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Effects of Pasteurization and Curd Cutting Size on Viscoelasticity of Costeño Cheese

José G Serpa*, Elvis Judith Hernández-Ramos, Liliana Polo-Corrales

Department of Agroindustrial Engineering, Innovation and Development of Food Processes (DESINPA) - Universidad de Sucre, Cra. 28 #5-267, Puerta Roja, Sincelejo, Colombia

Abstract : Effects of pasteurization temperature and curd cutting size on viscoelasticity of costeño cheese were evaluated. A 3^2-factorial experiment was developed in a completely random design (pasteurization temperature: 63ºC / 30min, 73ºC / 15s and 83ºC / 1s; curd cutting: 1, 3 and 5 cm). Pressure required to maintain a constant deformation was determined from relaxation tests by using an EZ Text Shimadzu® texturometer and a 2.04 Rheometer® software. Obtained data was represented by means of Peleg's standard and linear model. Results showed that interaction among temperature and cutting factors significantly affected residual asymptotic modulus "Ea.", resulting in a totally different cutting tendency for each temperature and time ratio level. Pressure decline level "a" and velocity at which pressure relaxes "b" were only affected by main effects of pasteurization, temperature and curd cutting size. When using pasteurization levels of 63ºC / 30min and 73ºC / 15s with curd cutting sizes of 2.8cm and 2.6cm respectively, an increase in the influence of the viscous component is produced in costeño cheese. The opposite occurs when using an 83ºC / 1s pasteurization level, since there is a decrease of this component; prevailing before the elastic component, though. Finally, it was possible to establish that for the 83ºC / 1s heat treatment level, curd cutting size did not affect viscoelasticity of costeño cheese.
Keywords : deformation, pressure, Peleg, relaxation.

Introduction

Costeño cheese is a product of the Colombian Caribbean region generally made from raw milk through enzymatic coagulation. It is a fresh, firm / semi-hard type cheese and according to fat content, classified as a fatty cheese[1].

"Fresh" cheese is a dairy product with high humidity content and textural properties such as firmness, elasticity and viscoelasticity determined by its components spatial arrangement and modifications during production process[2].

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Milk pasteurisation allows production of a microbiologically safe cheese[3]. However, this heat treatment causes a few changes in product structure altering final quality, texture and overall appearance[4, 5]. Denaturation of serum proteins (αs1 and β-caseins), lactalbumin and lactoglobulin have been cited as effects of pasteurization, producing cheeses with high moisture content[6].

Curd cutting is done to favor whey removal (i.e., syneresis), the thinner the curd cutting, the easier the whey drainage[7]. The size of the curd cubes formed is significantly important because cheese final moisture content, freshness, and hardness depend on these aspects[6].

Food rheological properties are essential to choose appropriate processing equipment and are a reference for product quality[8]. Food rheological behavior is highly complex and plays a very important role in many process systems. Its field includes mechanical properties of solids, semi-solids and liquids under various objectives such as: knowledge of raw materials, products and by-products, study of relationships among composition, chemical structure and rheological properties, analysis of physicochemical mechanisms leading to rheological properties modifications, and instrumental evaluation[9, 10].

The rheological behavior of distinct types of cheese has been studied by several authors through oscillatory, uniaxial compression and relaxation tests[11, 8,10,2]. However, differences in processing stages yielding cheese diversity can produce variations in structure and therefore in rheological behavior.

Relaxation test is a time-dependent rheological test. These so-called transient tests use deformations greater than the dynamics (as those applied when curd is pressed for whey removal or when cheeses are stored in a stack), causing breakdown of structural component interactions of short range, whereby it is possible to obtain information on casein network properties and other components occluded in the network[8].

