**Evaluation of physical and textural characteristics of pandebono**

**Evaluación de características físicas y texturales de pandebono**

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Abstract

The pandebono is a traditional gluten-free product from Colombia made mainly with cassava sour starch, cheese and milk or water. The cheese is critical in its formulation, because it imparts suitable sensory and textural properties. In this study, these properties were evaluated on pandebono made from two types of cheeses, costeño cheese and white cheese. Texture profile analysis, firmness, crust fracture, and determinations of weight, volume and density were performed using a one-way analysis of variance. ( sensory differentiation test of triangular type was performed to assess the overall flavor of the products. The firmness was higher in the pandebono made from costeño cheese because the crumb was more uniformity; whereas the crust fracture was higher in the pandebono made from white cheese, reflecting a greater crust thickness. There were not significant differences in texture profile analysis. The weight and volume were lower in pandebono made from costeño cheese, while the density was higher. The overall flavor of samples was different, mainly by the costeño cheese properties, which has a characteristic and salty taste.

**Key words:** Costeño cheese, gluten-free product, rheology.

Resumen

El pandebono es un producto libre de gluten típico de Colombia, elaborado principalmente con almidón agrio de yuca, queso y agua o leche. El queso es fundamental en su formulación, ya que le imparte al producto sus propiedades sensoriales y texturales características. En el estudio se evaluaron estas propiedades en pandebonos elaborados con dos tipos de quesos: costeño y blanco. Se realizaron análi- sis de perfil de textura, firmeza, fractura de la corteza y determinaciones de peso, volumen y densidad mediante un análisis de varianza de una sola vía. Para evaluar el sabor general se hizo una prueba sensorial de diferenciación de tipo triangular. La firmeza fue mayor en pandebono elaborado con queso costeño debido a que la miga fue más uniforme; mientras que la fractura de la corteza fue mayor en pandebono elaborado con queso blanco, reflejando un espesor de corteza mayor. En el anãlisis de perfil de textura no se encontraron diferencias significativas. Los pesos y los volümenes fueron menores en pandebono elaborado con queso costeño, pero la densidad fue mayor. El sabor fue diferente, principal- mente por las propiedades del queso costeño, el cual tiene un salado característico.

**Palabras clave:** Producto libre de gluten, queso costeño, reología.

Introduction

Pandebono is a bakery product obtained from fermented cassava starch and cheese as main components. According to the place of prepa­ration, there are variations in its formulation, although it is common the use of flour or corn starch, eggs, plant oil and water or milk. These ingredients are mixed to form small portion for baking. The most outstanding characteristics of this product are the spongy texture, open crumbs, low density and fast hardening.

A product with similar characteristics to the ones of pandebono is produced in the Mi­nas Gerais region, Brazil, which is known as cheese bread (pão de queijo, in Portuguese). As the pandebono, the cheese bread does not have an established quality standard neither a production technology or defined product, reason why it is in the market with products of the same denomination but, with very di­fferent characteristics (Minim *et al*., 2000; Aplevicz, 2006).

Cassava fermented starch is an important constituent of pandebono, since it gives vo­lume and porous crumbs with many cells containing air. Similarly, the cheese is a fun­damental ingredient because it gives the cha­racteristic aroma and taste, complements the crumbs structure and helps the texture of the final product (Pereira *et al*., 2004).

Characterization studies for these kind of products, specially cheese bread, have been focused on the evaluation of density, specific volume, expansion index, compression resis­tance and analysis of the texture profile (Pe­reira *et al*., 2010; Machado y Pereira, 2010a). Also, there are evaluations on the rheological profile and visco-elastic properties of the dough in the farinograph and texture ana­lyzer, respectively (Machado and Pereira, 2010a; Machado and Pereira, 2010b). Pe­reira *et al*. (2010) evaluated the response when replacing curated cheese by ricotta cheese on the properties of cheese bread and found an increase in that an increase in the percentage of the last one in the formulation generates a product that is softer, less gummy not prone to fracture and, with a lower crust thickness than the one generated with curated cheese. In these works there were no diffe­rences in the sensorial properties of the elabo­rated products with both cheeses, therefore is possible to replace the curated cheese with the ricotta type.

In Colombia is widely used the cheese called “costeño” which is fresh and with a salty taste between mild and strong. However, this cheese has the disadvantage that its sa­nitary quality is not the best due to the por conditions of processing and storage, that lead to finding some pathogen microorganisms (Gallegos *et al*., 2007). The objective of this research was to evaluate the physical and textural characteristics of the pandebono for­mulated with two types of cheese: costeño and White.

