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Gluten-free laminated baked products: effect of ingredients and emulsifiers on technological quality

*de la Horra, A. E., Barrera, G. N., Steffolani, M. E., Ribotta, P. D. and León, A. E.

Instituto de Ciencia y Tecnología de los Alimentos Córdoba (ICYTAC), Universidad Nacional de Córdoba (UNC), Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICET), Bv. Dr. Juan Filloy s/n, Ciudad Universitaria, Córdoba Capital, Argentina.

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Abstract

The aim of this work was to assess the effect of ingredients and emulsifiers on the physical and textural attributes of gluten-free laminated dough pieces and products. Gluten-free flours (soy, rice and cassava), different water levels (76, 68 and 60%), fat samples and emulsifiers (sodium stearoyl lactylate - SSL and diacetyl tartaric acid ester of mono and diglycerides - DATEM) were used to elaborate dough pieces and baked products. Laminated dough samples based on rice/cassava/soy (35:45:20), 60% of water and shortening, presented a high resistance to deformation and showed an inner sheeted structure after baking. The incorporation of the higher doses of SSL and DATEM leads to products of greater specific volume and a tortuous inner conformation due to their layered conformation. This work provides new perspectives into the study of additives with specific action over the components of gluten-free flours and starches, to develop laminated optimum quality products.

Introduction

In recent years, the scientific community has reported the existence of a wide spectrum of disorders related to gluten intake. Celiac disease (CD) is defined as a chronic enteropathy of the small intestine immuno-mediated and promoted by exposure to a diet with gluten, in genetically predisposed individuals (Ludvigsson *et al*., 2012). Currently, a strict gluten-free diet is the only treatment that leads to a recovery of the normal architecture and function of the intestine, as well as to the remission of symptoms (Cosnes *et al*., 2008; Zarkadas *et al*., 2013). The need of people with CD to have safe, affordable and tasty food was reported by Cueto-Rúa *et al.* (2013). In parallel, some people having no gluten restriction follow a gluten-free diet as part of a healthy eating plan. This trend at the domestic level has reached 15% of consumers in the United States. As a result, the gluten-free products market is expected to grow 10.2% annually through 2018 (Markets and Markets, 2015). This situation and the increase in the number of patients diagnosed with CD pose a challenge for the food industry and the scientific community. Finding combinations of raw materials and production processes to obtain gluten-free food with the same technological and nutritional quality as gluten-containing products is a priority to meet consumers demand for this type of products.

In bakery products, the gluten network with viscoelastic properties has a structural essential function. In bread production, gluten allows the gas retention during fermentation and confers viscoelasticity for the expansion of the structure in the baking step. Concomitantly, spongy crumbs with an alveolar configuration are obtained when gluten quality is good. Gluten also fulfills a critical function in products of laminated conformation, such as Danish and puff pastry, croissants and yeast-leavened salty products. The main development of the protein network occurs during the lamination and folding steps instead of kneading (Cauvain and Young, 2006). Therefore, if dough has an adequate viscoelasticity the layers will remain discrete and independent from the fat placed in sheets. Consequently, at the end of the process, the piece will show a sheeted conformation without losing the given shape (Matzs, 1999). The extent to which the piece expands in a vertical direction is related to, on the one hand, the water vapor generated during baking, when water from dough layers evaporates and is trapped in the melting fat layers, and on the other, the air pressure generated (Cauvain and Young, 2001).

The absence of gluten has an impact in the production process and the quality of baked products.

