

Research Article

Effect of Pasteurization Temperature, Starter Culture, and Incubation Temperature on the Physicochemical Properties, Yield, Rheology, and Sensory Characteristics of Spreadable Goat Cheese

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The local cheese factories currently use bovine commercial starter cultures, and the spreadable cheese process is not standardized. A detailed understanding of the effect of pasteurization temperature, starter culture, and incubation temperature must allow producers to optimize the process, increase cheese yield, and improve the quality of the final product. The main objective of the study was to describe the preparation method of spreadable goat cheese and investigate the effects of specific processing conditions (pasteurization temperature, starter culture, and incubation temperature) on the composition, yield, rheology, and sensory characteristics of the final product. Results showed the impact of pasteurization temperature, starter culture, and incubation temperature on spreadable goat cheese. The results indicated that it is possible to improve cheese yield, rheological properties, and sensory analysis when milk is pasteurized at 75°C for 30 minutes; cheese yield can also be improved by lowering incubation temperature to 37°C. Cheeses made with autochthonous starter culture showed better sensory characteristics and higher pH compared to the cheeses made with commercial culture.

1. Introduction

Fresh acid-curd cheeses refer to those varieties produced by the coagulation of milk, cream, or whey via acidification and those which are ready for consumption once the manufacturing operations are complete. They differ from rennet-curd cheese variety in that coagulation occurs close to the isoelectric point of casein; a very small amount of rennet may be used in the production of quarg, cottage, or spreadable cheese [1].

The production of spreadable cheese generally involves milk pretreatments, slow acidification and gelation, whey separation, and/or curd treatment. Many processing conditions influence coagulum structure and hence the rheological and physicochemical stability of the product [1]. In recent years, the manufacture of various cheese varieties

has received considerable interest, mainly because of the potential to improve cheese yield, through incorporation of whey proteins into cheese curd. There are only a few studies in spreadable cheese and fewer in spreadable goat cheese [2].

However, the cheese-making characteristics of heated milks (>65°C) differ markedly from those of typically pasteurized milk (63–65°C). Milk that has been heat-treated at higher temperatures shows longer coagulation times and forms weaker and finer curd which retains more water. These effects are considered to arise mainly from the formation of complexes between denatured whey proteins and micellar κ -casein, which subsequently modifies the surface characteristics and interactions of casein micelles [3, 4].

Goat milk microflora is essential for the manufacture of cheeses, conferring on them particular and distinctive flavor and generating high value-added products.

Usually commercial starters, selected for cow milk, are added in the manufacture and cheeses obtained have variable quality and little characteristic flavor.

The use of autochthonous cultures is not widespread yet; therefore it is essential to study the effect of autochthonous starter culture in spreadable goat cheese. Because of the growing interest in preserving the typical sensory properties of traditional cheeses, there is an increasing demand for autochthonous strains to replace or complement existing commercial starters currently used by the dairy industry [5, 6].

However, there are not studies about autochthonous starter culture for spreadable goat cheese. This study is necessary since the elaboration and sensory attributes of this variety are different from enzymatic coagulation cheese.

Gel formation is the most important functional property of fermented milk products. The rheological characteristics of this composite gel are governed by milk composition, dry matter content, type and quantity of the starter culture that is used to inoculate the milk, fermentation temperature, and storage conditions of the final product [7, 8].

There is an increasing demand for new products in the food market. Hedonic scales and preference tests are common instruments used when decisions on market introductions are made. Sensory analyses are also used for quality control, for the comparison of product prototypes to understand consumer responses in relation to products' sensory attributes, and for sensory mapping and product matching. It may also be used to track product changes over time with respect to understanding shelf life and packaging effects, to investigate the effects of ingredients or processing variables on the final sensory quality of a product and to investigate consumer perceptions of products [9].

The aim of this work was to investigate the effects of specific processing conditions (pasteurization temperature, starter culture, and incubation temperature) on the physico-chemical properties, yield, rheology, and sensory characteristics of the spreadable goat cheese and to describe an improved elaboration process.

2. Materials and Methods

2.1. Materials. Bulk goat milk from the morning milking was obtained from a local farm. Two vats of cheese were made on the same day at the pilot plant of the University of Santiago del Estero from June to December. Two elaborations were performed per month and the results presented are the mean values.