Materials and methods

**Physicochemical analysis of cheeses**

Physicochemical characteristics were deter­mined for both costeño and white cheese. Ac­tivity of water (aw) was measured with a dew­point hygrometer at 25 °C (Aqualab serie 3TE, Decagon, Devices, Pullman, WA, USA) (Cor­tés *et al*., 2007). pH was measured with a po­tentiometer by introducing the electrode di­rectly in the cheese dough Peláez *et al*., 2003). Percentages of humidity, fat and salt were determined following the methodology propo­sed by Kosikowski (1977). The cheese per­centage of humidity was determined by the drying in oven method, consisting on putting a 2 g cheese sample on a Petri dish to dry at 100 °C for 24 h in oven (U30, Memmert, Ger­many). The percentage of fat was determined by the modified method of Babcock. 9 g of grinded cheese were weighted on a butyro­meter and 10 ml of water at 54.4 °C and 17.5 ml of sulfuric acid were added. Later, the bu­tyrometer was subjected to centrifugation cycles of 5 min, 22 min and 1 min with addi­tions of water at 76.7 °C between each cen­trifugation. Finally, the butyrometer was transferred to a water bath at 60 °C for 5 min to determine the fat percentage.

The percentage of salt in the cheese was determined using the modified method of Volhard. To 3 g sample of grinded cheese on a flask were added 25 ml of silver nitrate (AgNO3) 0.1 N, 10 ml of nitric acid (HNO3) and 50 ml of distilled water and it was heated till ebullition under a gas extractor chamber. When the mix reached ebullition temperature 15 ml of potassium permanganate were added (KMnO4) in 5 ml portions. Then, the mixed was cool down to room temperature and 2 ml of nitrobenzene and 2 ml of ferric alum were added separately. The flask content was agi­tated and titrated with potassium thiocyanate (KSCN) 0.1 N till getting a light red color. The percentage of salt was calculated using the equation **1**:

$$\% Salt=\frac{\left[\left(AxB\right)-\left(CxD\right)\right] x 0.0585 x 100}{M} Eq. 1 $$

where, *A*: silver nitrate volume (ml) added (25 ml), *B* : silver nitrate normality (0.1 N), *C*: po­tassium thiocyanate volume (ml) used for ti­tration, D: potassium thiocyanate normality (0.1 N), *M*: amount (g) of simple used, 0.0585: sodium chloride milliequivalents.

**Proximal analysis of the cassava fermeted starch**

Percentages of starch were determined (ISO 10520, 1997), ashes (AOAC 942.05, 2000), raw fiber (NTC 668, 1973), crude fat (NTC 668, 1973), humidity (ISO 6496, 1999), pH (potentiometer) and protein (Kjeldahl’s method NTC 4657, 1999). Measurements were done in duplicate.

**Absorption of water (I.A.A.) and solubility in water(I.S.A.) indexes**

These indexes were determined by triplicate in cassava fermented starch according to the method proposed by Anderson *et al*. (1969) which consists in calculate by gravimetry the amount of dissolved material and the propor­tion of absorbed water after agitation of a starch suspension at an established tempe­rature. For that, on a centrifuge of 50 ml, a 2.5g a starch sample was placed with 30 ml of distilled water at 30 °C. Later, the tube was placed on a water bath at 30 °C. was agitated for 30 min and centrifuged at 3000 rpm for 10 min (Universal 320-R, Hettich, Germany). Supernatant was separated and the resulting gel was weighted to calculate I.A.A. (Equation 2). To calculate I.S.A., the supernatant was placed on a 30 ml beaker previously calibra­ted and dried out at 100 °C for 24 h till it reached constant weight. The soluble solids, or the supernatant dry weight, were used to calculate I.S.A. by the equation **3**.

