

Effect of vacuum packaging on artisanal goat cheeses during refrigerated storage

Florencia FRAU^{1*} , Jorge Nelson LEGUIZAMÓN CARATE², Florencia SALINAS¹, Nora PECE¹

Abstract

The aim of the present work was to investigate the effects of vacuum packaging and storage time on physicochemical composition, fatty acid content, color, microbiological content and rheological behavior of artisanal fresh goat cheese during refrigerated storage. The results show that both vacuum packaging and storage time had an influence on moisture content, color variation and rind formation, obtaining better visual appearance and higher moisture content in vacuum packed cheeses. The packaging also positively influenced the rheological study, observing that the vacuum packed cheeses at the end of the study exhibited a behavior similar to that of the cheeses at time 0. Vacuum packaging of artisanal goat cheeses represents the possibility of preserving the cheeses for a longer time and thus increasing their shelf life. On the other hand, the decrease in moisture loss also represents an economic benefit for producers.

Keywords: vacuum packaging; rheology; free fatty acids; artisanal cheeses.

Practical Application: Use of vacuum packaging in artisan goat cheeses and its effect on quality, rheology and color.

1 Introduction

Today, the tendency to consume organic and healthy foods in the world is increasing (Akarca, 2020). Goats' milk and the products made from it are perceived by consumers as ecological and having greater health benefits (Popović-Vranješ et al., 2017). These products have gained popularity due to the increased interest of consumers in both the tradition of cheesemaking and the sensorial and nutritional value attributed to goat milk. Artisanal goat cheeses are considered an excellent source of proteins, lipids, vitamins and mineral elements (Herman-Lara et al., 2019).

The importance of artisanal cheese is increasing both at the international and national due to changes in consumers' lifestyles (Cagri-Mehmetoglu, 2018). Indeed, demand for goat milk cheeses, especially for the fresh lactic varieties, has steadily increased among consumers of health and diet foods over the past 20 yr. These lactic-type cheeses are produced by acid coagulation through the addition of indigenous or selected lactic microflora and by addition of a small quantity of rennet. The final product has a high moisture content (50 to 65%), a low pH (4.1 to 4.5), and a short shelf life (<30 d) (Masotti et al., 2012).

The majority of goat milk cheese manufactured and sold in the north of Argentina is fresh cheese, and is usually made by farmers on a small scale in their farmhouse, using goat milk, traditional techniques, but not using packaging. The availability of manufactured cheese is limited by the short shelf life of the product and by the seasonal production of goat milk. These cheeses are distinguished from those produced on an industrial scale by their distinctive sensory qualities and are a showcase of their region or country of origin (Kuźnicka & Łapińska, 2014).

Producers of regional cheeses, having achieved a unique product, want their effort and determination to be reflected in consumer recognition through increased demand for their products (Barłowska et al., 2018). The storage of cheeses without packaging reduces their shelf life, decreases their quality and hinders their possible sale in markets far from the production area. It is necessary to study packaging alternatives that allow extending the shelf life of these types of cheeses, which may represent a viable alternative for small producers.

Types of cheese vary depending on changes in storing time and conditions during the ripening of the cheese, and very complex chemical and biochemical reactions such as glycolysis, proteolysis, and lipolysis. Lipolysis has a great importance in cheesemaking technology (Akarca, 2020).

While it is known that goat milk has a higher content of short chain fatty acids (C4:0-C12:0) and free fatty acids (Yurchenko et al., 2018; Ranadheera et al., 2019), the proportional content of both caprylic acid (C8:0) and capric acid (C10:0) is considerably greater in goat milk than in bovine milk (Vieitez et al., 2016; Ranadheera et al., 2019), the medium length fatty acids, branched chain in particular, contribute to the waxy and "goaty" flavors associated to some goat milk products (Verruck et al., 2019; Ranadheera et al., 2019) and possesses a higher proportion of conjugated linoleic acid, which has been linked to various physiological benefits (Yurchenko et al., 2018; Ranadheera et al., 2019); it is important to determine the content of fatty acids in each variety of cheese and the effect that packaging has on this composition.

Received 12 Jan., 2020

Accepted 15 Apr., 2020

¹Facultad de Agronomía y Agroindustrias, Universidad Nacional del Estero, Santiago del Estero, Argentina

²Universidad Nacional de Santiago del Estero, Santiago del Estero, Argentina

*Corresponding author: ffrau@unse.edu.ar

Vacuum packaging (VP) is not suitable for all types of cheeses, since although it delays the growth of some microorganisms, it can have undesirable effects on color, taste and texture or show an excess of moisture on the surface due to the migration of water from the interior to the surface (Pantaleão et al., 2007). Therefore, it is necessary to study the effect of VP in each specific cheese variety.

Although different authors have studied the effect of vacuum packaging on the composition and rheology of cheeses, there is no study that analyzes all the effects together (Casti et al., 2016; Adhikari et al., 2018; Todaro et al., 2018).

Cheese distribution is gradually shifting from cheesemakers selling directly to their consumers from their farms to large-scale distribution through market. Consequently, an extended shelf life is required and good quality must be maintained during long-term storage. At the market, goat milk cheeses are placed in open-deck refrigerated display cabinets under different storage conditions (i.e., time, temperature, and light irradiation), different from the cold rooms and dark conditions under which cheese is stored on farm (Masotti et al., 2012).

The aim of the present work was to investigate the effects of vacuum packaging and storage time on the physicochemical composition, fatty acids content, color, microbiological content and rheological behavior of artisanal fresh goat cheese during refrigerated storage.

2 Materials and methods

2.1 Cheeses samples

The cheeses were obtained from an artisanal cheese producer in Santiago del Estero (Argentina); half of the lot was vacuum packed using 100 µm polypropylene bags; the other half was not packed, maintaining the storage conditions currently used by artisanal producers. The samples, both unpackaged (UP) and vacuum packed (VP), were transported to the Food Processing Pilot Plant belonging to the Faculty of Agronomy and Agroindustries of the National University of Santiago del Estero, and stored at 4 °C for 30 days.