The autochthonous starter culture used in this study was isolated in the Laboratory of Centro de Referencia para Lactobacilos (CERELA, Tucumán, Argentina) from goat cheeses elaborated in Santiago del Estero. Four strains constituted the autochthonous culture: CRL 1799 (*Lactobacillus fermentum* with high acidifying activity), CRL 1803 (*Lactobacillus fermentum* with high proteolytic activity), CRL 1785 (*Enterococcus faecium* with diacetyl-acetoin production), and CRL 1808 (*Lactobacillus rhamnosus* exopolysaccharide producing strain) in the ratio 1 : 1 : 1 : 3. The criteria for selection of these

strains and development of autochthonous starter culture for spreadable goat's milk cheese are explained in [2].

Freeze dried bovine commercial culture (Diagrama SLB 95) was purchased from Diagrama (Santa Fé, Argentina).

2.2. Methods

2.2.1. Preparation of the Autochthonous Working Culture. The working culture was prepared according to the method described in [2].

2.2.2. Spreadable Cheese Processing

(1) *Effect of Pasteurization Temperature.* Two vats of cheese (three liters each) were made on one day from fresh goat milk obtained from a local farm. For each batch, milk was pasteurized for 30 minutes at two different temperatures (65 and 75°C) and then was cooled to 37°C and 0.035 g/L of CaCl₂ was added. After that, milk was inoculated with 1 mL/100 mL autochthonous goat culture (10⁷ CFU/mL). Samples were finally fermented in a thermostatically controlled incubator at 37°C. When pH ≤ 6.2 bovine curdle was added (20% of the quantity needed for enzymatic coagulation) and incubated at 37°C for 1 hour. After this procedure cheese curds were salted (1.5% w/w of the milk weight) and drained off in cheese cloth at 30°C overnight until pH ≤ 5.3. The cheese obtained was vacuum packaged using polyethylene bags (100 μm) and matured at 7°C for 5 days.

(2) *Effect of Starter Culture.* Milk was pasteurized at 75°C and cooled and CaCl₂ was added. Milk was divided into two batches and inoculated (1 mL/100 mL): one with autochthonous goat culture (10⁷ CFU/mL) and the other with bovine commercial starter culture (10⁷ CFU/mL). Elaboration proceeded as described in (1).

(3) *Effect of Incubation Temperature.* Milk was pasteurized and cooled; CaCl₂ added and inoculated as previously described in (2). After these procedures, milk was divided into two batches. Fermentation was carried out at different temperatures (37 and 42°C). Elaboration proceeded as described in (1).

2.2.3. Milk and Cheese Chemical Composition. Samples of goat milk were analyzed for fat, protein, lactose, and nonfat solids using LactoStar Funke Gerber 3560.

Cheese samples were analyzed for fat [10], protein [11], total solids content [12], and ash [13]. Moisture content was determined by

$$\text{Moisture (\%)} = 100 - \text{Total solids (\%)} . \quad (1)$$

2.2.4. pH Determination. Milk pH was determined using a Hanna model HI 98240 pH-meter. The pH value of the cheeses was measured at the end of maturation and shelf life.

The pH electrode was inserted directly into the sample and the pH reading taken when the value had stabilized (typically <5 min). Each sample was measured in duplicate.

TABLE 1: Chemical composition of spreadable goat cheese, milk, and whey.

Component	Cheese		Whey	Milk
	65°C	75°C		
Fat (%)	23.5 ± 2.35	22.42 ± 2.62	0.11 ± 0.01	5.52 ± 1.00
Protein (%)	22.75 ± 1.02	20.79 ± 1.03	1.47 ± 0.01	3.40 ± 0.22
Casein (%)	16.82 ± 0.31	14.13 ± 0.35	0.42 ± 0.06	2.17 ± 0.40
Lactose (%)	ND	ND	7.65 ± 0.01	4.28 ± 0.25
Nonfat solids (%)	ND	ND	9.72 ± 0.01	8.32 ± 1.39
Ash (%)	1.9 ± 0.02	1.81 ± 0.02	0.46 ± 0.01	0.79 ± 0.01
Total solids (%)	49.59 ± 1.02	43.99 ± 1.07	20.72 ± 0.03	13.87 ± 0.53
Moisture (%)	50.41 ± 0.98	56.01 ± 0.98	79.98 ± 0.03	86.16 ± 0.55