*Corresponding author.
Email: *anitadelahorra@agro.unc.edu.ar*

Different starches and gluten-free flours from rice, soy, and sorghum are commonly used to obtain dough, which is structurally different from the one made with wheat flour. The higher water content of gluten-free dough influences their rheological behavior, as they are less consistent (Miyazaki and Morita, 2005) and lose their machinability, which hinders their manipulation during the piece formation (Rosell *et al.*, 2007). At the same time, it has been reported that products obtained as bread has a dense, dry structure with a low volume and high crumb hardness (Arendt *et al*., 2002; Gujral *et al*., 2003). Many authors have evaluated the effect of several additives, such as emulsifiers, enzymes and hydrocolloids, to improve the dough properties and the product technological attributes (Gan *et al*., 2001; Gujral and Rosell, 2004; Demirkesen *et al*., 2010a). The emulsifiers have been studied as structuring agents in gluten-free systems. Current studies are mainly focused on baked products of sponge structure such as bread and cake (Turabi *et al.*, 2008; Aguilar *et al.*, 2015; Dhen *et al.*, 2016). Other authors have reported the use of emulsifiers in gluten-free pasta (Jeong *et al.*, 2017). Although their dough has a sheeted conformation, the final products do not present a laminated structure. Despite the importance of laminated bakery products in the consumption habits of the population, studies on the production of this type of gluten-free products are not found, leaving people with CD with no possibility of consuming this type of food. Thus, the aim of this work was to assess the effect of ingredients and emulsifiers on the physical and textural attributes of gluten-free laminated dough pieces and products.

Materials and Methods

Commercial samples of cassava starch (LITESOL MB, Argentina), soy (Complementos Proteicos SA, Argentina) and rice flours (Cultivos de Avena SRL, Argentina) were used. Two commercial fat samples were used: refined bovine fat (La Cordobesa para hojaldre, Argentina) and shortening (Mkt CALSA margarina para hojaldre, Argentina). The evaluated emulsifiers were sodium stearoyl lactylate (SSL, Alpha Emulsionantes, Argentina) and diacetyl tartaric acid ester of mono and diglycerides (DATEM, Alpha Emulsionantes, Argentina).

Ingredients physico-chemical characterization

Flour composition

The moisture and ash contents of the flour and starch samples were determined according to 44-15.02 and 08-01.01 from AACC Methods (2000), respectively. The nitrogen content was determined following the micro Kjeldahl method modified with boric acid (46-10.01 Method, AACC, 2000). The determinations were performed in duplicate.

Flour pasting properties

In order to evaluate the suitability of gluten-free flours to obtain a laminated baked product, two combinations of starch and flours were made: FC1 (rice/cassava/soy: 45:45:10%) and FC2 (rice/cassava/soy: 35:45:20%). The combinations were according to previous studies on gluten-free products, where a good quality of the samples was related to proteins and starches interactions (Ribotta *et al.* 2004; Sciarini *et al.* 2010). The viscosity properties of these combinations, flour and starch samples were studying using a Rapid Visco Analyser (RVA 4500, Perten Instruments AB, Australia) following the general pasting standard Newport Scientific Method 1 (STD1). For the analysis, a dispersion of 3.5 g of the sample in 25±0.1 ml of water was heated to 50°C for 10 s and subjected to a constant shear force (960 rpm). The dispersions were kept at 50°C for 1 min and then heated to 95°C at 9.4°C/min; the shear force speed was 960 rpm. The samples were kept at 95°C for 2.5 min and finally cooled to 50°C at 11.8°C/min. Parameters obtained from the time viscosity curves were pasting temperature (PT), peak viscosity (PV), medium viscosity (MV), final viscosity (FV), breakdown (BD) and setback (SB). The determinations were performed in duplicate.

Physical characterization of shortenings

The relationship between structural fat properties (fat melting, SFC profile and rheology behavior) and technological quality of wheat dough has been assessed by many authors (Pimdit *et al.*, 2008; Pajin *et al*., 2011). However, no studies have been conducted about the influence on gluten-free laminated systems. Therefore, to assess the effect of structural fat characteristics on gluten-free laminated dough pieces rheological behavior, two fat samples were evaluated. Fat samples used in the regional production of laminated salty products among local producers in Argentina were previously characterized by de la Horra *et al*. (2017).

Gluten-free laminated dough evaluation

Dough pieces elaboration

To define the ingredients combination which leads to a laminated system, dough pieces were produced with flour combinations, FC1 and FC2, two fat samples and different water percentages