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| **Table 1.** Raw materials to prepare pandebono. |
| **Raw materials** | **Costeño cheese** | **White cheese** |
|  | **Amount (g)****(g)** | **Percentage (%)****(%)** | **Amount (g)****(g)** | **Percentage (%)****(%)** |
| Cheese | 300 | 40.1 % | 300 | 42.7 % |
| Fermented starch | 150 | 20.0 % | 150 | 21.4 % |
| Corn flour | 60 | 8.0 % | 60 | 8.6 % |
| Margarine | 30 | 4.0 % | 30 | 4.3 % |
| Sugar | 18 | 2.4 % | 18 | 2.6% |
| Salt | – | – | 9 | 1.3% |
| Milk | 190.5 | 25.5 % | 135 | 19.2% |

$$I.A.A (g/g)=\frac{gel weight}{sample weight (d.w.)} Eq. 2$$

$$I.S.A \left(\%\right)=\frac{supernatant dry weight}{sample weight (d.w.)} x100 Eq. 3$$

**Preparation**

To prepare pandebonos the following ingre­dients were used: costeño cheese, white cheese, cassava fermented starch, precooked corn flour, margarine, sugar, salt and UHT whole milk, bought at a local market. The for­mulations to prepare both kinds of pandebono are shown in Table 1. Initially, dry ingredients and margarine were mixed on a mixer (Profe­ssional Series 600-KP26M1XER, KitchenAid, St. Joseph, MI, USA). Then, milk was slowly added till getting a soft and homogeneous dough that was divided in 30 g portions and manually molded with the help of a cylinder (diameter=47 mm, height 14 mm). Each pan­debono was baked at 235 °C for 15 min on a gas oven (GFO-4B, Guangzhou Youjia Ma­chinery Co.).

**Weight, volume and density**

Pandebono weight was determined on a preci­sion balance (BL-6206, Shimadzu). Density was calculated using the weight:volume ratio. This ratio was obtained with the modified methodology proposed by Carrillo (2007) using the displacement method of millet seeds placed on a 250 ml beaker with 33 mm ratio. The procedure was the following: a fixed amount of millet seeds was placed in a beaker till a fixed height, then seeds were moved to another vase. Then, the pandebono was intro­duced in the beaker, the millet seeds were moved to the beaker and the distance from the fixed height till the top of the seeds was measured. The pandebono volume was calcu­lated by the following equation.

$$V=π x r^{2} x d Eq. 4$$

where, *V* is the pandebono volume (ml), , *r* is the beaker ratio (cm) and *d* is the distance measured (cm).

**Texture properties**

The texture of the pandebono samples was determined by puncture and compression tests and texture profile analysis (TPA) on a texture analyzer (TA-XT2i, Stable Micro Sys­tems, Godalming, U.K.) using the Texture Ex­pert Exceed version 2.64 (2002) software. Crust fracture was obtained by a penetration assay using a 2 mm cylinder probe (SMS P/2). The firmness of whole pandebonos formulated with both cheeses was determined by a uni­axial compression assay using a100 mm cy­linder compression platen (SMS P/100). TPA was performed compressing two times the whole sample with a100 mm cylinder com­pression platen (SMS P/100) to obtain all the texture properties of hardness, elasticity and cohesiveness (Bourne, 2002). For the com­pression test and the TPA, sample and com­pression platen were lubricated with liquid paraffin to minimize friction effects. Parameter on the analyzer were pre-assay velocity 2.0 mm/s, assay velocity 2.0 mm/s, post-assay velocity 5.0 mm/s, compression distance 15 mm and load cell 50 kg.

**Sensorial analysis**

A triangular test according to the NTC 2681(2006) policy was performed on a panel of 32 members to determine the perceptible sensory difference on general taste between both kind of pandebonos.

**Statistical analysis**

Experimental data were evaluated by one way analysis of variance (Anova) to determine the effect of the cheese type on the physical and texture characteristics of pandebono. For data management the software Statgraphics Cen­turion XV version 15.2.05 (2006) was used with the minimum significant difference method (DMS) and a confidence level α= 0.05. For the sensorial response test data the same confidence level was used. The statistical analysis of that test follows a binomial distri­bution, requiring 16 hits on a 32 members panel in order to get a perceptible difference between samples (NTC 2681, 2006).

 Results

**Raw material analysis**

Physico-chemical analyses on cheese type are show in Table 2. According to the results on fat and humidity percentage, costeño cheese can be classifies as fat and hard, while the white cheese is fat and semi-hard (Ministerio de la Protección Social de Colombia, 1989). Costeño cheese had a lower humidity content than the one found by Rodríguez and Novoa (1994) (45-47%) and a higher fat content (23-25%). Chávez-Acosta and Romero-Naranjo (2006) found in costeño cheese samples pro­duced in different fabrics a humidity range between 35.7–42.7% and fat 19-26%. Other important aspect is the high salt content pre­sent in costeño cheese (3.5%), which is a characteristic of this product. Salt has the function of strengthen taste and ensure a long shelf life. The salt percentage for costeño cheese found in this study agrees with the findings of Chávez-Acosta and Romero-Na­ranjo (2006), although the pH (5-5.2) differs from the value of 6.5 found by these authors.