2.2.5. *Cheese Yield.* Cheese yield was calculated after maturation according to [14]

$$\text{Cheese Yield} = \frac{\text{Cheese Weight (Kg)}}{\text{Milk Weight (Kg)}} \times 100. \quad (2)$$

2.2.6. *Rheological Analysis.* Dynamic oscillatory measurements were performed with an AR 1000 rheometer (TA Instruments, Leatherhead, Surrey, UK). Storage modulus (G') and loss modulus (G'') were selected as parameters for characterizing the rheological properties of the spreadable cheeses. Rheological measurements were evaluated for duplicate samples after maturation and at the end of shelf life. Samples were carefully placed on the plate using a plastic spoon. 25 mm stainless steel parallel plate geometry with gap size of 1 mm was used. All experiments were performed at a constant temperature of 25°C with a Peltier plate employed to control temperature [15, 16].

2.2.7. *Sensory Analysis.* Sensory evaluation was carried out by acceptance test by consumers [17]. Cheeses were evaluated after maturation and at the end of shelf life by thirty regular consumers of goat products (nontrained panel). Panel members evaluated cheese for visual appearance, odor, spreadability, taste, texture, and general acceptance using a five-point hedonic scale, with 1 being the worst and 5 the best quality.

2.2.8. *Shelf Life.* According to actual legislation [18] and previous studies, shelf life of spreadable goat cheese was established in 5 weeks since the elaboration date.

2.2.9. *Statistical Analysis.* Analysis of variance (ANOVA) was carried out using STATISTICA software (statistical packet Release 6.0 by Statsoft, Inc. 2001, Tulsa, USA).

Data are expressed as the means ± standard deviation of values obtained from duplicates of the same experiment. The Duncan multiple range test (DMRT) was used to determine the differences among data means at a 5% significance level.

3. Results and Discussion

3.1. *Chemical Composition.* The only operating variable that significantly affected ($P < 0.05$) chemical composition was pasteurization temperature.

The mean values for the chemical characteristics of spreadable cheese produced, whey obtained, and milk used for elaboration are shown in Table 1.

Cheese elaborated from milk pasteurized at 75°C presented higher moisture content, probably due to the presence of whey proteins and their hydrophilic property (Section 3.3.1) [19, 20]. This characteristic affects the rest of the parameters evaluated, since a higher content of whey increases also cheese yield and enzymatic activity [20]; this enzymatic activity influences positively sensory analysis (Section 3.4). The decrease in levels of protein and fat with pasteurization temperature is due to concomitant increase in moisture and hence the reductions in level of cheese dry matter.

Cheese composition is shown in Table 1; the fat and protein content found in the present study is similar to those reported for other authors for this variety of cheese [21]. According to CAA (art. 605) spreadable goat cheese can be classified as fatty (in dry basis) and very high moisture.

The chemical characteristics of the spreadable goat cheese were analyzed at the end of maturation and shelf life; there were no significant differences ($P > 0.05$) in the parameters between the cheeses at different times. The high values of standard deviation found in fat reflect the variations in this component found in milk used for the elaboration [22].

3.2. *pH Determination.* pH of the spreadable goat cheese was determined at the end of maturation and shelf life.

Cheeses made with commercial starter culture had significantly ($P < 0.05$) lower pH compared to the cheeses made with autochthonous culture (Table 2).

Figure 1 shows the effect of different starters on pH development during milk coagulation. The rate of pH decrease was higher in cheeses made from bovine commercial starter, reaching the desired pH at 3 hours of process, whereas cheeses from autochthonous starter after 4 h. The high rate

TABLE 2: Processing conditions on spreadable goat cheeses pH values.

Processing conditions		pH after maturation	pH after shelf life
Pasteurization temperature	65°C	5.25 ± 0.22 ^a	4.47 ± 0.20 ^a
	75°C	5.30 ± 0.30 ^a	4.51 ± 0.30 ^a
Starter culture	Autochthonous	5.30 ± 0.29 ^a	4.51 ± 0.30 ^a
	Commercial	4.36 ± 0.17 ^b	3.31 ± 0.15 ^b
Incubation temperature	37°C	5.30 ± 0.29 ^a	4.51 ± 0.30 ^a
	42°C	5.27 ± 0.31 ^a	4.49 ± 0.29 ^a

Means in each column having different superscripts are significantly different ($P < 0.05$).

TABLE 3: Cheese yield and moisture content of spreadable goat cheese as affected by different processing conditions.

