (standard references) was used for the evaluation of the attribute intensity (Barcenas *et al*. 2007). Panel performance was evaluated using the three-way ANOVA (with factors sample, replicate, and judge). In each session judges tasted two cheeses to avoid sensorial fatigue. Eight sessions for each storage time were performed.

Statistical analysis. Significant differences between cheeses were evaluated using a mixed procedure with a split-plot design (SAS/STAT software; SAS Institute, Inc., Cary, USA) with two interactions, with curd cooking temperature (40 and 42°C), pressing (P and NP), storage (0, 1, 2, and 3), and trial (2) as factors. This model is a split-plot model with repeated measurements over time where the factor trial is the random effect. Means, when required, were separated according to Duncan's Multiple Range test, significance level $P \leq 0.05$.

RESULTS AND DISCUSSION

Chemical analysis. The curd cooking temperature influenced significantly only pH and NaCl content, lower and higher, respectively, in curd cooked at 42°C, with respect to 40°C (Table 1), in accordance with Abdalla and Nusr (2009). A lower pH value is to be ascribed to the probably higher lactobacilli activity due to the higher curd cooking temperature. Pressing gave a curd with higher dry matter and lower a_w, fat, SN, and NaCl. A major increase of the

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Table 1. Average values, standard deviations, and Anova analysis of chemical composition of ewe's milk cheeses

Factors	a_w	pH	Moisture (%)	Dry matter (%)	Fat (%)	TN (%)	Protein (%)	SN	Ripening index (SN/TN) %	Casein N (TN-SN)	Salt-in moisture (%)
Curd cooking temperature (°C)											
40	0.974 ± 0.001^{a}	5.5 ± 0.057^{a}	46.8 ± 0.283^{a}	53.1 ± 0.354^{a}	31.26 ± 0.035^{a}	3.3 ± 0.141^{a}	21.0 ± 0.283^{a}	0.8 ± 0.028^{a}	22.9 ± 0.424^{a}	2.5 ± 0.071^{a}	1.0 ± 0.057^{b}
42	0.973 ± 0.001^{a}	5.4 ± 0.028^{b}	46.3 ± 0.424^{a}	53.6 ± 0.424^{a}	31.21 ± 0.042^{a}	3.3 ± 0.212^{a}	21.1 ± 0.424^{a}	0.8 ± 0.057^{a}	22.9 ± 0.424^{a}	2.5 ± 0.141^{a}	1.2 ± 0.085^{a}
Cheese pressing											
P	0.972 ± 0.001^{a}	5.5 ± 0.071^{a}	46.4 ± 0.141^{b}	53.6 ± 0.141^{a}	31.47 ± 0.071^{a}	3.3 ± 0.141^{a}	21.0 ± 0.283^{a}	0.8 ± 0.028^{a}	22.9 ± 0.424^{a}	2.5 ± 0.141^{a}	1.1 ± 0.283^{a}
NP	0.975 ± 0.001^{b}	5.5 ± 0.085^{a}	46.7 ± 0.141^{a}	53.2 ± 0.141^{b}	31.00 ± 0.127^{b}	3.3 ± 0.212^{a}	21.2 ± 0.424^{a}	0.7 ± 0.042^{b}	22.7 ± 0.283^{a}	2.6 ± 0.212^{a}	1.0 ± 0.042^{b}
Storage time (days)											
1	0.998 ± 0.005^{a}	5.3 ± 0.057^{c}	47.3 ± 0.212^{a}	52.7 ± 0.849^{b}	31.2 ± 0.283^{a}	3.2 ± 0.028^{c}	20.7 ± 0.141^{c}	0.3 ± 0.042^{d}	8.6 ± 0.566^{d}	3.0 ± 0.141^{a}	0.0 ± 0.000^{d}
30	0.978 ± 0.003^{b}	5.5 ± 0.057^{b}	46.2 ± 0.707^{a}	53.8 ± 0.283^{a}	30.7 ± 0.141^{b}	3.3 ± 0.057^{b}	21.2 ± 0.283^{b}	0.7 ± 0.071^{c}	21.7 ± 0.707^{c}	2.6 ± 0.071^{b}	1.7 ± 0.085^{a}
60	0.961 ± 0.001^{c}	5.61 ± 0.042^{a}	46.6 ± 0.424^{a}	53.4 ± 0.141^{b}	31.4 ± 0.283^{a}	3.3 ± 0.042^{b}	21.0 ± 0.141^{b}	0.9 ± 0.085^{b}	28.2 ± 1.131^{b}	2.4 ± 0.042^{c}	1.4 ± 0.085^{b}
90	0.957 ± 0.001d	5.5 ± 0.042^{b}	46.3 ± 0.424^{a}	53.7 ± 0.141^{a}	31.6 ± 0.283^{a}	3.4 ± 0.042^{a}	21.4 ± 0.071^{a}	1.1 ± 0.085^{a}	32.3 ± 1.556^{a}	2.3 ± 0.071^{d}	1.2 ± 0.113^{c}