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| **Table 2.** Physico-chemical characteristics of evaluated cheeses.  |
| **Characteristic** | **Costeño cheese** | **White cheese** |
| Humidity (%) | 40.0 ± 0.01 a\* | 49.7 ± 0.01 b |
| aw | 0.9 ± 0.004 b | 1.0 ± 0.001 b |
| pH | 5.4 ± 0.05 a | 6.4 ± 0.01 b |
| Fat (%) | 31.0 ± 1.41 a | 26.5 ± 0.71 a |
| Salt (%) | 3.5 ± 0.06 a | 1.0 ± 0.04 b |
| \* Values in the same row followed by different letters are significantly different (P < 0.05). |

Cassava fermented starch is indispensable to prepare different bakery products, among them, pandebono. The proximal composition, I.A.A and I.S.A., are shown in Table 3. To highlight are the high starch content associa­ted with the botanical source and the low pH due to the fermentation step involving acid-lactic bacteria. Cadena *et al*. (2006) found in cassava fermented starch different values to the ones presented in this study: ashes (0.23% - 0.54%), fat (0.13% - 0.59%) and protein (0.82% - 1.28%); however, for humi­dity (8.04% - 12.35%), fiber (0.23% - 1.06%), and carbohydrates (starch 85.22% - 90.28%) the values were similar. These values agree with the ones determined in Brazil for this product, humidity (14%), maximum ashes (0.5%) and minimum starch content (80%) (Diniz, 2006). Variation in humidity content could be due to the exposition time and the weather conditions during the drying process under the sun. Differences in protein content are associated with the fermentation time be­cause the developed microorganisms can pro­duce protein metabolites (Diniz, 2006). Varia­tion in ashes and fiber content could be attri­buted to the starch contamination with fo­reign materials like dust, insects and soil from the environment, including the water used on the extraction process (Cadena *et al*., 2006).

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| **Table 3.** Proximal composition and I.A.A. and I.S.A. of cassava fermented starch. |
| **Characteristic** | **Value** |
| Starch (%) | 87.8 ± 2.1 |
| Ashes (%)  | 0.05 ± 0.02 |
| Raw fiber (%) | 0.30 ± 0.04 |
| Gross fat (%) | 0.05 ± 0.04 |
| Humidity (%) | 10.7 ± 0.05 |
| Protein (%) | 0.40 ± 0.2 |
| pH | 3.63 ± 0.09 |
| I.A.A. (g/g) | 3.30 ± 0.05 |
| I.S.A. (%) | 0.70 ± 0.07 |
| I.A.A.= Water absorption index. I.S.A.= Water solubility index . |

Cassava fermented starch I.A.A. and I.S.A. were between the reference values established by Aristizábal and Sánchez (2007), 0.82 and 15.52 g gel/g for the first one and, 0.27 and 12.32% for the second one. Rodríguez *et al*. (2006) found I.A.A. of 4.66, 5.00 and 5.44 g gel/g for cassava flour samples obtained from precooked parenchyma resting at low tempe­ratures (5 °C, -5 °C and -20 °C) respectively; similarly they found I.S.A. of 12.49, 10.79 and 13.18% for the same flours. Machado *et al*. (2010) observed I.S.A. values between 0 and 0.3% in suspensions of 30 °C fermented starch from Brazil.

**Weight, volume and density**

These characteristics are important on bakery products preparation, since they are related with the amount of cells with air present in the interior. In pandebono and cassava fer­mented starch products an expansion occurs while cooking dough implying gas production and volume increase (Mestres *et al*., 1996). In Table 4 are shown these characteristics of the pandebono formulated with both cheeses. Significant differences (p <0.05) were observed between pandebonos. Weight and volume were higher with white cheese, and density was higher with costeño cheese. White cheese affected weight due to its high water content. On the other hand, salt could act directly with the liquid component of the formulation causing water retention and reducing its availability during evaporation in the baking process. Volume, distribution of air cells and global shape were more uniform in the costeño cheese pandebono, while in the white cheese pandebono there were some bumps and cracks.