Processing conditions		Moisture (%)	Yield (%)
Pasteurization temperature	65°C	50.41 ± 0.98 ^a	23.36 ± 1.87 ^a
	75°C	56.01 ± 1.08 ^b	32.40 ± 1.64 ^b
Starter culture	Autochthonous	56.01 ± 0.98 ^a	32.40 ± 1.64 ^a
	Commercial	55.89 ± 1.12 ^a	32.35 ± 1.02 ^a
Incubation temperature	37°C	55.88 ± 1.09 ^a	32.40 ± 1.64 ^a
	42°C	48.97 ± 1.23 ^b	23.20 ± 1.21 ^b

Means in each column having different superscripts are significantly different ($P < 0.05$).

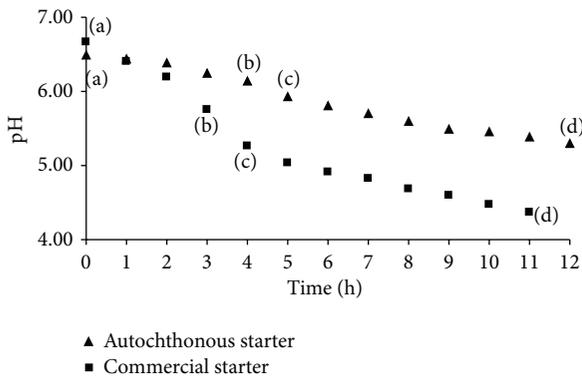


FIGURE 1: pH changes during spreadable goat cheese elaboration for BOTH starters: (a) inoculation; (b) rennet addition; (c) cut and draining; (d) end of draining.

of acidification is not required for this variety due spreadable cheese production involves slow acidification of the curd culture [23]. High rate of acidification causes an acid cheese with tendency growth of fungi and yeasts [22, 23].

It should be noted that pH of cheeses did not remain constant after maturation (autochthonous, 5.30; commercial, 4.36) and storage (autochthonous, 4.51; commercial, 3.31). This indicates that the activity of neither starter culture used was inhibited by the low pH achieved.

3.3. Cheese Yield. Operating variables that significantly affect ($P < 0.05$) cheese yield were pasteurization and incubation temperature. The mean values for cheese yield and moisture content are shown in Table 3.

3.3.1. Effect of Pasteurization Temperature. The pasteurization temperature had strong positive effect on cheese yield. Cheeses made from pasteurized milk to 75°C had higher moisture content, probably due to the presence of whey proteins, since their hydrophilic property allowed higher moisture retention [20]. Upon heating milk above 65°C, whey proteins are denatured by the unfolding of their polypeptides, thus exposing the side chain groups originally buried within the native structure. The unfolded proteins then interact with casein micelles or simply aggregate with themselves, involving thiol-disulphide interchange reactions, hydrophobic interactions, and ionic linkages [4]. The spreadable cheese structure is similar to yogurt; because of this, the effect of high temperature pasteurization on whey proteins is desirable since heat treatment of the milk considerably enhances firmness. The deposition of denatured serum proteins increases the volume fraction of aggregating protein; it also may alter the number and the nature of the bonds between protein particles [24].

3.3.2. Effect of Incubation Temperature. The incubation temperature significantly affected ($P < 0.05$) cheese yield. Other authors have reported that increased incubation temperature during acidification causes the onset of gelation at higher pH values, obtaining a thicker gel more susceptible to spontaneous syneresis during storage [1]. This effect may be attributed to a higher ratio of aggregation to disaggregating forces during the earlier stages of acidification owing to decreased casein dissociation from the micelles, a reduction in repulsive forces due to increased hydrophobicity, and faster rate of acidification [1, 25].