Data followed by different letters for each column and factor are significantly different by Duncan's multiple range test ($P \leq 0.05$); TN – total nitrogen; SN – soluble nitrogen; P – pressed; NP – not pressed; each value is the mean of two batch production with four samples analysed per batch ($N = 4$)

Table 2. Average values, standard deviations, and Anova analysis of texture parameters of ewe's milk cheeses

Factors	TPA parameters					Puncture test parameters		
	hardness (N)	adhesiveness (N·s)	elasticity (mm)	chewiness (N·mm)	cohesiveness	gradient (N·s)	force (N)	area (N s)
Curd cooking temperature (°C)								
40	20.1 ± 6.41^{a}	2.1 ± 0.70^{b}	6.1 ± 0.55^{a}	64.5 ± 27.93^{a}	0.5 ± 0.01^{a}	0.16 ± 0.01^{a}	5.1 ± 0.55^{a}	104.1 ± 18.89^{a}
42	20.8 ± 5.46^{a}	2.5 ± 0.99^{a}	6.2 ± 0.38^{a}	66.4 ± 21.63^{a}	0.5 ± 0.01^{a}	0.17 ± 0.02^{a}	5.2 ± 0.78^{a}	97.8 ± 15.76^{a}
Cheese pressing								
P	20.6 ± 6.85^{a}	2.4 ± 0.95^{a}	6.3 ± 0.48^{a}	67.0 ± 28.73^{a}	0.5 ± 0.01^{a}	0.16 ± 0.02^{b}	4.9 ± 0.71^{b}	96.1 ± 18.14^{b}
NP	20.3 ± 4.91^{a}	2.3 ± 0.80^{a}	6.1 ± 0.46^{b}	63.9 ± 20.47^{a}	0.5 ± 0.01^{a}	0.18 ± 0.01^{a}	5.4 ± 0.51^{a}	106.1 ± 14.99^{a}
Storage time (days)								
1	28.4 ± 2.27^{a}	1.1 ± 0.12^{c}	6.9 ± 0.32^{a}	102.5 ± 12.27^{a}	0.52 ± 0.00^{a}	0.18 ± 0.01^{a}	5.6 ± 0.28^{a}	116.9 ± 12.46^{a}
30	21.6 ± 4.04^{b}	3.0 ± 0.49^{a}	6.2 ± 0.15^{b}	67.5 ± 13.34^{b}	0.51 ± 0.00^{b}	0.16 ± 0.02^{b}	5.1 ± 0.52^{b}	99.2 ± 14.27^{b}
60	16.7 ± 3.28^{c}	2.5 ± 0.79^{b}	5.9 ± 0.30^{c}	50.5 ± 11.90^{c}	0.50 ± 0.01^{b}	0.17 ± 0.01^{ab}	5.2 ± 0.54^{b}	97.7 ± 8.59^{b}
90	17.1 ± 3.47^{c}	2.5 ± 0.37^{b}	5.9 ± 0.18^{c}	50.7 ± 9.59^{c}	0.50 ± 0.00^{b}	0.15 ± 0.02^{c}	4.5 ± 0.68^{c}	82.6 ± 14.16^{c}