The samples were analyzed the day of the delivery (T0); at 10 (T10), 20 (T20) and 30 (T30) days of refrigerated storage for physicochemical composition, color analysis, microbiological content, rheological behavior; and at 0 and 30 days composition and fatty acids profile. The maximum number of storage days was determined according to the shelf life that artisanal producers estimate for this variety of cheese. Each piece was analyzed in duplicate.

2.2 Compositional analysis

The analysis of composition was carried out on days T0 and T30, according to the references indicated.

- a) Fat: The fat content of the cheeses was determined following the technique described in FIL IDF 9C: 1987 (International Dairy Federation, 1987);

- b) Protein: The protein content of the cheese was determined using Hach's rapid protein determination method (Hach et al., 1985);
- c) Fatty Acids Perfil: Gas chromatography was used according to the procedure ICR-PE-CR-39-R02 based on ISO 15884 IDF 182 (International Organization for Standardization, 2002);
- d) Moisture content: The moisture content of the cheeses was determined using the method described in FIL IDF 4A: 1982 (International Dairy Federation, 1982);
- e) pH determination: It was determined directly, using pH meter "Digital Instruments" with tip electrode. The pH was measured using a Lutron pH-207 pH Meter calibrated with pH 7 buffer (Sigma).

2.3 Color analysis

Color measurements were performed with a colorimeter Minolta ChromaMeter CR-400, Osaka, Japan. The instrument was calibrated before each analysis. The color of cheeses was analyzed on the top. Three readings were taken and averaged for each of the three replications. Color was described as coordinates: lightness (L^*), redness (a^* , $\pm$ red-green) and yellowness (b^* , $\pm$ yellow-blue) (Sangaletti et al., 2009; Todaro et al., 2018).

2.4 Microbiological analysis

Sample preparation

Ten grams of cheese and 90 mL of a 2% (w/v) sodium citrate solution were transferred to a sterile blender and blended for 1 min at normal speed and 1 min at high speed. Serial dilutions of the sample homogenate were prepared in 0.1% sterile peptone water and inoculated in growth media for the estimation of microbial counts. During cheese storage (0, 10, 20 and 30 days after elaboration), for enumeration of Aerobic mesophilic bacteria and *Staphylococcus* spp, plates with dehydrated medium (NISSUI Pharmaceutical Co. Ltd., Tokyo, Japan) were used following the manufacturer's instructions.

Acid Lactic Bacteria determination was performed following the technique described in Silva et al. (1997). Three dilutions were selected: using a 1 mL automatic pipette, each dilution was placed in sterile Petri dishes, and the MRS culture medium was added.

The plates were incubated in microaerobiosis at 32 ± 1 °C for 48 hours.

All determinations were made in duplicate.

2.5 Rheological measurements

The rheological characteristics of the experimental cheese were obtained using an AR 1000 rheometer (TA Instruments, Leatherhead, Surrey, UK). A 40 mm stainless steel parallel plate geometry with gap size of 4.5 mm was used. All the experiments were performed at a constant temperature of 25 °C using a Peltier plate to control temperature. Linear viscoelastic range for each cheese was determined by a stress sweep (Frau, 2013; Rogers et al., 2009; Van Hekken et al., 2007a).

All the samples were studied and the linear viscoelastic region was determined by stress sweep measurements; the stress was linearly increased from 1 to 1000 Pa at a frequency of 10 Hz. During the time of the experiment, one data point was collected per second. In order to create a rheogram describing the structure of each sample, a frequency sweep was carried out (Frau, 2013). From the stress sweep, the value for the critical stress was found (Fernández-García et al., 2006; Rogers et al., 2009; Frau, 2013; Melito et al., 2013; Galindo-Rosales et al., 2019).

Dynamical rheological measurements (frequency sweep) were used to determine the elastic or storage module (G'), viscous or loss module (G''), and complex viscosity (η^*) of the cheeses elaborated in terms of frequency (ω); the parameter used was 0.10-100 Hz in the viscoelastic region, previously determined (Van Hekken et al., 2007b).

All determinations were made in triplicate.

2.6 Statistical analyses

Experimental data were analyzed using statistical software (InfoStat version 2018). A 2x4 arrangement with 2 repetitions was used in complete randomized blocks.

Data were submitted to ANOVA by INFOTAT. Data were analyzed using the Tukey multiple comparisons method. A p-value <0.05 was considered significant.

3 Results and discussion

The mean values of the physicochemical parameters are given in Table 1. The pH of the cheese remained stable, varying from 5.89 to 5.71 in UP and 5.89 to 5.98 in VP throughout

the study, and was not affected by any length of refrigerated storage ($p > 0.05$). There are no significant differences in the pH values between the treatments ($p > 0.05$). These results agree with those of other authors, who also did not find significant variations in pH during cheese storage (Van Hekken et al., 2005; Masotti et al., 2012).

There are no significant differences in pH values between treatments or times. It was observed that in both treatments the pH value increased slightly during the first 20 days and decreases at the end of the period. This coincides with what was reported by Pala et al. (2016) in *ricotta fresca*. Other authors have found a constant decrease in pH values, however the final pH values are similar to those found in this work (Sangaletti et al., 2009).

Significant differences ($p < 0.01$) were found in the moisture content between treatments and between times; UP cheeses had a humidity decrease of 38.4%, while VP cheeses decreased only 9.2% (Table 1). Although UP cheeses are expected to lose more moisture than VP cheeses, these results indicate that the refrigerated storage conditions analyzed in this article are not adequate, and they should be maintained in a more humid environment in order to avoid water loss. Vacuum packaging prevents moisture loss, which also represents an economic benefit when selling cheese by weight.