(76, 68 and 60%). The dough was prepared with 12.8 g fat, 0.5 g compressed yeast (Red Saf-instant, Lesaffre, Argentina), 2.5 g refined dry salt (Dos Anclas, Argentina), 1.4 g sugar (Ledesma, Argentina) and 3.5 g vanilla essence. The flour combinations and starch were mixed for 3 min in a mixer (MPZ Pedro Zambom e hijos, Argentina) until the dough was made. The water temperature was such that the final temperature of the dough obtained was 21±1°C. The dough was covered with film, saved in a plastic container and let rest at 9°C for 24 hr. After the refrigerated rest period, a 33.3 g shortening sheet was folded envelope-style into a dough sheet and then gaged to a 60-mm thickness in six steps with a sheeter (MA-AR ACRILIC Tissot, Argentina). The dough was given a two-fold turn and allowed to rest for 20 minutes at 9°C; it was then gaged to a 50-mm thickness in seven steps and given another two-fold turn. The dough was let rest again for 20 min at 9°C and gaged to a thickness of 50 mm. It was laminated with a two-fold turn and the final gaging was to about 15-mm thick. Round holes (diameter d =2 mm) were cut into the dough 1.6 cm apart from each other to prevent complete separation of layers during baking. Square dough pieces (5x5 cm) were cut. The dough samples used in the evaluations were made at least twice and six pieces of each flour combination were analyzed.

Assessment of dough resistance to deformation

Dough samples were compressed up to 40% of their initial height using a cylindrical probe (diameter d =25 mm) in an INSTRON 3342 (Norwood, MA, USA) texture analyzer (Barrera *et al.*, 2016). Force deformation curves were determined at a crosshead speed of 1 mm/s. Dough resistance to deformation was defined as the maximum force obtained. The analysis was performed on non-fermented laminated dough pieces prepared according to the above mentioned procedure with flour combinations, fat samples and water percentages. The tests were carried out at room temperature (25°C). The dough samples used in the evaluations were made at least twice and three dough pieces of each sample were tested

Elaboration of gluten-free laminated products

To determine which flour combination resulted in a laminated baked system; products were done including FC1 and FC2, 60% of water and shortening. Dough pieces were cooked in a convector oven Beta 107 IPA (Pauna, Argentina) at 210ºC for 20 min.

Emulsifiers, SSL and DATEM, in two dosis, 1 and 2.5 g/100g flour, were added with the aim to improve the technological quality of the products. A control, with no additives, was also prepared. Dough laminated pieces were prepared as described previously, with 50.5% of water, and baked as mentioned before. Three products were elaborated with each additive and without it, and the procedure was done at least by duplicate.

Gluten-free laminated baked products technological quality evaluation

Conformational evolution

The behavior of the samples during the production process was evaluated according to de la Horra *et al.* (2015). The height of laminated dough pieces before cooking and of baked products was determined at three points in the surface (5 mm from the edges and at the center), and an average height was calculated. The width of dough samples and products was also registered before and after the cooking step and the average was presented. The height (H) and width (W) ratios were estimated with the dimensions (height-h and width-w) of each baked product (bp) and laminated dough pieces (dp) (Equations 1 and 2):

$$H = \frac{h_{bp}}{h_{dp}} \qquad (1)$$

$$W = \frac{w_{bp}}{w_{dp}} \qquad (2)$$

The shape factor (SF) of the baked products was calculated as follows (Equation 3) with the baked product dimensions:

$$SF = \frac{Height}{\frac{Width+Length}{2}} \qquad (3)$$

Specific volume

The baked product was weighed and the volume was determined by rapeseed displacement after cooling for 1hr. The specific volume was expressed as the volume/weight ratio of the final product (10-05 AACC Method, 2000).

Crust color

The crust color was determined on a CM-700d/600d KONICA MINOLTA spectrophotometer (Ramsey, USA). Measurements were done at three points on the crust (left-upper edge, center and right-lower edge). Values were measured in terms of brightness (L^*), redness (a^*) and yellowness (b^*), and the results were expressed as CIE $L^*a^*b^*$ (14-22 AACC Method, 2000).