Data followed by different letters for each column and factor are significantly different by Duncan's multiple range test ($P \leq 0.05$); P – pressed; NP – not pressed; each value is the mean of two batch production with four samples analysed per batch ($N = 4$)

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Table 3. Average values, standard deviations, and Anova analysis of colour parameters of ewe's milk cheeses

Factors	L	a	b	Z
Curd cooking temperature (°C)				
40	84.2 ± 0.92[b]	–2.9 ± 0.43[a]	12.2 ± 0.84[a]	51.8 ± 1.49[b]
42	84.7 ± 1.20[a]	–2.9 ± 0.22[a]	11.9 ± 0.47[b]	52.9 ± 1.96[a]
Cheese pressing				
P	84.6 ± 1.10[a]	–2.7 ± 0.37[b]	12.1 ± 0.74[a]	52.6 ± 1.77[a]
NP	84.3 ± 1.06[a]	–3.0 ± 0.27[a]	12.1 ± 0.66[a]	52.1 ± 1.84[a]
Storage period (days)				
30	84.9 ± 0.81[a]	–3.1 ± 0.12[a]	12.6 ± 0.74[a]	52.5 ± 1.71[a]
60	84.6 ± 1.01[a]	–2.9 ± 0.30[b]	12.1 ± 0.57[b]	52.5 ± 1.73[a]
90	84.1 ± 1.19[b]	–2.7 ± 0.39[c]	11.7 ± 0.62[c]	52.0 ± 1.91[a]

Data followed by different letters for each column and factor are significantly different by Duncan's multiple range test ($P \leq 0.05$); P – pressed; NP – not pressed; each value is the mean of two batch production with four samples analysed per batch ($N = 4$)

ripening occurred after the first month of ripening and reached the value of about 30% at 90 days.

Microbiological analysis. TMC was very low in fresh cheese and increased up to 5.5 log CFU/g at the end of storage, thus the vacuum packaging was effective in reducing the microbial development (Esmer *et al.* 2009). *Salmonella*, *L. monocytogenes*, and *E. coli* were always absent in the cheeses. Coliforms appeared only in the second trial but with low counts. Yeasts and moulds were present at low levels (data not shown), probably due to the combined effect of vacuum packaging and low storage temperature that are a valid hurdle strategy to extend the shelf-life (Gonzales-Fandos *et al.* 2000; Abdalla & Nusr 2009; Esmer *et al.* 2009).

Texture analysis. Data are reported in Table 2. The only TPA parameter affected by cooking temperature was the adhesiveness that was higher in samples cooked at 42°C. Cooking did not affect the puncture test parameters, probably for the small difference in treatment temperature, as suggested by Madadlou *et al.* (2006), who found differences with a higher cooking temperature span (34, 37, and 41.5°C). No significant differences resulted from the interaction between temperature and storage time. The puncture test showed that NP cheeses are significantly firmer than P samples, whereas the TPA evidenced a higher elasticity of P cheeses compared to NP ones. Significant changes were detected during storage,