Cheese rheological properties depend on water content, fat particles and salt present in the proteins matrix or network. Low moisture in cheeses leads to limited hydration of protein, less movement freedom of protein molecules, greater matrix firmness and stronger structures[5, 10]

Cheese viscoelastic behavior has been modeled by many authors with models such as Maxwell's. Nonetheless, although these models very well show viscoelastic behavior of some foods, some authors[12-19] have opted to use an empirical model based on the procedure first described by Peleg (1979) and later by Peleg and Normand (1983); basically considering it less complex, since it has only two parameters, and relaxation data are determined as a normalized *pressure* and adjusted to a linear equation[20] as follows:

$$\frac{t}{Y(t)} = \frac{1}{ab} + \frac{t}{a}$$

Where "a" is the pressure decline level during relaxation. If a = 0, pressure does not relax (elastic solid); If a = 1 the pressure will eventually fall to zero (liquid); If 0 <a <1, it will be a viscoelastic solid in which pressure will reach a residual asymptotic value. Parameter "b" is a measure of the velocity at which *pressure* relaxes; If b = 0, *pressure* does not relax. The residual asymptotic modulus, Ea, can be calculated with the following expression:

$$Ea = Eo(1 - a)$$

Where Eo is the initial relaxation modulus.

This research study appraised effects of temperature and time of pasteurization and curdcutting size on rheological parameters of the normal and linear model of Peleg, by analyzing effects on viscoelasticity of Costeño cheese. Results allowed to obtain information about influence of these factors on product structure and serve as a comparative and useful reference for purposes of designing machinery for pressing and, improving this product texture and quality, very important for the Colombian Caribbean economy

Experimental

Milk was standardized to a 4.0% fat content using an Adipack® industrial skimmer. Acidity was determined by volumetric titration (NTC 4978); soluble solids by refractive index (NTC 4086); protein content by Kjeldhal method (NTC 5025) and fat verification by the GERBER method (NTC 4723). Cheeses were prepared according to the methodology described in Figure 1.

Milk Reception
Filtration and Standardization (4% Fat)
Standardization
Pasteurization (according to TTOS)
CaCl2 addition (20 g / 100 L a 40 °C)
Rennet Addition and coagulation
Curd Cutting (According to TTOS
Syneresis
Chopping (2 x 2 cm approx.)
Salting (Brine at 20 ° Be / 15 min)
Molding
Pressing: 6 times its weigh/3h
Storage (4-8 °C)

Figure 1. Elaboration process of pasteurized costeño cheese.

Viscoelastic characterization of cheese samples was performed by means of a relaxation test using an EZ Text Shimadzu® texturometer. A 2-cm diameter by 2-cm height cylindrical sample of cheese was subjected to uniaxial compression with a 50-mm diameter dish. A 50 mm / min velocity was used up to a 20% deformation of its initial height for 1200 seconds. The Pressure required to maintain a constant deformation in each cheese sample was determined by using a 2.04 RheoMeter software. Obtained data were represented through Peleg's normal and linear model, by determining the parameters of the model in each case.

A 3^2 factorial experiment was developed in a completely random design corresponding to three levels of temperature and time pasteurization ratios (63ºC / 30min, 73ºC / 15s and 83ºC / 1s,) and three levels of curd cutting size (1, 3 and 5 cm). Experiments were performed in a triple form for a total of twenty-seven trials. Analysis of variance (ANOVA) was performed with a significance of 0.05. Interaction analysis was carried out using the methodology of orthogonal polynomials at each temperature and time pasteurization ratio, with subsequent regression analysis of significant effects. The Tukey's multiple comparison test was only performed in trials in which main effects were significant. The R v.2.9.1 statistical software (The R Foundation for Statistical Computing) was used to process data.

Results and Discussion

Milk characterization used in the cheese processing was within the normal values established in the decree 616 of 2006 from the Ministry of Social Protection of Colombia. It contained a 16.09 ± 0.16 ºDornic acidity, 3.11 ± 0.03 protein, 4.0 ± 0.03 fat and 12.8 ± 0.02% of total solids.