Compression test

The baked product was compressed up to 40% of

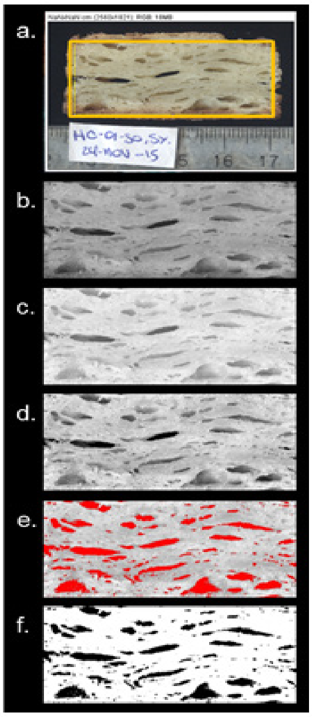

Figure 1. Texture image analysis of laminated baked product inner structure. a. Field of view of a product inner structure image. b. Grayscale image. c. Subtracted background image. d. Enhanced contrast image. e. Application of Otsu's threshold algorithm. f. Binarized image.

its initial height using a cylindrical probe (diameter d =2.5 cm) in an INSTRON 3342 (Norwood, MA, USA) texture analyzer (Barrera *et al.*, 2016). Force deformation curves were determined at a crosshead speed of 1 mm/s. Crumb firmness was defined as the maximum force obtained and it was expressed in Newtons (N). The previous determinations were done at least twice and six pieces of each sample were analyzed.

Inner structure

The inner structure of the product was evaluated by image texture analysis. Cross-section images of the product were obtained with a scanner (HP Scanjet G3010, Palo Alto CA, USA) and analyzed with Image J Software (National Institutes of Health, USA). Different fields of view (FOV) were selected in each image depending on the sample size (Figure 1.a). The images were pre-processed by turning to grayscale, subtracting the background and enhancing the contrast (Figure 1.b, c, d). The Gray Level Co-Occurrence Matrix algorithm was applied to the images and textural features were obtained according to Arzate-Vázquez et al. (2012). Contrast, homogeneity and entropy were considered. The Otsu's threshold algorithm was applied to binarize the images (Figure 1.e); the fractal texture was evaluated by the Fractal Box Counting method and the fractal dimension was established (Quevedo *et al.,* 2002) (Figure 1.f). The image analysis was done by duplicate and three pieces of each sample were considered.

Statistical analysis

The results obtained were compared by analysis of variance (ANAVA) using the least significant difference (LSD) multiple comparison test, where the relationship between the measured parameters was assessed by the Pearson's test (significant level at $p \leq 0.05$) (Infostat statistical software, Facultad de Ciencias Agropecuarias, UNC, Argentina).

Results and Discussion

Assessment of ingredients

The moisture content of flour was lower than 12% (rice flour: 9.2±0.3%, cassava starch: 11.5±0.3%, soy flour: 7.1±0.0%). The ash contents (rice flour: 0.8±0.0%, cassava starch: 0.1±0.0%, soy flour: 5.7±0.0%) were according to the values reported by other authors (Aristizábal and Sánchez, 2007; Sciarini *et al*., 2012a). Soy flour showed the highest protein percentage (41.8±0.1%) and no viscosimetric properties were observed in the Rapid Visco Analyzer test, related to the lower content of starch. Rice flour and cassava starch had lower protein contents (6.9±0.1% and 0.4±0.1%, respectively).

Pasting temperature of cassava starch (table 1) agreed with the values informed by Wickramasinghe *et al.* (2009). Rice flour had a higher pasting temperature similar to the one reported by Zhou *et al*. (2003). With temperature increment, viscosity of cassava starch showed a faster and greater growth than rice sample. During the cooling stage, the viscosity profile of both samples increased, being the cassava starch the sample with the lowest final viscosity. The behavior of these samples could be associated with a grain of weaker structure and a greater capacity to absorb water than rice flour. Debet and Gidley (2006) observed an association between the swelling pattern of starch granules, shear force and lipid and protein contents of the starch. Therefore, starch granules that swell faster during heating tend to be more sensitive to shear forces and contain less lipids and proteins than starches exhibiting more controlled swelling. Cassava starch had a greater breakdown value than rice flour, in accordance to the relationships found by Ragaee and Abdel-Aal (2006) for starches of different cereals. These authors showed a positive and significant association between the breakdown and peak viscosity and a negative association with

Table 1. Parameters of the Rapid Visco Analyser test

Sample	PT (°C)	PV (P)	MV (P)	FV (P)	BD (P)	SB (P)
Rice flour	85.2^{c}	40.0^{c}	34.2^{d}	67.7^{d}	6.0^{b}	33.5^{c}
Cassava Starch	67.8^{a}	69.7^{d}	21.4^{c}	33.6^{c}	48.3^{c}	12.2^{b}
FC1	71.0^{b}	18.0^{b}	13.0^{b}	22.5^{b}	5.0^{b}	9.5^{ab}
FC2	71.5^{b}	10.1^{a}	7.9^{a}	13.7^{a}	2.1^{a}	5.8^{a}