The analysis of variance indicates that the fat content decreased during the storage period ($p < 0.01$), both for UP and VP cheeses. These results agrees with the results of Osman et al. (2009), but are in disagreement with the findings of Tarakci & Kucukoner (2006), who found no significant variation in fat content during the ripening period of vacuum packaged Turkish Hashar cheese and El Owni & Hamid (2008), who found

Table 1. Values of physicochemical composition of fresh goat cheese during shelf life under different storage conditions

Parameter	Cheese	Storage time (days)			
		0	10	20	30
pH	UP	5.89 ± 0.06 ^{aA}	6.00 ± 0.38 ^{aA}	6.20 ± 0.33 ^{aA}	5.71 ± 0.39 ^{aA}
	VP	5.89 ± 0.06 ^{aA}	5.94 ± 0.10 ^{aA}	6.00 ± 0.11 ^{aA}	5.98 ± 0.17 ^{aA}
Moisture (%)	UP	46.25 ± 0.96 ^{aA}	33.00 ± 1.41 ^{aA}	28.75 ± 0.96 ^{bA}	28.50 ± 0.50 ^{bA}
	VP	46.25 ± 0.96 ^{aA}	40.25 ± 0.50 ^{bB}	41.00 ± 0.00 ^{bB}	42.00 ± 0.00 ^{cB}
Total Fat (g/100g dry weight)	UP	55.96 ^{aA}	s/d	s/d	47.56 ^{bB}
	VP	55.96 ^{aA}	s/d	s/d	48.57 ^{cB}
Saturated (g/100g dry weight)	UP	38.31 ^{aA}	s/d	s/d	32.14 ^{bA}
	VP	38.31 ^{aA}	s/d	s/d	32.28 ^{cA}
Monounsaturated (g/100g dry weight)	UP	14.78 ^{aA}	s/d	s/d	12.29 ^{bA}
	VP	14.78 ^{aA}	s/d	s/d	13.10 ^{cA}
Polyunsaturated (g/100g dry weight)	UP	1.54 ^{aA}	s/d	s/d	2.29 ^{bB}
	VP	1.54 ^{aA}	s/d	s/d	2.31 ^{bB}
Trans (g/100g dry weight)	UP	1.33 ^{aA}	s/d	s/d	0.83 ^{bA}
	VP	1.33 ^{aA}	s/d	s/d	0.88 ^{cA}
Rind (mm)	UP	0,00 ^{aA}	3,32 ± 0.75 ^{bB}	4.09 ± 0.72 ^{bC}	4.61 ± 0.82 ^{cD}
	VP	0,00 ^{aA}	0,00 ^{aA}	0,00 ^{aA}	0,00 ^{aA}

Means within a row with different lowercase superscript letters significantly differ ($p < 0.01$). Means within a column with different uppercase superscript letters significantly differ ($p < 0.01$)

increasing fat content during storage period of Sudanese White cheese. There are no significant differences in fat content between vacuum packed cheese and unpackaged cheese.

In this study, a significant difference was observed only during the storage period in the content of polyunsaturated fats ($p < 0.05$).

It was observed that in the UP cheeses a rind was formed by exposure to air and the consequent drying process to which it was subjected; this was not observed in vacuum packed cheeses. Due to the fact that these are fresh cheeses, the formation of rind is not desirable. Table 1 shows the thickness of the rind formed.

The FFAs profiles of both UP and VP cheeses are shown in Table 2. Significantly different values ($p < 0.05$) are presented with different superscripts. The amount of individual FFAs increased during ripening. This tendency has also been reported for the great majority of cheeses (Mallatou et al., 2003). Among all the detected free fatty acids, only C10:1, C12:1, C15:1 and

Table 2. Comparison of mean free fatty acid concentration (mg/g cheese) of UP and VP cheese.

Free Fatty Acid	Ripening time 0 days	Ripening time 30 days	
	UP and VP	UP	VP
C4:0	1.57 ^a	1.58 ^a	1.64 ^b
C6:0	1.91 ^a	1.95 ^b	2.03 ^c
C8:0	2.56 ^a	2.59 ^b	2.64 ^c
C10:0	9.74 ^a	9.29 ^b	9.20 ^c
C10:1	0.24 ^a	0.23 ^a	0.26 ^a
C12:0	4.23 ^a	4.01 ^b	3.94 ^c
C12:1	0.13 ^a	0.12 ^a	0.11 ^a
C14:0	10.11 ^a	9.53 ^b	9.40 ^c
C14:1 + iso C15:0	0.57		
C14:1		0.14	0.15
C iso15:0		0.39	0.36
C15:0	1.22 ^a	1.15 ^b	1.07 ^c
C15:1	0.29 ^a	0.29 ^a	0.26 ^a
C16:0	26.88 ^a	26.01 ^b	25.65 ^c
C16:1	1.17 ^a	1.14 ^{ab}	1.20 ^{ac}
C17:0	0.97 ^a	0.95 ^{ab}	0.92 ^{ab}
C17:1	0.54 ^a	0.54 ^a	0.56 ^a
C18:0	10.94 ^a	11.07 ^b	10.65 ^c
C18:1	24.10 ^a	23.75 ^b	24.85 ^c
C18:1 trans	1.81 ^a	1.73 ^b	1.69 ^c
C18:2	1.87 ^a	1.83 ^b	1.82 ^b
C18:2 trans	0.63 ^a	0.05 ^b	0.15 ^c
C18:3	0.40 ^a	0.59 ^b	0.58 ^b
CLA	0.56 ^a	0.88 ^b	0.78 ^c

Means within a row with different lowercase superscript letters significantly differ ($p < 0.05$).

C17:1 did not show significant differences ($p > 0.05$) neither between treatments nor storage time.

The long-chain saturated (C16:0, C18:0) and unsaturated C18:1 FFA were the most abundant in the samples; these results agree with the report by Sousa et al. (1997).

The final content of butyric, caproic and caprylic acids are higher in VP cheeses, which would have an influence on the cheese flavor, since these FFA have a direct impact on the characteristic flavor of goat products.

3.1 Color values

The average values of the color analysis are shown in Table 3.

The cheeses evaluated showed a high luminosity (L^*), a negative value of a^* (imperceptible green color) and a positive value of b^* ; which indicates yellowing. This is based on the low carotenoid content of goat milk, due to the fact that it prevents yellowness similar to that of cow milk, with fresh goat cheeses being characterized by their whiter color in relation to cow. These results coincide with other authors, although the values of the parameters vary depending on the different varieties of cheese (Chacón Villalobos & Pineda Castro, 2009).