The pressure relaxation behavior adjusted to the normal and linear Peleg model is shown in Figure 2. A determination coefficient $R2 \geq 0.99$ was obtained in all treatments.

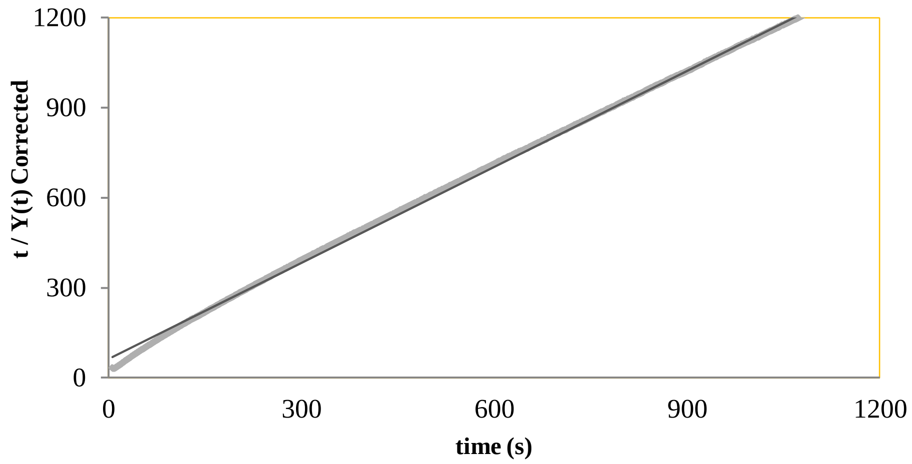

Figure 2. Graphical representation of the Relaxation curve linearization

Table 1: Rheological parameters of Peleg for each treatment

temperature/time pasteurization	**Cutting (cm)**	**Parameter “a”[1]**	**Parameter “b”[2] (s-1)**	**Residual Asymptotic module Ea (kpa)**
63ºC/30min	1	0.918±0.0093	0.013±0.0005	31.44±4.1
63ºC/30min	3	0.933±0.0018	0.014±0.0002	20.59±1.9
63ºC/30min	5	0.895±0.0083	0.011±0.0002	36.99±2.7
73ºC/15s	1	0.893±0.0111	0.012±0.0100	23.05±1.9
73ºC/15s	3	0.915±0.0017	0.014±0.0002	12.01±0.6
73ºC/15s	5	0.895±0.0083	0.011±0.0002	36.99±2.7
83ºC/1s	1	0.900±0.0142	0.015±0.0015	13.88±3.6
83ºC/1s	3	0.889±0.0152	0.015±0.0005	14.66±2.9
83ºC/1s	5	0.871±0.0252	0.014±0.0006	15.38±2.9

[1] Pressure Decline Level; [2] Velocity at which Pressure relaxes

The rheological parameters for each treatment were obtained through relaxation test and determined from the slope and intercept of the normal and linear Peleg model. They are listed in Table 1.

The rheological parameters obtained for the pressure decline level indicate that pasteurized cheese presents a characteristic behavior of viscoelastic food, i.e. the "a" Peleg parameter ranges between zero and one ($0 < a < 1$). These results are consistent with studies conducted by previous researchers[2, 5, 9, 10].

According to the rheological behavior shown, in which the *pressure* decline level (Parameter "a") is far from zero and closer to one (Table 1); pasteurized costeño cheese can be classified as a viscoelastic product in which the viscous component maintains a greater influence.

Residual asymptotic modulus:

Nalysis of variance ANOVA, showed that interaction of temperature and time pasteurization factors with curd cutting size significantly affected the residual asymptotic modulus ($p < 0.05$), therefore there is a greater effect from the simultaneous action of these factors on variable "Ea." The analysis is focused on such interaction.

Residual asymptotic modulus means per treatment for curd cutting sizes at each temperature and time pasteurization levels are listed in Table 2.

