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Abstract

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Keywords (separated by '-')	Laminated dough - Sensory analysis - Laminated baked product - Puff pastry - Solid fat content - Fat rheology
Footnote Information	

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ORIGINAL ARTICLE

Relationships between structural fat properties and sensorial, physical and textural attributes of yeast-leavened laminated salty baked product

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Abstract The aim of this study was to establish relationships between structural fat properties and sensory, physical and textural attributes of yeast-leavened laminated salty products. Refined bovine fat (MG1) and shortening (MG2), with a SFC higher than 20% at temperature range of 15–35 °C were more viscous and less sensitive to temperature changes. The micrographs of dough|fat|dough sections corresponding to samples with MG1 and MG2 revealed a lower penetration of the fat sheet in the dough section due to the more entangled fat structures that did not allow a great flow throughout the dough layer. Consequently, the structuration of laminated dough pieces allowed the obtainment of systems highly resistant to deformation. The laminated dough pieces elaborated with these fats experiment the highest increments in their height and maintained symmetry. Products with fat of least SFC and higher destructuration rate produce smoother laminated structures due to the pores. While products with MG1 and MG2 showed tortuous images and complex structures, associated to layers and extended pores. MG1 and MG2 products were preferred (flavor and appearance) over those with MG3. The highest ranking samples in the acceptability analysis were symmetric, presented very flaky crusts and had a high level of lamination.

Keywords Laminated dough · Sensory analysis · Laminated baked product · Puff pastry · Solid fat content · Fat rheology

Introduction

In the production of laminated baked products (puff and Danish pastry), fat can be added in the base dough formulation and as layers between two adjacent dough sheets (Cauvain and Young 2001). The portion of fat between the dough layers affects puff pastry lift and flakiness (O'Brien 2004). Telloke (1991) established the influence of some fat-related aspects on puff pastry. The amount of added fat, the solid fat content (SFC) and the firmness of the fat at point of use were some of the variables bearing a proportional relationship with pastry lift. The crystalline form showed an inverse proportional relationship with the lifting. Matthews and Dawson (1963) used a sensory analysis to determine the performance of six kinds of solid and liquid fats at different levels of fat content. Baardseth et al. (1995) studied the influence of eleven roll-in shortenings made of milk fat or vegetable oil on the sensory characteristics of Danish pastries. They found that roll-in shortening concentration influenced the texture and color of the baked product, and the roll-in shortening type affected flavor, odor and color. Simovic et al. (2009) investigated the effect of low-trans margarines on the physical and sensory properties of puff pastry and reported that the most important linear and square effect was the quantity of margarine. Pajin et al. (2011) and Pimdit et al. (2008) studied the influence of fat composition on fat suitability to produce puff pastry.

Although many authors have studied in detail some of the fat characteristics proposed by Telloke (1991), they

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have either used fats with a similar SFC or have not considered it at all. Only Stauffer (1996) and Doerry (1996) presented a SFC profile and related it with fat functionality. Cauvain (2001) indicated that an SFC of 38–45% at 20 °C produced the maximum-specific height of puff pastry. The relationship between structural fat properties (fat melting, SFC profile and rheology behavior) and the sensory and physical qualities of laminated systems has not been assessed yet. In fact, no studies have been conducted about the relationship between fat fundamental rheology and the characteristics of laminated baked products.

AQ3 Variables involved in the process of production such as the influence of number, continuity and thickness distribution of fat layers on Danish pastry have been reported by some authors (Deligny and Lucas 2015; Bousquieres et al. 2014a, b) and on puff pastry by others (Collewet et al. 2014). Most of these studies focused on systems based on yeast and a high sugar content (15–25%)—commonly called Danish pastry—and on products with no yeast or sugar (leavened with water vapor)—known as puff pastry.

The simultaneous presence of salt and yeast in a laminated system should affect both dough behavior during the production stages and quality of the product. Yeast plays a major role in dough aeration during fermentation and baking, and it also disrupts the integrity of fat and dough layers (Cauvain and Young 2001). Therefore, the study of yeast-leavened laminated salty products will contribute to the scientific knowledge about laminated systems and their industrial use in countries where laminated baked goods are some of the most popular consumer products (Giannoni 2012). In this context, the aim of this study was to establish relationships between structural fat properties and the sensory, physical and textural attributes of yeast-leavened laminated salty products.

Materials and methods

Material

A commercial "000-type" wheat flour (Graciela Real, Argentina), popular among local producers in Argentina, was used to manufacture baked products. Three commercial shortening samples used in the regional production of yeast-leavened laminated salty products were evaluated.