L^* values in UP cheese decreased significantly during storage. This was also reported by other authors, both in goat and cow cheeses (Chacón Villalobos & Pineda Castro, 2009; Akarca et al., 2015). This is because cheeses with high moisture content tend to be brighter and less saturated (Chacón Villalobos & Pineda Castro, 2009) and reduces light scattering degree as light penetrates in the upper cheese layers and is scattered by both whey and fat globules (Moreira et al., 2019).

Yellowness values (b^*) do not show significant differences during storage time. The value of b^* at the end of the storage period of UP cheeses is three times higher than reported by Chacón Villalobos & Pineda Castro (2009) and Moreira et al. (2019) for goat cheeses. This is a consequence of the cheese to air exposure, thus causing color variation. This is not a desired feature, since consumers of goat products expect white cheeses.

Redness values (a^*) were significantly different ($p < 0.05$) among storage time on UP cheeses. There are significant differences ($p < 0.05$) between treatments from 10 days of storage. High a^* values in goat dairy products have been mainly attributed to their fatty acid profiles (Moreira et al., 2019).

As reported by Moreira et al. (2019), all assessed samples presented high luminosity (L^*) values, with a predominance of the yellow component (b^*) compared with the green component (a^*), suggesting that white-yellowness mostly contributes to cheese color characteristics.

3.2 Microbiological analyses

The results of the microbiological analysis are shown in Table 4.

The packaging did not affect the microbiological profiles of the cheeses. No significant differences ($p > 0.05$) were observed between UP and VP cheeses in any of the microorganisms analyzed.

Table 3. Changes in L*, a* and b* values of goat cheese during storage.

Parameters	Cheese	Storage time (days)			
		0	10	20	30
L*	UP	89.15 ± 5.56 ^{aA}	82.1 ± 0.91 ^{bA}	79.57 ± 0.63 ^{cA}	78.93 ± 0.03 ^{dA}
	VP	89.15 ± 5.56 ^{aA}	90.48 ± 0.55 ^{aB}	89.99 ± 0.53 ^{aB}	89.96 ± 0.69 ^{aB}
a*	UP	-4.92 ± 0.95 ^{aA}	-6.79 ± 0.29 ^{bA}	-5.77 ± 0.02 ^{cA}	-5.40 ± 0.01 ^{dA}
	VP	-4.92 ± 0.95 ^{aA}	-3.83 ± 0.04 ^{bB}	-3.91 ± 0.26 ^{bB}	-3.79 ± 0.10 ^{bB}
b*	UP	33.71 ± 24.84 ^{aA}	32.68 ± 0.34 ^{aA}	30.68 ± 0.26 ^{aA}	32.2 ± 0.01 ^{aA}
	VP	21.21 ± 2.82 ^{aA}	18.40 ± 0.10 ^{aB}	18.91 ± 1.45 ^{aB}	18.17 ± 1.40 ^{aB}

Means within a row with different lowercase superscript letters significantly differ ($p < 0.05$). Means within a column with different uppercase superscript letters significantly differ ($p < 0.05$).

Table 4. Total aerobic mesophilic bacteria, lactic acid bacteria and *Staphylococcus aureus* counts of UP and VP cheese during storage (log CFU/g).

Microorganisms	Cheese	Storage time (days)			
		0	10	20	30
Aerobic mesophilic bacteria	UP	4.47 ^{aA}	4.37	5.53	5.47 ^{bA}
	VP	4.47 ^{aA}	4.70	4.78	4.60 ^{aB}
Lactic Acid Bacteria	UP	4.46 ^{aA}	4.24	4.46	5.01 ^{bA}
	VP	4.46 ^{aA}	4.70	5.48	5.90 ^{bB}
<i>Staphylococcus aureus</i> .	UP	1.41 ^{aA}	2.53	2.72	3.08 ^{bA}
	VP	1.41 ^{aA}	2.68	2.69	2.68 ^{bB}

Means within a row with different lowercase superscript letters significantly differ ($p < 0.05$). Means within a column with different uppercase superscript letters significantly differ ($p < 0.05$).

The count of aerobic mesophilic bacteria has been used as an indicator of the hygienic quality of food, since it gives an idea of the shelf life (Sangaletti et al., 2009). This study shows an increase in the count of aerobic mesophilic bacteria in UP cheeses as a result of the higher oxygen content that allows their growth. Total counts are lower than those reported by other authors in other cheese varieties (Akarca et al., 2015; Sangaletti et al., 2009). VP cheeses do not show significant differences between the beginning and the end of the study. Other authors, however, have reported a decrease in the count of these microorganisms during cheese storage (Akarca et al., 2015). The content of these microorganisms in VP cheeses remained constant between day 20 and 30, possibly as a result of the decrease in total aerobic mesophilic bacteria. It is thought to be caused by intra-package conditions and the increase in cheese acidity (Akarca et al., 2015).

Lactic acid bacteria (LAB) counts for both UP and VP cheeses indicate values similar to those reported by Akarca et al. (2015) and Sangaletti et al. (2009), who studied cheeses of similar humidity and pH values. However, was lower than those reported by Fuentes et al. (2015) and Masotti et al. (2012), who indicate values between 7 and 9 (log CFU/g). To understand these differences, it is important to analyze the cheeses studied by Fuentes et al. (2015), obtained from raw milk, and the Masotti cheeses studied with different manufacturing processes, where the fermentation is longer and the curd is maintained for 24 hours at 25 °C; processes that could stimulate the growth of LAB. A significant increase ($p < 0.05$) was detected in VP cheeses, at 30 days of shelf life. The reason for the increase in LAB count can be attributed to the oxygen sensitivity of these microorganisms, whose development is favored in the intra-package conditions

of VP cheeses. These results agree with what was reported by other authors (Sangaletti et al., 2009; Akarca et al., 2015).

The count of *Staphylococcus aureus* in the samples is higher than that reported by other authors (Sangaletti et al., 2009; Akarca et al., 2015; Moreira et al., 2019;) since day 0 of the study, which implies that there has been a high level of contamination in cheese making. The UP samples increased the content of *Staphylococcus aureus* during the 30 days of study, while the VP increased until day 10 and then remained constant. This may result from the protective effect of lactic bacteria and the low oxygen content in the VP environment. However, the cheeses obtained for this particular test are not suitable for consumption.