Mean ± standard deviation. Different lowercase letters in the same column indicate a significant difference ($p < 0.05$). FC1: rice/cassava/soy: (45:45:10) %, FC2: rice/cassava/soy: (35:45:20) %, PT: pasting temperature, PV: peak viscosity, MV: medium viscosity, FV: final viscosity, BD: breakdown, SB: setback.

the peak temperature. This reveals that starch that swells in greater proportion breaks more easily and imparts greater viscosity to the system.

When the combinations were evaluated, an overall decrease in the RVA profiles was observed in comparison with the individual profiles of rice flour and cassava starch. Combinations presented lower peak viscosities, due to the presence of exogenous proteins from soy and rice flours, which compete for water with starch from cassava and rice flour. Thus, the water available for the granules to swell is smaller and therefore the viscosity imparted to the system decreases. Ryan and Brewer (2007) evaluated the association between soy proteins and wheat starch by adsorption and desorption studies and found that starch-associated proteins affect the binding of incorporated (exogenous) proteins to the surface of the granule. They concluded that starch associated proteins attract and retain exogenous proteins in close association with the granule.

The profile of FC2, with the highest amount of soy flour and lower starch content, appeared at lower viscosity values than FC1 and consequently had a lower peak viscosity. Although the pasting temperature did not change, the presence of a higher amount of soy protein had an effect on the availability of water in the system and on the starch capacity to hydrate. Proteins exogenous to starch can affect the gelatinization properties in different ways depending on their ability to retain water or to interact with the starch or surface of the granules (Ribotta and Rosell, 2010). On the other hand, the hydrated starch granules in the FC1 combination showed a greater ease to be disintegrated by the shear forces and when the temperature decreased, the amylose chains were rearranged to a greater extent than FC2.

The combinations FC1 and FC2 were evaluated in the production of gluten-free laminated dough pieces with three percentages of water, 60, 68 and 76% and two fat samples. When fat samples were added to the gluten-free dough, only shortening could be spread in a layered conformation without disrupting the dough integrity. The fat samples used had a solid content, greater than 20% over a temperature range of 15-35°C and a viscous behavior. However, the bovine fat solid content dropped by 135 %, whereas in shortening it decline by 160 %. Furthermore shortening had a more viscous behavior than bovine fat. In a previous study (de la Horra *et al*., 2017), fat samples with these structural properties generated laminated products with wheat flour of good technological and sensorial characteristics.

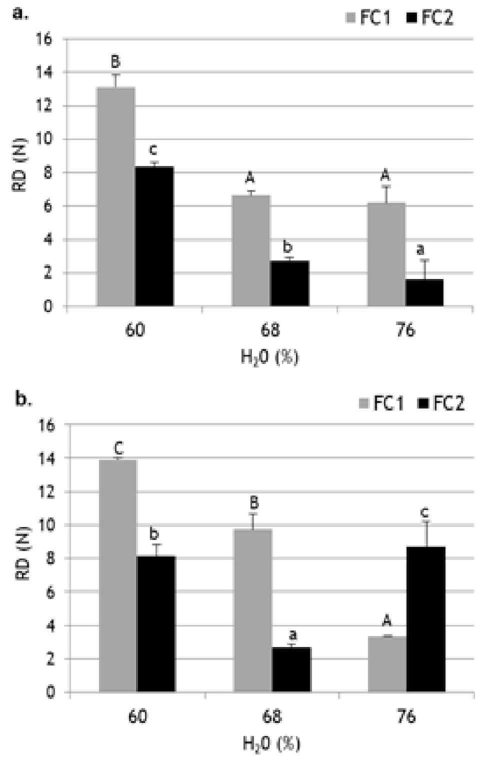

Figure 2 Resistance to deformation of laminated dough pieces. a. Samples made with refined bovine fat. b. Samples made with shortening. Mean ± standard deviation. Different capital letters indicate a significant difference ($p < 0.05$) between water percentages for FC1 combination (rice/cassava/soy: (45:45:10) %). Different lowercase letters indicate a significant difference ($p < 0.05$) between water percentages for FC2 combination (rice/cassava/soy: (35:45:20) %). RD: resistance to deformation.