Table 2: Means of residual asymptotic modulus "Ea."

	63ºC/30min	73ºC/15s	83ºC/1s
Corte 1	31.44	23.05	13.88
Corte 3	20.59	12.01	14.66
Corte 5cm	36.99	36.99	15.38

Table 3: Effect of cutting size for "Ea" at each pasteurization level

	63ºC/30min		73ºC/15s		83ºC/1s	
	SC	F	SC	F	SC	F
Cutting: Linear Effect	46.23	6.02*	291.41	37.94***	3.35	0.437 ^{NS}
Cutting: Cuadratic Effect	371.13	48.33***	648.49	84.44***	0.002	0.0003^{NS}

* Indicates significance of the effect ($p < 0.05$)

^{NS} indicates non-significant ($p > 0.05$)

Significance of the linear and quadratic effects of the curd cutting size at each level of temperature / time pasteurization ratio for the residual asymptotic modulus "Ea" is listed in Table 3.

The quadratic equation representing the residual asymptotic modulus "Ea" as a function of cutting size for the 63 ° C / 30min pasteurization level is: Ea = 47.08-19.05 (cut) +3.406 (cut) ^{2} (R^2 = 0.88); corresponding to an open upward curve, i.e. the residual asymptotic modulus "Ea" decreases by increasing the cut size from 1 to 3 cm and then increases considerably by using 5 cm curd cutting sizes. Thus, by applying concepts of maximum and minimum differential calculus it was possible to establish that a 2.8 cm curd size generates a relative minimum in the residual asymptotic modulus value "Ea" corresponding to 20.44 kpa, indicating that under these conditions the viscous component in cheese becomes even more influential.

The quadratic equation representing the residual asymptotic modulus "Ea" as a function of cutting size for the 73ºC / 15s pasteurization level is: Ea = 42.08-23.53 (cut)+4.5(cut)^2 (R^2 = 0.98); corresponding equally to an open upward curve, i.e. the residual asymptotic modulus "Ea" decreases from 1 to 3 cm and then considerably increases by passing to a 5 cm cutting size. Consequently, at this level of thermal treatment, with a curd size of 2.6 cm, there is an 11.1 kpa relative minimum for the residual asymptotic value "Ea", indicating that under these conditions there is an increase in the viscous component of costeño cheese.

Table 3 shows that under an 83 ° C / 1s temperature and time pasteurization ratio, the curd cutting size does not affect the residual asymptotic modulus "Ea".

The analysis of orthogonal polynomials for the means of residual asymptotic modulus "Ea" showed that the tendency of the effects of cutting size at each level of temperature and time pasteurization ratio turned out to be totally different, explaining the interaction significance.

The results obtained for the residual asymptotic module agree with the results reported by Tunick and coworkers[21]. In general, moisture levels generated in cheese by heat treatment and cutting size are inversely related to firmness and pressure[6, 8, 10].However, the results showed that this relationship was not fulfilled by increasing cutting size to 5 cm and the pasteurization temperature to 83 ° C. This behavior is attributed to weakness and instability of curd generated from such treatments[22].

Pressure decline level and relaxation velocity. The pressure decline level during relaxation (parameter a) and the rate at which pressure is relaxed (parameter b) were only significantly affected by the main effects of temperature and time of pasteurization, and cutting size ($p < 0.05$).

The effects of the temperature and time pasteurization ratio on the pressure decline level during relaxation (parameter a) and the rate at which the pressure is relaxed (parameter b) are shown in Table 4.

There were no significant differences (p> 0.05) between heat treatments of 63ºC / 30min at 73ºC / 15s, nor between 73ºC / 15s and 83ºC / 1s, but there was significant difference (P <0.05) between the thermal treatments of 63ºC / 30min and 83ºC / 1s, decreasing the level of pressure decline from 0.915 to 0.887, respectively (See Table 4).

Table 4: Effects of temperature on parameters a and b of Peleg.