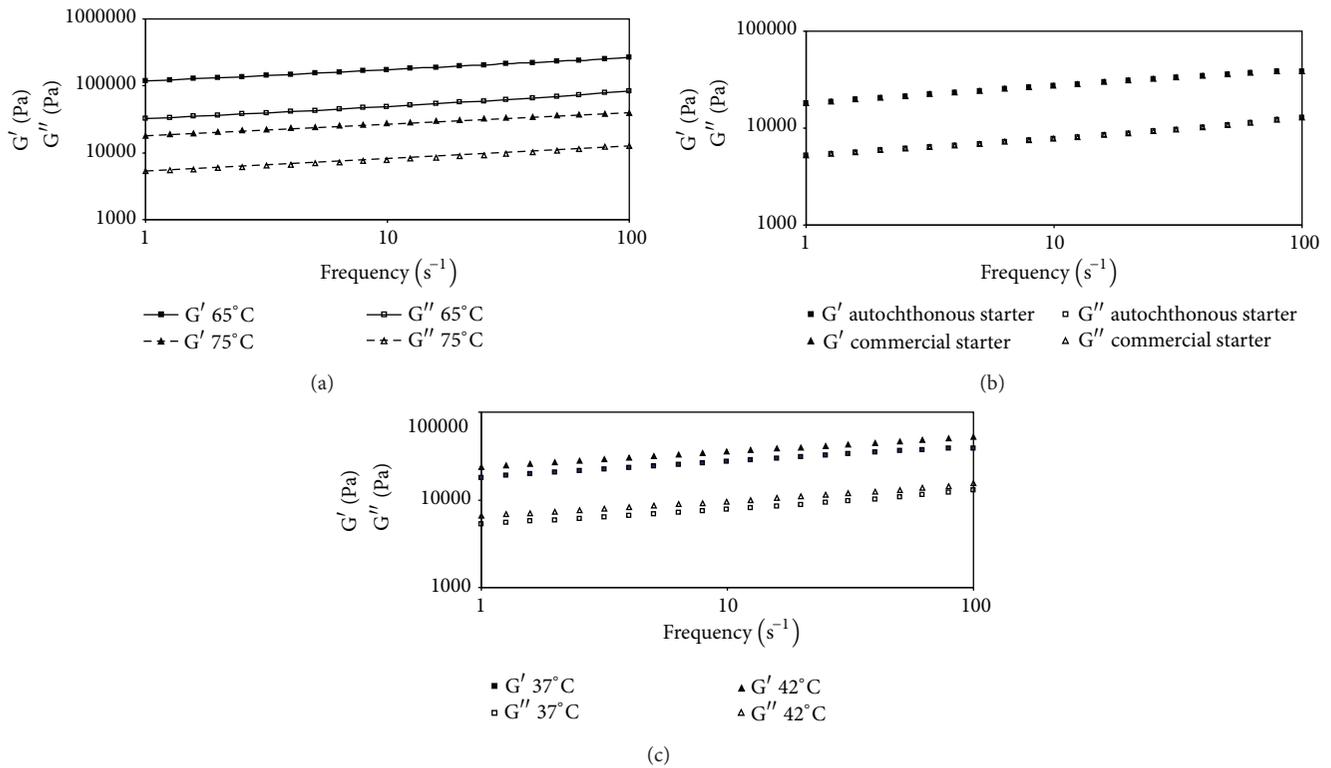


FIGURE 2: Frequency dependence of G' and G'' for spreadable goat cheeses samples affected by (a) pasteurization temperature; (b) culture; (c) fermentation temperature.

The average cheese yield for samples elaborated from milk pasteurized at 75°C and using autochthonous goat culture was 32.4% (3.24 L milk/Kg cheese). This value exceeds by 40–50% reported in the literature (5–7.5 L milk/Kg cheese) [26].

3.4. Rheological Measurement. The only operating variable that significantly affected ($P < 0.05$) rheological characteristics was pasteurization temperature. Increasing milk pasteurization temperature significantly decreased the mean values for critical stress.

The stress sweep carried out on the samples pasteurized at 65 and 75°C indicates that both have a critical stress value: 65°C, 2508.7 Pa; 75°C, 1363.1 Pa. Applying a small stress (\ll critical stress) on the gel provokes a reversible stretching of the threads making up the cheese matrix; however, if the stress applied is higher than the critical stress, the threads break [16].

Cheeses elaborated from milk pasteurized at 65°C show higher ($P < 0.05$) critical stress value than 75°C samples; this behavior can be explained by the significant changes occurring upon heating milk above 65°C that include the denaturation of whey proteins and the increase of moisture; these effects reduced strength of rennet gels [3, 4]. This trend, which concurs with previous studies [27], was expected because of the increase in moisture content and reduction in protein percentage as the pasteurization temperature was increased [28, 29].

The other factor contributing to reduction of critical stress with pasteurization temperature is the increase in the level of denatured whey proteins, as a percentage of total protein in the cheese. These proteins that are complexed with the casein micelles during heating reduce the degree of casein aggregation during subsequent rennet coagulation and curd formation and lead to a finer gel matrix structure [29–31].