The dough resistance to deformation was assessed (Figure 2). Figure 2.a shows the values of samples when refined bovine fat was used. In pieces elaborated with FC1 and FC2, a decrease in the resistance to deformation was observed as the water content added in the formulation increased. When shortening was used (Figure 2.b) samples from FC1 showed the same tendency described before for samples with refined bovine fat. On the other hand, dough samples with FC2 showed a non-clear tendency, being the pieces with the lowest and highest water content the hardest systems. De la Horra *et al.* (2015) found positive associations between dough

Table 2. Technological quality parameters of laminated gluten-free products

Sample	Control	SSL 1 %	SSL 2.5 %	DATEM 1 %	DATEM 2.5 %
Dough height (cm)	$(1.4\pm0.0)^{a}$	$(1.9\pm0.0)^{b}$	$(1.9\pm0.0)^{b}$	$(1.9\pm0.0)^{b}$	$(1.9\pm0.0)^{b}$
H	$(1.5\pm0.1)^{b}$	$(1.3\pm0.0)^{a}$	$(1.2\pm0.0)^{a}$	$(1.3\pm0.0)^{a}$	$(1.3\pm0.0)^{a}$
Product height (cm)	$(2.1\pm0.00)^{a}$	$(2.4\pm0.1)^{a}$	$(2.4\pm0.0)^{a}$	$(2.4\pm0.0)^{a}$	$(2.4\pm0.1)^{a}$
W	$(1.0\pm0.0)^{a}$	$(1.0\pm0.0)^{a}$	$(1.0\pm0.0)^{a}$	$(1.0\pm0.0)^{a}$	$(1.0\pm0.0)^{a}$
SF	$(0.4\pm0.0)^{a}$	$(0.5\pm0.0)^{a}$	$(0.5\pm0.0)^{a}$	$(0.5\pm0.0)^{a}$	$(0.5\pm0.02)^{a}$
SV (cm^3)	$(64.4\pm4.4)^{a}$	$(69.8\pm1.5)^{ab}$	$(70.4\pm0.6)^{b}$	$(70.4\pm1.8)^{b}$	$(72.1\pm0.6)^{b}$
L*	$(55.8\pm1.1)^{ab}$	$(57.4\pm0.6)^{a}$	$(59.9\pm3.2)^{a}$	$(58.5\pm0.8)^{a}$	$(58.6\pm1.2)^{a}$
a*	$(12.5\pm1.1)^{c}$	$(9.8\pm0.3)^{b}$	$(6.8\pm1.5)^{a}$	$(9.43\pm0.4)^{b}$	$(11.3\pm0.4)^{bc}$
b*	$(31.4\pm0.1)^{b}$	$(31.4\pm0.8)^{b}$	$(28.1\pm0.4)^{a}$	$(31.0\pm0.1)^{b}$	$(31.5\pm1.2)^{b}$
Firmness (N)	$(62.2\pm4.0)^{a}$	$(78.0\pm4.1)^{ab}$	$(95.6\pm9.6)^{bc}$	$(74.6\pm5.8)^{ab}$	$(109.3\pm22.1)^{c}$
Masticability	$(62.7\pm3.0)^{c}$	$(58.1\pm2.3)^{a}$	$(62.6\pm14.1)^{a}$	$(55.7\pm6.2)^{a}$	$(73.6\pm4.1)^{a}$
Homogeneity	0.24^{b}	0.17^{a}	0.18^{a}	0.19^{a}	0.32^{c}
Contrast	90.42^{b}	90.56^{b}	92.06^{b}	81.97^{b}	45.30^{a}
Entropy	7.06^{a}	6.99^{a}	7.42^{b}	7.08^{a}	7.01^{a}
FD	1.44^{a}	1.48^{ab}	1.57^{c}	1.48^{ab}	1.53^{bc}

Mean ± standard deviation. Different letters in the same row indicate a significant difference ($p < 0.05$). H: height relationship, W: weight relationship, SF: shape factor, SV: specific volume, FD: fractal dimension.

resistance to deformation and quality attributes of laminated products made with wheat flour. A laminated structure capable of exerting a resistance higher than 8 N against an applied deformation has a good capacity during baking to maintain the original given shape, avoid growth in lateral direction and have higher values of height. However, a higher increment in the dough resistance to deformation was related with harder crust and crumb. This revealed the importance to found a range in dough rheological parameters, in order to do not affect negatively the product texture. And particularly to determine a range for laminated gluten-free systems.