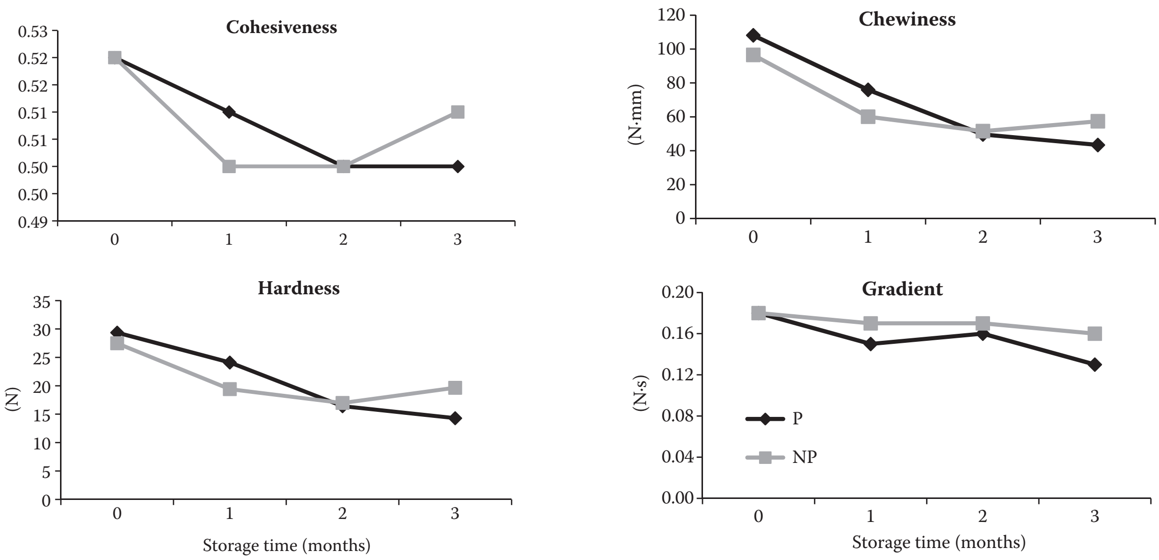

Figure 1. Interaction between cheese pressing and storage time in relation to Texture Profile Analysis (TPA) parameters of vacuum packaged ewe's cheese

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Table 4. Average values, standard deviations, and Anova results of the interaction between the factors curd cooking temperature and storage time for a and b colorimetric coordinates

Storage time (days)	a		b	
	40°C	42°C	40°C	42°C
30	3.1 ± 0.06[a]	3.1 ± 0.12[a]	13.2 ± 0.12[a]	11.9 ± 0.31[a]
60	3.0 ± 0.34[a]	2.8 ± 0.12[b]	12.3 ± 0.27[b]	11.8 ± 0.67[a]
90	2.5 ± 0.46[b]	2.8 ± 0.01[b]	11.5 ± 0.75[c]	12.0 ± 0.21[a]

Data followed by different letters for each column and factor are significantly different by Duncan's multiple range test ($P \leq 0.05$); each value is the mean of two batch production with four samples analysed per batch ($N = 4$)

as TPA and puncture test values decreased, apart the adhesiveness that increased. The cohesiveness, which normally diminishes during cheese ripening due to water loss and increased proteolysis (Akalin & Karaman 2010), decreased in our samples after the first 30 days of ripening and kept constant thereafter, probably due to the vacuum packaging that stopped water loss, as revealed by the moisture data (Table 1). Contrary to what Akalin and Karaman (2010) reported, adhesiveness significantly changed during ripening. The elasticity decrease observed was already reported (Akalin & Karaman 2010).

The interaction between pressing and storage resulted, at the end of storage, in NP cheese having higher cohesiveness, chewiness, hardness, and gradient ($P < 0.05$) than P cheese (Figure 1).

Colour analysis. The curd cooking temperature influenced significantly the L, b, and Z parameters, as cheeses cooked at 42°C were lighter than those cooked at 40°C (Table 3). In particular, the Z index was higher on cheeses processed at 42°C but the b coordinate was lower, with respect to samples cooked at 40°C. Pressing influenced the parameter, which was higher in NP than in P cheeses, thus resulting more red. L, a, and b decreased significantly during storage, in contrast to what was reported by Favati *et al*. (2007), who evidenced that vacuum packaging may help in stabilising the cheese colour. Despite the decrease in b values during the storage period, due to the retarding effect of vacuum packaging on ripening, the Z index did not change significantly. The interaction between temperature and storage time showed a decrease of the a parameter in cheeses cooked at 40°C , while it remained constant after 60 days in samples cooked at 42°C (Table 4). Moreover, the b coordinate decreased over time in cheeses cooked at 40°C, while it kept constant or even increased after 30 days in samples processed at 42°C (Table 4). The interaction of pressing with storage time did not result in any significant differences between the cheeses.