3.3 Rheological behavior

Stress sweep

Critical stress (Figure 1a and b) values from the linear viscoelastic region (LVR) provides the point where a material deviates from its linear stress and strain relationship; these points show where network properties of the material change on a nano or micro scale (Rogers et al., 2009). The stress sweep carried out on the cheese samples indicates that both UP and VP have a critical stress value at time 0 (158.5 Pa); this means that the application of a force higher than critical stress caused a weakening of the structure (Rogers et al., 2009).

In UP cheeses the value of G* increased with shelf life and a critical stress value was not observed within the range studied. This behavior is a consequence of the variations suffered by the

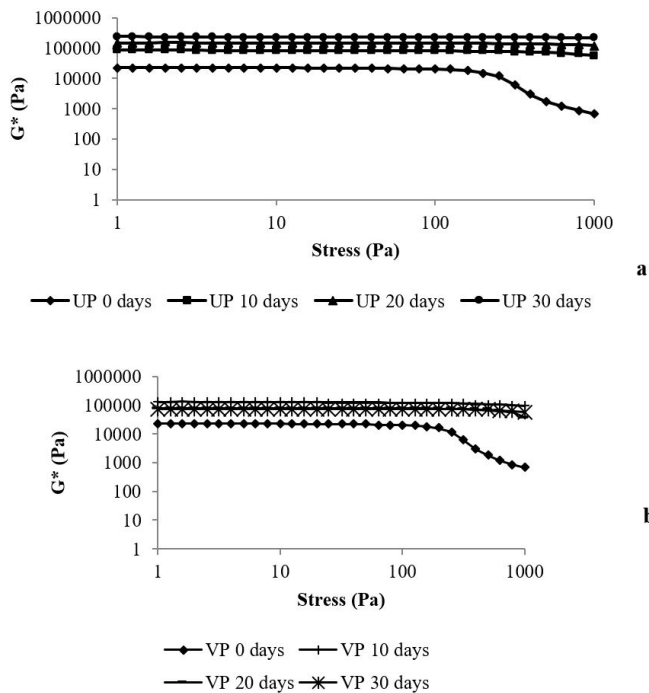


Figure 1. G^* variation with stress in UP (a) and VP (b) cheeses.

cheese matrix, where the loss of moisture would cause the increase in the number of interactions between the protein aggregates surrounding them (Frau, 2013). This result is expected for this type of cheese, and the difference during shelf life is the result of moisture loss.

In the case of VP cheeses, an opposite behavior can be observed, as the greater value of G^* occurs after 10 days of packaging and then begins to decrease until achieving day 30, where a critical stress value appears again. These results show that after 30 days of vacuum packaging, the cheese has a rheological behavior that resembles the initial cheese.

3.4 Frequency sweep

Figures 2 and 3 show both UP and VP cheeses exhibiting characteristics typical of a viscoelastic gel, with G' greater than G'' , and both showed frequency dependence. In both types of samples analyzed, the elastic component contributes more than the viscous module to viscoelasticity ($G' > G''$) which leads to a structure resembling a solid within the range of frequencies studied (Frau, 2013).

Both G' and G'' in UP cheese increased ($p < 0.05$) as the shelf life increased. In the case of VP cheeses, the values of G' y G'' increased until day 20, decreasing towards the end of the shelf life, resembling the structure of the VP cheese at the beginning of the study. This behavior coincides with what was reported in this study for critical stress. The values of G' and G'' from day 10 are higher in UP cheeses than in VP.

The elastic modulus (G') dominated the at-rest response of the samples, implying that at the frequencies tested, the sample behaves as a solid (Figure 3 and 4).

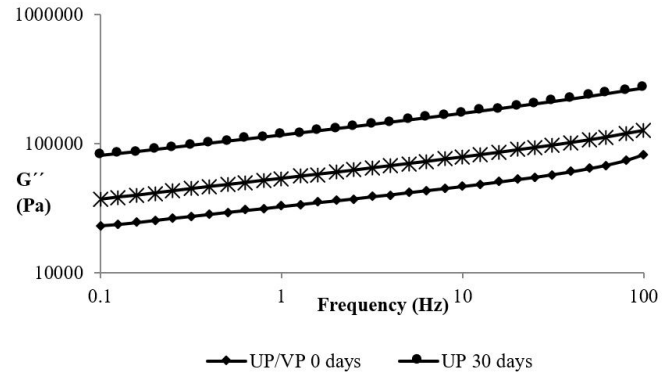


Figure 2. G' variation with ω in UP cheeses.

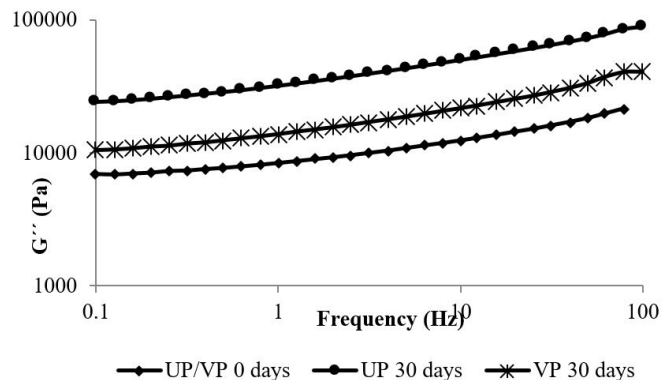


Figure 3. G'' variation with ω in VP cheeses.

The interesting data obtained through this type of dynamic (or oscillatory) measurements are the contributions to the internal structure of the sample from the elastic and viscous module, G' and G'' (Pa), respectively, and the complex viscosity, η^* (Pa s) (Kealy, 2006; Kelly & O'Kennedy, 2001).

Figure 4 shows a typical pseudoplastic profile (Kealy, 2006) for both UP and VP cheeses. It is expected that the complex viscosity η^* relates somehow to the cohesiveness of the sample (estimating deformation before the structure breakdown) (Kealy, 2006). In the analysis of complex viscosity, the rheological behavior of the samples is similar to that analyzed in this rheology study, observing that the 30-day VP cheese resembles the initial cheese.