The rheological behavior of spreadable goat cheese as a function of frequency is presented in Figure 2. Cheeses elaborated under different processing conditions ((A) pasteurization temperature, (B) starter culture, and (C) fermentation temperature) exhibited similar characteristics, typical of a weak viscoelastic gel, with storage modulus (G') greater than loss modulus (G''), and all samples showed some frequency dependence. (G') and (G'') moduli increased with the increase of frequency; this was also noted by other authors [8, 16].

The rise of G' with frequency might be due to casein particles fusion as a consequence of the rearrangement of inter- and intramolecular forces, which in turn results in an increased contacting surface between the casein aggregates and possibly to the additional particles added to the web [16].

Under all processing conditions, the elastic component contributes viscoelasticity more than viscous component ($G' > G''$) which leads to a structure resembling more of a solid within the range of frequencies studied, which was also noted by other authors [16, 32, 33].

Increasing milk pasteurization temperature significantly decreased ($P < 0.05$) the mean values for G' and G''

TABLE 4: Effects of pasteurization temperature and starter culture on the sensory properties of spreadable goat cheese.

Sensory properties	Processing conditions					
	Pasteurization temperature		Starter culture		Incubation temperature	
	65°C	75°C	Autochthonous	Commercial	37°C	42°C
Visual appearance	3.05 ± 0.41 ^a	4.79 ± 0.32 ^b	4.80 ± 0.29 ^a	4.82 ± 0.29 ^a	4.80 ± 0.29 ^a	4.75 ± 0.27 ^a
Odor	4.52 ± 0.38 ^a	4.80 ± 0.32 ^a	4.83 ± 0.35 ^a	3.21 ± 0.28 ^b	4.84 ± 0.32 ^a	4.83 ± 0.35 ^a
Spreadability	2.28 ± 0.14 ^a	4.61 ± 0.25 ^b	4.59 ± 0.23 ^a	4.61 ± 0.26 ^a	4.59 ± 0.23 ^a	4.23 ± 0.23 ^a
Taste	4.65 ± 0.38 ^a	4.81 ± 0.32 ^a	4.81 ± 0.32 ^a	2.00 ± 0.32 ^b	4.81 ± 0.32 ^a	4.80 ± 0.32 ^a
Texture	2.87 ± 0.33 ^a	4.77 ± 0.27 ^b	4.78 ± 0.27 ^a	4.82 ± 0.31 ^a	4.78 ± 0.26 ^a	4.73 ± 0.24 ^a
General acceptance	3.21 ± 0.25 ^a	4.79 ± 0.28 ^a	4.80 ± 0.26 ^a	2.50 ± 0.32 ^b	4.80 ± 0.25 ^a	4.77 ± 0.26 ^a
Total score	20.58 ± 1.21	28.57 ± 1.17	28.61 ± 1.22	21.96 ± 1.19	28.62 ± 1.22	28.11 ± 1.24

Values are means of shelf life time; different superscript letters after values indicate significant differences; Duncan's multiple range test ($P < 0.05$).

(Figure 2(a)); this trend was expected because of the increase in moisture content and in level of denatured whey protein (as explained in stress sweep). The strands of the matrices in cheeses from higher pasteurization temperature milks may be less capable of bearing stress than those in cheese made from milk pasteurized at 65°C [29]; this is related with the lowest critical stress found in cheese elaborated from milk pasteurized at 75°C. The rheological results agree with the macroscopic appearance of experimental cheeses (Figures 3 and 4). Cheese elaborated from milk pasteurized at 65°C did not show the soft texture and spreadability expected, unlike the cheeses elaborated from milk pasteurized at 75°C.

No significant difference ($P > 0.05$) was noticed in G' and G'' values among spreadable cheeses samples made from autochthonous or commercial starter (Figure 2(b)). This result is positive for the study, since the principal sensorial attributes of the cheese elaborated with commercial starter culture were spreadability and texture; therefore similar rheological characteristics were desired in cheese elaborated with autochthonous starter culture. These results agree with sensory characteristics (Section 3.4).

G' and G'' values increased gradually with fermentation temperature, but no significant difference ($P > 0.05$) was noticed among spreadable cheeses samples (Figure 2(c)). Other authors have reported significant differences employing incubation temperatures between 20 and 28°C [8].

The rheological behavior of the spreadable goat cheese was analyzed at the end of maturation and shelf life; there were no significant differences ($P > 0.05$) in the parameters.