- Refined bovine fat (MG1) (La Cordobesa para hojaldre, Argentina)
- Shortening (MG2) (Mkt CALSA margarina para hojaldre, Argentina)
- Oleomargarine (MG3) (Margarina Dánica, Argentina)

Flour characterization

The commercial flour was analyzed for moisture, ash, protein, and wet and dry gluten content (44–19.01, 08.01.01, 46–10.01 and 38–10.01 AACC Methods 1999; respectively). The falling number was obtained by the AACC standard method 56–81.03 (Falling Number 1400, Perten, Sweden).

Predictive tests were carried out to evaluate the suitability of this flour to produce yeast-leavened laminated salty products. The solvent retention capacity profile and the sodium dodecyl sulfate sedimentation index were determined (56–11.01 and 56–70.01 AACC Method 1999; respectively). Dough expansion properties were evaluated through a biaxial extension test using a Chopin alveograph (MA 95, Trippette & Renaud, France) following the 54–30.02 AACC Method (1999). The experiment was carried out with five dough pieces and an average of the obtained alveographs was used to calculate dough resistance to deformation (P), dough extensibility (L), the area under the graph which is proportional to the energy required to rupture the dough piece and the P/L relationship. Each test was performed at least twice.

Physical characterization of shortenings

The following analyses were performed on each shortening sample at least three times.

Melting profile: the melting-crystallization process of the shortenings was evaluated by Differential Scanning Calorimetry (DSC 823 Mettler-Toledo, Zurich, Switzerland). An aliquot (7–10 mg) of the shortenings was placed in 40 µl aluminum pans, heated at 30–80 °C (10 °C/min) and kept at 80 °C for 10 min. They were then cooled to −20 °C (1 °C/min), kept at −20 °C for 30 min and finally heated to 80 °C (10 °C/min) (Danthine 2012). The melting temperature was determined from the second curve of heat flow versus temperature.

Solid Fat Content (*SFC*): it was determined at different temperatures (10, 15, 20, 25, 30, 35, 40 and 45 °C) and expressed as % SFC (Firestone 1989) (Minispec mq20 Pulse Analyzer).

Rheology behavior: each sample was first heated and cooled to destroy any previous crystalline structure. The rheological measurements were performed on a RHEOPLUS/32 rheometer (Anton Paar, Germany) with a parallel plate geometry (8-mm plate diameter and 1-mm plate gap) according to Jiménez-Colmenero et al. (2012). Stress amplitude sweeps (at 1 Hz and 25 °C) were carried out on all the samples to determine the linear viscoelastic region (LVR) of each. Frequency sweeps (0.01–10 Hz) within the LVR were performed over shortening pieces at a constant

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temperature (25 °C) and frequency (1 Hz). Temperature sweeps were carried out from 25 to 90 °C (heating rate: 2.99 °C/min, frequency: 1 Hz, strain: 0.1%). The storage modulus (G′), loss modulus (G″) and tan δ (G″/G′) were calculated in terms of frequency and temperature of each sample. The influence of temperature on the complex viscosity was evaluated with the Arrhenius equation (Eq. 1) (Rao 1999a), where η* is the complex viscosity (Pa.s), A is a pre-exponential factor (Pa.s), Ea is the activation energy (cal/mol), R is the universal gas constant (1.987207 cal/mol K) and T is the temperature (K).

$$\eta* = A^{-Ea/RT} \qquad (1)$$

A plot of Ln [η*] versus 1/*T* was made with temperature sweeps results. The slope of the plot was equal to *Ea*/*R* from, where *Ea* was evaluated (Esteban et al. 2012).

Production of yeast-leavened laminated salty products

The yeast-leavened laminated salty products were made with the three shortening samples according to de la Horra et al. (2015). The dough was prepared with 100 g wheat flour, 20 g shortening, 2.8 g compressed yeast (Red Saf-instant, Lesaffre, Argentina), 2.5 g refined dry salt (Dos Anclas, Argentina), 1.4 g sugar (Ledesma, Argentina) and 50 mL water. The ingredients were mixed for 3 min in a mixer (MPZ Pedro Zambom e hijos, Argentina) until the dough was made. 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 twofold turn and allowed to rest for 20 min at 23 °C; it was then gaged to a 50-mm thickness in seven steps and given another twofold turn. The dough rested again for 20 min and was gaged to a thickness of 50 mm. It was laminated with a twofold turn and the final gaging was to about a 15-mm thickness. 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 (5 × 5 × 1.5 cm) were fermented at 35 °C and 80% relative humidity until they doubled their height. The baking process took place at 175 °C for 27 min in a Beta 107 IPA convector oven (Pauna, Argentina). The products used in the evaluations were made at least twice and six pieces of each sample were analyzed.