Clearly, measurements in the linear viscoelastic region involve probing the structure of the sample in a non-destructive manner, but an irreversible deformation takes place in the mouth. However, it is likely that these quantities can indicate the initial experience of a consumer (Kealy, 2006).

Experimental cheeses with lower moisture content (UP at 30 days) have the highest values of G' and G'' (233 kPa and 73.25 kPa, respectively, at 50.26 Hz). This means that UP cheeses are more elastic than cheeses with higher moisture contents (Pereira, et al., 2001). Both UP and VP at 0 days of study are the least elastic of all cheeses studied.

In order to compare G' and G'' , it was necessary to choose a data point at a single frequency because these values are functions

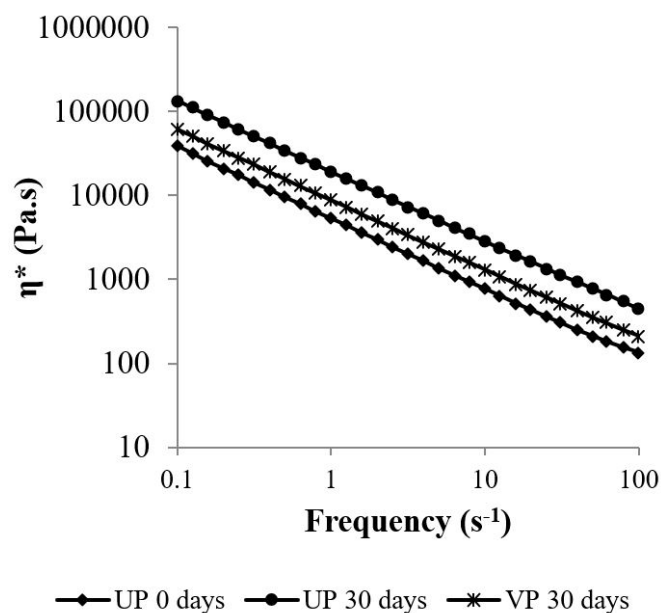


Figure 4. Complex viscosity (η^*) in UP and VP cheeses.

Table 5. Viscoelastic parameters of cheese made with different culture combinations.

Parameter	UP and VP	UP	VP
	0 days	30 days	30 days
Elastic modulus, G' at 0.1 Hz (kPa)	23.13 ^a	80.89 ^b	36.85 ^a
Elastic modulus, G' at 50.26 Hz (kPa)	64.26 ^a	233 ^b	107 ^a
Elastic modulus, G' at 99 Hz (kPa)	82.57 ^a	270 ^b	127 ^a
Viscous modulus, G'' at 0.1 Hz (kPa)	6.93 ^a	24.19 ^b	10.49 ^a
Viscous modulus, G'' at 50.26 Hz (kPa)	18.23 ^a	73.25 ^b	33.45 ^a
Viscous modulus, G'' at 99 Hz (kPa)	21.75 ^a	88.98 ^b	40.54 ^a

Means within a row with different lowercase superscript letters significantly differ ($p < 0.05$).

of the frequency of oscillation; the following values 0.1, 50.26, and 99 s^{-1} were arbitrarily chosen for comparison (Table 5).

There were no significant differences ($p < 0.05$) between: UP and VP cheeses at 0 days; both UP/ VP cheeses at 0 days and UP at 10 days of storage; both UP/ VP cheeses at 0 days and VP at 30 days of storage, which would demonstrate that vacuum packaging allows the rheological characteristics of cheeses to be maintained.

The rheological results agree with the macroscopical appearance of experimental cheeses. Vacuum packed cheeses preserved the white color and soft texture at the end of the analysis; rind formation and yellowish development were not observed. On the other hand, cheeses that have remained exposed to the air developed a yellowish color on the surface, in addition to showing a cracked rind; attributes that are not appreciated by consumers of goat products.

4 Conclusion

The results show that both vacuum packaging and storage time had an influence on moisture content, color variation and rind formation, obtaining better visual appearance and higher moisture content in vacuum packed cheeses.

The packaging also positively influenced the rheological study, observing that the vacuum packed cheeses at the end of the study exhibited a behavior similar to cheeses at the beginning of this study.

Regarding the analysis of fatty acids, the final content of butyric, caproic and caprylic acids are higher in VP cheeses, which would have an influence on the cheese flavor, since these FFA have a direct impact on the characteristic flavor of goat products.

Vacuum packaging of artisanal goat cheeses represents the possibility of preserving the cheeses for a longer time and thus increasing their shelf life. On the other hand, the decrease in moisture loss also represents an economic benefit for producers.

References

- Adhikari, A., Yemmireddy, V. K., Costello, M. J., Gray, P. M., Salvadalena, R., Rasco, B., & Killinger, K. (2018). Effect of storage time and temperature on the viability of *E. coli* O157:H7, *Salmonella* spp., *Listeria innocua*, *Staphylococcus aureus*, and *Clostridium sporogenes* vegetative cells and spores in vacuum-packed canned pasteurized milk cheese. *International Journal of Food Microbiology*, 286, 148-154. <http://dx.doi.org/10.1016/j.ijfoodmicro.2018.07.027>. PMID:30114563.
- Akarca, G. (2020). Lipolysis and aroma occurrence in Erzincan Tulum cheese, which is produced by adding probiotic bacteria and ripened in various packages. *Food Science and Technology (Campinas)*, 40(1), 102-116. <http://dx.doi.org/10.1590/fst.33818>.
- Akarca, G., Tomar, O., & Gök, V. (2015). Effect of different packaging methods on the quality of stuffed and sliced mozzarella cheese during storage. *Journal of Food Processing and Preservation*, 39(6), 2912-2918. <http://dx.doi.org/10.1111/jfpp.12542>.
- Barłowska, J., Pastuszka, R., Rysiak, A., Król, J., Brodziak, A., Kędzierska-Matysek, M., Wolanciuk, A., & Litwińczuk, Z. (2018). Physicochemical and sensory properties of goat cheeses and their fatty acid profile in relation to the geographic region of production. *International Journal of Dairy Technology*, 71(3), 699-708. <http://dx.doi.org/10.1111/1471-0307.12506>.
- Cagri-Mehmetoglu, A. (2018). Food safety challenges associated with foods of Turkey. *Food Science and Technology (Campinas)*, 38(1), 1-12. <http://dx.doi.org/10.1590/1678-457x.36916>.
- Casti, D., Scarano, C., Pala, C., Cossu, F., Lamon, S., Spanu, V., Ibba, M., Mocci, A. M., Tedde, F., Nieddu, G., Spanu, C., & Santis, E. P. L. (2016). Evolution of the microbiological profile of vacuum-packed ricotta salata cheese during shelf-life. *Italian Journal of Food Safety*, 5(2), 57-60. <http://dx.doi.org/10.4081/ijfs.2016.5501>. PMID:27800440.
- Chacón Villalobos, A., & Pineda Castro, M. L. (2009). Características químicas, físicas y sensoriales de un queso de cabra adaptado del tipo "Crottin de Chavignol". *Agronomía Mesoamericana*, 20(2), 297. <http://dx.doi.org/10.15517/am.v20i2.4946>.
- El Owni, A. O. O., & Hamid, I. A. O. (2008). Effect of storage period on weight loss, chemical composition, microbiological and sensory characteristics of Sudanese white cheese (Gibna Bayda). *Pakistan Journal of Nutrition*, 7, 75-80. <http://dx.doi.org/10.3923/pjn.2008.75.80>.