Therefore, gluten-free laminated products were elaborated from combinations FC1 and FC2, using shortening and 60% of water. In baked samples made from FC1 no layers were observed (Figure 3.a), but rather pores at the top and bottom of the crumb. In the central area, the internal structure had a compact appearance. On the other hand, when combination FC2 was used to elaborate the product, it showed an inner crumb characterized by the presence of some sheets, which had a heterogeneous distribution and presented some continuity throughout the structure. The behavior of dough from FC2 during heating was probably related to the results observed in the RVA, where the presence of a higher amount of soy proteins had an effect over the starch capacity to gelatinize and the decrease of the system viscosity. Some authors (Miller and Hoseney, 1997) have found that during baking, the expansion of laminated dough cookies was accompanied by a reduction in viscosity, until a point where the structure is suddenly fixed, due to the starch gelatinization. Therefore, the greatest reduction in the viscosity observed in FC2 can lead to a late fixation of the product structure during baking, and thus promote the development of a sheeted structure.

Hence, the effect of emulsifier incorporation on the physical and textural attributes of the product was evaluated using the FC2 combination, low water content and shortening.

Effect of emulsifiers on the technological quality of gluten-free laminated baked products

The height of laminated dough pieces was determined after lamination and rest periods, before baking. Although dough pieces were manipulated equally and the thickness was adjusted by roller at 1.5 cm, samples with additives were higher than the control (Table 2). This could be associated with pieces of different elasticity properties. The control structure supported the lamination in a lesser extent and had a final height lower than 1.5 cm. The presence of emulsifiers could have strengthened the dough as they done in wheat systems (Chung and Tsen, 1975). Their amphiphilic nature promotes the interactions between proteins, starch and lipids and is dependent of to the emulsifier structures and the hydrophilic-lipophilic index. Despite SSL had a hydrophilic-lipophilic balance (HLB) of 21, higher than DATEM (9.2) (Stauffer, 1990) no differences were found between additive dough heights. Onyango *et al*. (2009) reported that SSL and DATEM had an incremental effect on the deformation resistance and the elastic recovery of the gluten-free dough pieces.

The height relationship is associated with the system ability to grow in a vertical direction. Control had a higher height relationship than samples with emulsifiers. However, products with additives were higher than the control at the end of the baking step. The incorporation of emulsifiers in the formulation did not change the lateral expansion of the dough pieces during baking, since no significant differences were found between the width relationship values. No significant differences were found in the shape factor values among the evaluated samples.

The presence of additives had an effect on the product specific volumes. Samples with 2.5% of SSL and with 1% and 2.5% of DATEM showed higher specific volumes than control. The baked structures were strengthened when emulsifiers were added, although only samples with 2.5% of SSL and DATEM were significant harder than control. In the same way, when emulsifiers were incorporated, products masticability was higher than control. In agreement with these results, Sciarini *et al.* (2012b) reported harder rice breads when SSL and DATEM were added and Onyango *et al.* (2009) observed harder crumbs when emulsifiers were in the formulation. On the contrary, Borges and Salas-Mellado (2016) found that gluten-free breads with sorbitan monooleate (Polysorbate 80) presented less hard crumbs as compared with other additives and, there was no positive effect on the specific volume.