Sensory analysis. Sensory evaluation did not reveal any significant differences between the 4 attributes chosen with respect to curd cooking temperature and cheese pressing. On the contrary, only the cheese

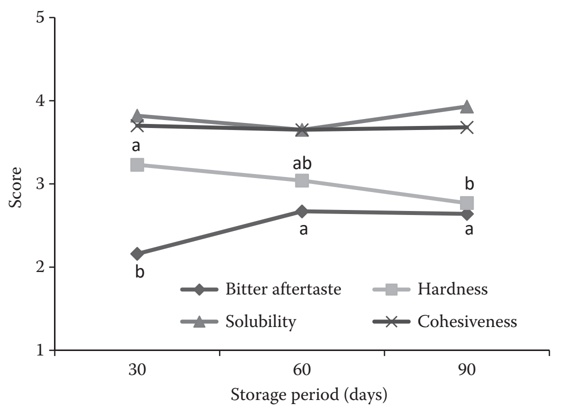

Figure 2. Changes in sensory attributes during the storage of vacuum packaged ewe's cheese (average data of four cheeses, 40P, 40 NP, 42P, and 42 NP). Different letters for each attribute mean a significant difference ($P \leq 0.05$)

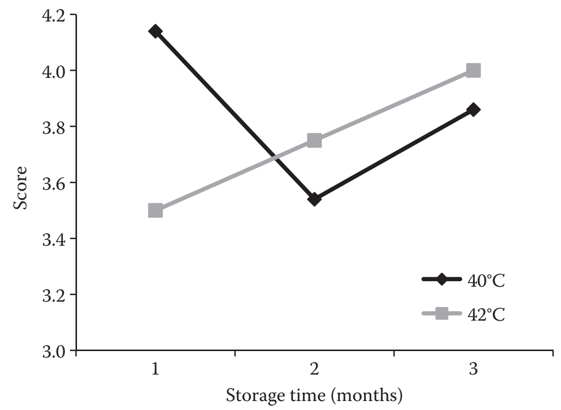

Figure 3. Interaction between curd cooking temperature and storage in relation to the sensory attribute solubility of vacuum packaged ewe's cheese. Different letters for each line mean a significant difference during storage ($P \leq 0.05$)

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storage significantly influenced the bitter aftertaste and hardness (Figure 2). The bitter aftertaste increased at 60 days and then it remained constant, in agreement with Akalin and Karaman 2010. Hardness decreased during the storage time as expected, due to proteolysis. Solubility and cohesiveness did not change during storage, in contrast to what was reported by Dabour *et al*. (2006). The interaction between curd cooking temperature and storage time showed significant differences for the solubility, which decreased after 30 days in cheeses cooked at 40°C and then increased at 90 days of storage, whereas the samples cooked at 42°C evidenced an increase in solubility over time (Figure 3).

CONCLUSIONS

Results showed that the curd cooking temperature influenced the pH, and salt content while pressing influenced the dry matter, a_w, fat, SN and salt content of ewe's milk cheeses. Textural parameters were partially modified mainly by pressing that was able to improve ewe's cheese rheological characteristics; in fact NP cheeses were always harder and less elastic than P cheeses. Cooking temperature changed mainly colour parameters, where the Z index, which indicates the change in yellowness during ripening, was lower in cheeses cooked at 40°C. Storage time was the most important factor in influencing the cheese characteristics. During storage the proteolysis was observed despite the low temperature and vacuum packaging, which slowed down the water loss and colour changes. Only the storage time influenced sensory characteristics of cheeses with particular reference to bitter aftertaste and hardness. At last, the cheeses cooked at 42°C showed an increase in solubility over time.

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