- Fernández-García, E., Carbonell, M., Calzada, J., & Nuñez, M. (2006). Seasonal variation of the free fatty acids contents of Spanish ovine milk cheeses protected by a designation of origin: a comparative study. *International Dairy Journal*, 16(3), 252-261. <http://dx.doi.org/10.1016/j.idairyj.2005.02.010>.
- Frau, F. (2013). Rheology of spreadable goat cheese made with autochthonous lactic cultures differing in their ability to produce exopolysaccharides. *Food Science and Technology*, 33(2), 233-238. <http://dx.doi.org/10.1590/S0101-20612013005000034>.
- Fuentes, L., Mateo, J., Quinto, E. J., & Caro, I. (2015). Changes in quality of nonaged pasta filata Mexican cheese during refrigerated vacuum storage. *Journal of Dairy Science*, 98(5), 2833-2842. <http://dx.doi.org/10.3168/jds.2014-8152>. PMID:25726117.
- Galindo-Rosales, F. J., Campo-Deaño, L., Afonso, A. M., Alves, M. A., & Pinho, F. T. (Eds). (2019). *Proceedings of the Iberian Meeting on Rheology (IBEREO 2019)*. Cham: Springer.
- Hach, C., Brayton, S. V., & Kopelove, A. B. (1985). A powerful Kjeldahl nitrogen method using peroxy monosulfuric acid. *Journal of Agricultural and Food Chemistry*, 33(6), 1117-1123. <http://dx.doi.org/10.1021/jf00066a025>.
- Herman-Lara, E., Bolívar-Moreno, D., Toledo-Lopez, V. M., Cuevas-Glory, L. F., Lope-Navarrete, M. C., Barron-Zambrano, J. A., Díaz-Rivera, P., & Ramírez-Rivera, E. J. (2019). Minerals multi-element analysis and its relationship with geographical origin of artisanal Mexican goat cheeses. *Food Science and Technology (Campinas)*, 39(suppl 2), 517-525. <http://dx.doi.org/10.1590/fst.23918>.
- International Dairy Federation – IDF. (1982). *FIL-IDF 4A:1982: determination of total solids content*. Brussels: IDF.
- International Dairy Federation – IDF. (1987). *FIL-IDF 9C:1987: determination of fat content*. Brussels: IDF.
- International Organization for Standardization – ISO. (2002). *ISO 15884:2002/IDF 182:2002: milk fat: preparation of fatty acid methyl esters*. Geneva: ISO.
- Kealy, T. (2006). Application of liquid and solid rheological technologies to the textural characterisation of semi-solid foods. *Food Research International*, 39(3), 265-276. <http://dx.doi.org/10.1016/j.foodres.2005.07.016>.
- Kelly, P. M., & O'Kennedy, B. T. (2001). The effect of casein/whey protein ratio and minerals on the rheology of fresh cheese gels using a model system. *International Dairy Journal*, 11(4-7), 525-532. [http://dx.doi.org/10.1016/S0958-6946\(01\)00076-0](http://dx.doi.org/10.1016/S0958-6946(01)00076-0).
- Kuźnicka, E., & Łapińska, A. (2014). Goat cheese on an organic farm in Grzybów as an example of organic products, direct sales and local markets. *Wiadomości Zootechniczne*, 2, 75-82.
- Mallatou, H., Pappa, E., & Massouras, T. (2003). Changes in free fatty acids during ripening of Teleme cheese made with ewes' goats' cows' or a mixture of ewes' and goats' milk. *International Dairy Journal*, 13(2-3), 211-219. [http://dx.doi.org/10.1016/S0958-6946\(02\)00153-X](http://dx.doi.org/10.1016/S0958-6946(02)00153-X).
- Masotti, F., Battelli, G., & De Noni, I. (2012). The evolution of chemical and microbiological properties of fresh goat milk cheese during its shelf life. *Journal of Dairy Science*, 95(9), 4760-4767. <http://dx.doi.org/10.3168/jds.2011-5039>. PMID:22916879.
- Melito, H. S., Daubert, C. R., & Foegeding, E. A. (2013). Relationships between nonlinear viscoelastic behavior and rheological, sensory and oral processing behavior of commercial cheese. *Journal of Texture Studies*, 44(4), 253-288. <http://dx.doi.org/10.1111/jtxs.12021>.
- Moreira, R. V., Costa, M. P., Castro, V. S., Paes, C. E., Mutz, Y. S., Frasao, B. S., Mano, S. B., & Conte-Junior, C. A. (2019). Short communication: antimicrobial activity of pequi (*Caryocar brasiliense*) waste extract on goat Minas Frescal cheese presenting sodium reduction. *Journal of Dairy Science*, 102(4), 2966-2972. <http://dx.doi.org/10.3168/jds.2018-15268>. PMID:30712936.
- Osman, M., Abdalla, M., & Nusr Mohamed, S. (2009). Effect of storage period on chemical composition and sensory characteristics of vacuum packaged white soft cheese. *Pakistan Journal of Nutrition*, 8(2), 145-147. <http://dx.doi.org/10.3923/pjn.2009.145.147>.
- Pala, C., Scarano, C., Venusti, M., Sardo, D., Casti, D., Cossu, F., Lamon, S., Spanu, V., Ibba, M., Marras, M., Paba, A., Spanu, C., & Santis, E. P. (2016). Shelf life evaluation of ricotta fresca sheep cheese in modified atmosphere packaging. *Italian Journal of Food Safety*, 5(5502), 134-139. <http://dx.doi.org/10.4081/ijfs.2016.5502>. PMID:27853705.
- Pantaleão, I., Pintado, M., & Pocas, F. (2007). Evaluation of two packaging systems for regional cheese. *Food Chemistry*, 102(2), 481-487. <http://dx.doi.org/10.1016/j.foodchem.2006.05.058>.
- Pereira, R. B., Bennett, R. J., Hemar, Y., & Campanella, O. H. (2001). Rheological and microstructural characteristics of model processed cheese analogues. *Journal of Texture Studies*, 32(5-6), 349-373. <http://dx.doi.org/10.1111/j.1745-4603.2001.tb01242.x>.
- Popović-Vranješ, A., Pihler, I., Paskaš, S., & Krstović, S. (2017). Production of hard goat cheese and goat whey from organic goat's milk. *Mljekarstvo*, 67, 177-187. <http://dx.doi.org/10.15567/mljekarstvo.2017.0302>.
- Ranadheera, C. S., Evans, C. A., Baines, S. K., Balthazar, C. F., Cruz, A. G., Esmerino, E. A., & Vasiljevic, T. (2019). Probiotics in Goat Milk Products: Delivery Capacity and Ability to Improve Sensory Attributes. *Comprehensive Reviews in Food Science and Food Safety*, 18(4), 867-882. <http://dx.doi.org/10.1111/1541-4337.12447>.
- Rogers, N. R., Drake, M. A., Daubert, C. R., McMahon, D. J., Bletsch, T. K., & Foegeding, E. A. (2009). The effect of aging on low-fat, reduced-fat, and full-fat Cheddar cheese texture. *Journal of Dairy Science*, 92(10), 4756-4772. <http://dx.doi.org/10.3168/jds.2009-2156>. PMID:19762791.
- Sangaletti, N., Porto, E., Brazaca, S. G. C., Yagasaki, C. A., Dea, R. C. D., & Silva, M. V. (2009). Estudo da vida útil de queijo Minas. *Food Science and Technology*, 29(2), 262-269. <http://dx.doi.org/10.1590/S0101-20612009000200004>.
- Silva, N., Junqueira, V., & Silveira, N. (1997). *Manual de métodos de análise microbiológica de alimentos*. São Paulo: Livraria Varela.
- Sousa, M. J., Balcão, V. M., & Malcata, F. X. (1997). Evolution of free fatty acid profile during ripening in cheeses manufactured from bovine, ovine and caprine milks with extracts of *Cynara cardunculus* as coagulant. *Zeitschrift für Lebensmittel-Untersuchung und -Forschung A*, 205(2), 104-107. <http://dx.doi.org/10.1007/s002170050133>.
- Tarakci, Z., & Kucukoner, E. (2006). Changes on physicochemical, lypolysis and proteolysis of vacuum packed Turkish Kashar cheese during ripening. *Journal of Central European Agriculture*, 7(3), 459-464.
- Todaro, M., Palmeri, M., Cardamone, C., Settanni, L., Mancuso, I., Mazza, F., Scatassa, M. L., & Corona, O. (2018). Impact of packaging on the microbiological, physicochemical and sensory characteristics of a "pasta filata" cheese. *Food Packaging and Shelf Life*, 17, 85-90. <http://dx.doi.org/10.1016/j.fpsl.2018.06.005>.
- Van Hekken, D. L., Tunick, M. H., & Park, Y. W. (2005). Effect of frozen storage on the proteolytic and rheological properties of soft caprine milk cheese. *Journal of Dairy Science*, 88(6), 1966-1972. [http://dx.doi.org/10.3168/jds.S0022-0302\(05\)72872-1](http://dx.doi.org/10.3168/jds.S0022-0302(05)72872-1). PMID:15905426.
- Van Hekken, D. L., Tunick, M. H., Tomasula, P. M., Corral, F. J. M., & Gardea, A. A. (2007a). Mexican Queso Chihuahua: rheology of fresh cheese. *International Journal of Dairy Technology*, 60(1), 5-12. <http://dx.doi.org/10.1111/j.1471-0307.2007.00291.x>.