Costeño cheese favors the expected charac­teristics in this type of products, like homoge­neous air cell distribution in the crumps and better crust aspect (Pereira *et al*., 2004), this is due to the interaction among components, mainly protein and fat with cassava starch. For its higher fat content, this cheese could act inhibiting hydration and volume gain of the starch granules avoiding amylose lixivia­tion, as it happens in cereal starches (Mitolo, 2006). Additionally, density depends on the two previously mentioned characteristics but, in bakery products is associated more with volume. A low volume implies higher density and particularly for bread wheat flour means poor carbon dioxide retention in the gluten network. Pandebono made with costeño cheese has a lower volume and showed a higher density when compared to white cheese pandebono. Pereira *et al*. (2010) did not find differences on cheese bread when replacing curated cheese by ricotta cheese; according to the authors this result was due to the fact that they calculated the ingredients used in function of the content of fermented starch. Clareto *et al*. (2006) found that the use of a protein concentrate as a substitute for 100% of fat did not affect the cheese bread density.

**Texture properties**

Texture in bakery products is of great impor­tance since it is mainly associated with fresh­ness and the aging process on product that have two layers or zones, an exterior one called crust and an interior one or crumb (Cauvain, 2004). Crust fracture, firmness and texture profile analysis (TPA) of the pande­bonos formulated with both cheeses are on Table 4. In this study, the crust fracture and whole product firmness were different between both types of pandebono (p < 0.05), being bi­gger the fracture in the white cheese pande­bono, while the firmness was higher in the costeño cheese type. Fracture results indicate that a thicker crust was achieved in white cheese pandebonos, indicating that a larger amount of water migrated from the center towards the surface during baking, which generated an increase in thickness by diffe­rent layer with larger and more irregular air cells. When these kinds of cells are formed in the crust a higher fracture force is required (Altamirano-Fortoul *et al*., 2012).

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| **Table 4.** Physical and texture properties of pandebono formulated with costeño and white cheese. |
| **Properties** |  | **with costeño cheese** | **with white cheese** |
| Physical | Weight (g) | 23.8±0.2 a\* | 24.4±0.4 b |
|  | Volume (cm3) | 57.4±0.9 a | 61.1±0.9 b |
|  | Density (g/cm3) | 0.4±0.0028 a | 0.4±0.0034 b |
| Texture | Crust fracture (N) | 1.4±0.06 a | 1.6±0.07 b |
|  | Firmness (N) | 19.3±2.68 a | 15.9±0.45 b |
|  | TPA – hardness (N) | 17.1±2.93 a | 15.0±0.91 a |
|  | TPA – elasticity | 0.8±0.03 a | 0.8±0.03 a |
|  | TPA – cohesivity | 0.4±0.01 a | 0.4±0.03 a |
| \* Values in the same row followed by different letters are significantly different (P < 0.05). |

Product firmness is associated with the uniform distribution of air cells or alveoli in the pandebono crumbs. In this study, the pandebono prepared with costeño cheese was more uniform and had a higher percentage of air cells of smaller size, which favors firmness increments. This result is better explained by the higher fat content in this type of cheese. When the fat crystals are melted during ba­king, the fat-liquid interphase generates extra material in interphase for the bubbles surface allowing expansion without breakup. There­fore, a high number of small bubbles can sur­vive during baking and, contribute to a better crumb quality and uniformity (Brooker, 1996).

Machado and Pereira (2010b) observed different values for compression resistance in cheese bread with different formulations and elaboration processes. For the breads made with milk and blanching, the results were similar to the ones of this study (16.64 N). Hardness, elasticity and cohesiveness of both pandebonos were similar at population level. However, is important to notice that the hard­ness had a high coefficient of variation (CV=14.1%) making difficult the interpretation of results. Pereira *et al*. (2010) found elasti­city and cohesiveness values to the ones of this study using ricotta cheese in cheese bread preparation.

**Sensorial analysis**

In the sensorial analysis test there were 22 hits, concluding that there were difference (p <0.05) in general taste of both pandebonos. Some participants state that costeño cheese presents a strong and salty characteristic taste; others found differences in texture. These observations agree with the results ob­tained for texture analysis that showed costeño cheese pandebono was firmer and has a thinner crust with a lower fracture level.

Conclusions

* The results of this study showed that there is an effect of the cheese type on the physical and texture characteristics of pandebono. These characteristics define sample quality and are related to size, amount and distribution of air cells in the product.
* When comparing both formulations of pan­debono it can be concluded that the costeño cheese product allows crumbs with uniform air cell sizes, giving more firmness and hardness to the product, and generating a strong sensorial difference in taste and texture.
* Costeño cheese affects the perceived pro­perties by the consumer, being funda­mental for pandebono preparation.

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