	Parameter a	**Parameter b(s-1)**
63ºC/30min	0.915^{a}	0.0126^{b}
73ºC/15s	0.900^{ab}	0.0123^{b}
83ºC/1s	0.887^{b}	0.0145^{a}

Means with different letter indicates significant difference (p <0.05)

The velocity at which the pressure is relaxed (parameter b) did not show significant differences between the heat treatment of 63ºC / 30min and 73ºC / 15s, but there were statistically significant differences among these and the heat treatment of 83ºC / 1s (Table 4); This indicates that severe heat treatments significantly increase velocity at which the pressure relaxes.

As the temperature and time pasteurization ratio increases, cheese has a lower influence of its viscous component, although that component still predominates regarding its elastic component. This behavior is associated to structural and micellar aggregation differences in the casein matrix, characterized by a higher moisture retention, lower firmness and greater elasticity in cheeses made from these heat treatments[6, 8, 10, 22].

Effects of the curd cutting size on the pressure decline level during relaxation (parameter a) and velocity at which the pressure relaxes (parameter b) are listed in Table 5.

Table 5: Effects of cut size on parameters a and b of Peleg.

	Parameter a	**Parameter b(s-1)**
Cutting 1 cm	0.903^{ab}	0.0134^{a}
Cutting 3 cm	0.912^{a}	0.0142^{a}
Cutting 5 cm	0.887^{b}	0.0118^{b}

Means with different letter indicates significant difference (p <0.05)

The pressure decline level during relaxation (parameter "a") did not show significant differences (p> 0.05) between treatments with 1 and 3 cm curd cutting size, nor between treatments with curd cutting with 1 and 5cm; but significant differences (p <0.05) were observed between the 3 and 5 cm curd cutting size. Regression analysis showed that cutting size shows a quadratic effect on the Peleg parameter "a", characterized by an open curve downwards according to equation $a = 0.8858 + 0.0215\ (cut) - 0.0042\ (cut)^2$ ($R^2 = 0.99$), i.e. the response of the parameter "a" increases when passing from the 1cm cutting to the 3cm cutting and then decreases for a 5 cm cutting size. From the determined equation, it was possible to establish that a 2.5 cm cut size generates a relative maximum of the pressure decline (parameter a) of 0.9133, making more influential the viscous component in the cheese.

On the other hand, the velocity at which the pressure is relaxed (parameter "b") did not show significant differences between treatments with curd cutting sizes of 1 cm and 3 cm; But there were differences (p <0.05) among these and the treatment of 5 cm cutting size.The parameter "b" presented a quadratic response in function of the curd cutting size, according to the following equation: $b = 0.0118 + 0.002\ (cut) - 0.0004\ (cut)^2$ ($R^2 = 0.99$); corresponding to an open curve downwards. The response of the velocity at which pressure is relaxed increases from a 1cm cutting size to a 3cm cutting size and then decreases when it reaches a 5cm cutting size. From the determined equation, it was possible to establish that the use of a 2.5 cm curd cutting size generates a maximum point in the stress relaxation velocity of 0.0143 s-1.

Conclusion

Pasteurized Costeño cheese can be classified as a product of viscoelastic behavior with predominance of the viscous component.

When pasteurization levels of 63ºC / 30min and 73ºC / 15s are used with curd sizes between 2.5 and 2.8cm respectively, an increase in the influence of its viscous component is generated in the Costeño cheese; the opposite occurs when using a pasteurization level of 83 ° C / 1s which produces a decrease of said component, although it continues to predominate before the elastic component. Under the heat treatment level of 83ºC / 1s, it was possible to establish that the curd cutting size did not affect viscoelasticity of Costeño cheese.

With 2.5 cm curd cutting sizes, a 0.9133 relative maximum in the pressure decline (parameter a) and in the pressure relaxation rate is generated; which confirms the marked influence of the viscous component of cheese processed under these conditions

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