3.5. Sensory Characteristics. Sensory characteristics were evaluated after maturation and at the end of shelf life and there was no significant difference ($P < 0.05$). Operating variables that significantly affect ($P < 0.05$) sensory characteristics were pasteurization temperature and starter culture.

3.5.1. Effect of Pasteurization Temperature. Pasteurization temperature affected significantly ($P < 0.05$) texture, spreadability, and visual appearance (Table 4). This finding may be attributed to the effect of the pasteurization temperature on water-holding capacity (Figures 3 and 4).



FIGURE 3: Cheese made from milk pasteurized at 65°C.



FIGURE 4: Cheese made from milk pasteurized at 75°C.

Samples pasteurized at 75°C had higher scores in visual appearance, spreadability, and texture; this is agreed with rheological results.

3.5.2. Effect of Starter Culture. The spreadable cheese made from autochthonous starter received higher scores in the

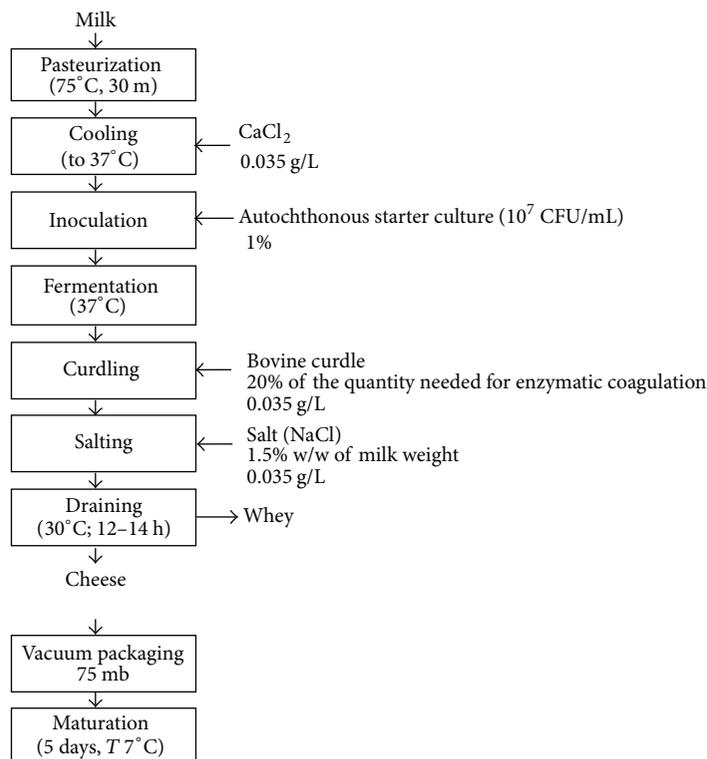


FIGURE 5: Spreadable goat cheese elaboration process.

sensory evaluation than cheese made using commercial starter. The starter culture had a statistically significant effect ($P < 0.05$) on odor, taste, and general acceptance (Table 4); these samples had an intense and typical goat flavor attributes that consumers expect to find in goat products and a slightly acidic taste. Similarly, other authors have reported aroma intensity to be higher in cheeses made with an autochthonous culture [6, 34, 35]. Commercial starter batch had the lowest scores in taste, odor, and general acceptance due its highly acidic taste and the absence of characteristic goat flavor.

There was no significant difference ($P > 0.05$) in visual appearance, spreadability, texture, or general acceptance between different starter culture. These were the expected outcomes due to the fact that cheeses elaborated with bovine commercial culture present textural properties suitable for this cheese variety.

After the study of the specific processing conditions (pasteurization temperature, starter culture, and incubation temperature), the optimal process for spreadable goat cheese elaboration was defined; this result is diagrammed in Figure 5.

4. Conclusion

An attempt was made to assess the impact of pasteurization temperature, starter culture, and incubation temperature on spreadable goat cheese. The results indicated that pasteurization at 75°C for 30 minutes has a positive impact on cheese yield, rheological properties, and sensory analysis.

Cheeses made with autochthonous starter culture showed better sensory characteristics and higher pH compared to the cheeses made with commercial culture; therefore the use of the selected autochthonous starter could be an interesting way to produce on an industrial scale, a uniform product of constant quality with improved sensory characteristics. By lowering the incubation temperature to 37°C was able to improve cheese yield.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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