- Van Hekken, D. L., Tunick, M. H., Tomasula, P. M., Corral, F. J. M., & Gardea, A. A. (2007b). Mexican Queso Chihuahua: rheology of fresh cheese. *International Journal of Dairy Technology*, 60(1), 5-12. <http://dx.doi.org/10.1111/j.1471-0307.2007.00291.x>.
- Verruck, S., Dantas, A., & Prudencio, E. S. (2019). Functionality of the components from goat's milk, recent advances for functional dairy products development and its implications on human health. *Journal of Functional Foods*, 52, 243-257. <http://dx.doi.org/10.1016/j.jff.2018.11.017>.
- Vieitez, I., Irigaray, B., Callejas, N., Gonzalez, V., Gimenez, S., Arechavaleta, A., & Gambaro, A. (2016). Composition of fatty acids and triglycerides in goat cheeses and study of the triglyceride composition of goat milk and cow milk blends. *Journal of Food Composition and Analysis*, 48, 95-101. <http://dx.doi.org/10.1016/j.jfca.2016.02.010>.
- Yurchenko, S., Sats, A., Tatar, V., Kaart, T., Mootse, H., & Jõudu, I. (2018). Fatty acid profile of milk from Saanen and Swedish Landrace goats. *Food Chemistry*, 254, 326-332. <http://dx.doi.org/10.1016/j.foodchem.2018.02.041>. PMID:29548460.