The product inner structure was evaluated by texture image analysis; four textural parameters were used to characterize the crumb in terms of texture (Table 2). Figure 3.b shows the inner conformation of all samples analyzed. The control presented a compact structure with the presence of isolated pores. SSL 1% showed a spongier structure, while an increment in the additive doses promoted the formation of some pores with extended conformation. In DATEM 1% there were some wide layers in the upper section and with 2.5% of DATEM the sheets presented a more defined shape along the whole structure. Samples with additives had a distribution of the structural elements, pores and layers, less homogenous than the control. Except DATEM 2.5% who presented the opposite trend. Neither of SSL doses cause significant changes in contrast values. DATEM 1% had a decrease in this parameter which was accentuated as the additive doses increased, being significantly lower and associated with the presence of layers. No significant differences were detected for entropy between the considered samples, although SSL 2.5% had a slightly but significant increment. This sample showed a greater randomness in the distribution of the image intensity, related with more complex images. The fractal dimension provides a numerical descriptor for the morphology of objects with complex irregular structures like pores and layers (Perez-Nieto *et al*., 2010), and it is associated with surface roughness (Santacruz-Vázquez *et al*., 2007). The lower emulsifier's doses did not affect this textural parameter. While with the higher doses the products presented structural elements of a greater tortuosity than the control, related with layers formation and the presence of pores with extended conformation.

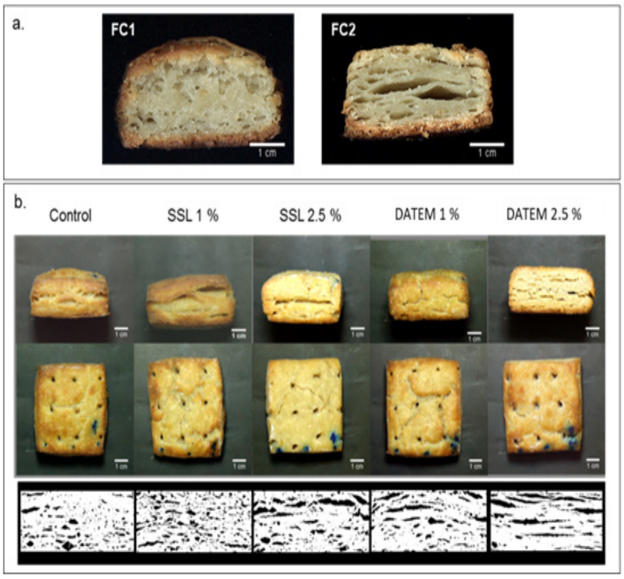

Figure 3. Gluten-free laminated products. a. Products elaborated with combinations FC1 and FC2, shortening and 60 % of water. b. Products with emulsifiers. FC1: rice/cassava/soy: (45:45:10) %, FC2: rice/cassava/soy: (35:45:20) %.

The evaluated emulsifiers are often used in baked goods, where they improve the gas retention of the dough during oven spring and crumb structure of bread (Stampfli and Nersten 1994; Demirkesen *et al*., 2010b). The same phenomenon could take place in laminated gluten-free systems, where the emulsifier improved the ability of dough sheets to retain the gas generated during the baking step and prevent the structure collapse. In this sense, higher emulsifiers doses exerted a more marked effect; leading to more laminated structures and higher firmness values.

Emulsifiers did not affect the crust luminosity. There were no significant differences between L^* values, according to Aguilar *et al.* (2015). While there was an effect on the a^* parameter. Crusts with both doses of SSL and 1% of DATEM showed a decrease in the intensity of the red color compared to control. The values of b^* were positive for all analyzed products, SSL 2.5% had a crust with a slightly lower yellow color intensity than the control and other samples. De la Horra *et al*. (2017) found that the wheat laminated products most preferred in an acceptability analysis were those with less red and yellow crusts.

Conclusion

The presence of different amounts of soy and rice flours, water contents and fat samples affect the deformation capacity of the system and the conformation of a layered baked inner structure. A laminated gluten-free product was obtained using 35% of rice flour, 45% of cassava starch, 20% of soy flour, 60% of water and shortening. Through the incorporation of emulsifiers, an improvement in product quality was observed. Dough pieces with emulsifiers had a good tolerance to the lamination and folding steps. Besides, baked products with higher doses of SSL and DATEM presented an improvement in their specific volumes. The strengthening of the baked structures with additives was related to the presence of tortuous structural elements due to the layers development in the inner structure. Technological quality parameters to characterize gluten-free laminated baked products were defined. Particularly, the proposed texture image analysis allowed us to quantify the differences observed between the inner structure samples. This work raises future possibilities in the study of other additives with specific action over the components of gluten-free flours and starches to obtain a laminated product with an optimum technological and sensorial quality.

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