Evaluation of dough characteristics

The following analyses were performed on the non-fermented laminated dough pieces prepared according to the above mentioned procedure with the three shortening samples. 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.

Microstructure: the dough microstructure was observed under a Confocal Nikon Eclipse C1si Microscope (Nikon Inc., Tokyo, Japan). Dough samples were prepared according to Peighambardoust et al. (2006) with some modifications described here. The dough samples were frozen at −18 °C and then cut into thin slices. The protein network was dyed with a solution of 1% Rhodamine B in dimethylformamide. The starch components were labeled with a 1% flourescein solution in dimethylformamide. A 514-nm argon ion laser excitation was used to observe the starch components (green) and a 543-nm neon ion laser excitation to visualize the protein fraction (red).

Compression test: the dough was compressed up to 40% of 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. Dough resistance to deformation was defined as the maximum force obtained.

Evaluation of baked product physical and textural attributes

The following analyses were done at least twice and six pieces of each sample were analyzed.

Conformational evolution: the behavior of the dough pieces during the production process was evaluated according to de la Horra et al. (2015). The height was determined at three points in the surface (5 mm from the edges and at the center), and an average height was calculated. The height (H) and width (W) ratios were determined with the dimensions (height and width) of the baked products (bp) and the unfermented dough pieces (ud) (Eqs. 2 and 3).

$$H = \frac{H_{\mathrm{bp}}}{H_{\mathrm{ud}}} \qquad (2)$$

$$W = \frac{W_{\mathrm{bp}}}{W_{\mathrm{ud}}} \qquad (3)$$

The shape factor (SF) of the baked products was calculated as follows, with the baked product dimensions.

$$\mathrm{SF} = \frac{\mathrm{Height}}{\frac{\mathrm{Width} + \mathrm{Length}}{2}} \qquad (4)$$

Specific volume: the baked product was weighed and the volume was determined by rapeseed displacement after cooling for 1 h. The specific volume was expressed as the

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volume/weight ratio of the final product (10–05 AACC AQ4 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 1999).

Compression test: the baked product was compressed up to 40% of 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).

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. The images were pre-processed by turning to grayscale, subtracting the background and enhancing the contrast. The Gray Level Co-Ocurrence 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; the fractal texture was evaluated by the Fractal Box Counting method and the fractal dimension was established (Quevedo et al. 2002).

Sensory evaluation of the baked product

An acceptability analysis with 83 untrained panelists was carried out to determine consumer preference over the baked products prepared with the three shortening samples. A discontinuous scale of seven points was used and the evaluated parameters were flavor, odor and appearance of the baked products. The results were assessed with a non-parametric Friedman test.

A multiple discrimination test was carried out with 14 semi-trained panelists from Laboratorio de Química Biológica, Facultad de Ciencias Agropecuarias (Universidad Nacional de Córdoba). A continuous eleven-point scale was used to quantify the differences between the products made with shortenings and a sample arbitrarily designated like the control (Tang et al. 1999). The control was positioned in the middle of the scale and considered as zero point, subsequently were 5 positive points to the right and 5 negative points to the left. The positive values were used in case the sample was more than the control (+5: the most), while negative values were used in case the samples was less than control (−5: the lowest). The sensory attributes considered and the descriptor definitions were as follows and according to Hozová et al. (2002) with some modifications described here:

Attributes evaluated by visual observation

- Symmetry: the product symmetry
- Crust flakiness: level of flakiness of the product crust
- Lamination: amount of sheets in a cross section of the product
- Uniformity: distribution of pores and sheets in a cross section of the product
- Porosity: amount of pores in a cross section of the product

Attributes evaluated by mouth manipulation of samples

- Firmness: the force required to compress the product in two chews between the molars
- Fat perception: intensity of fat perceived during mastication

Drinking water was provided for palate cleansing between each sample. The results of the discrimination test were assessed using analysis of variance (ANOVA), generalized linear mixed models and the least significant difference (LSD) multiple comparison test.

Statistical analysis

The results obtained were compared by analysis of variance (ANOVA) 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

Flour characterization

The commercial flour used to make the yeast-leavened laminated salty products had an ash and protein content of 0.739 ± 0.001 and 11.25 ± 0.07%, respectively. The wet and dry gluten content was 35.37 ± 0.67 and 14.755 ± 0.003%, respectively. The wet gluten content was higher than that reported for Argentinian wheat flours by Colombo et al. (2008). Amylase activity has an important effect on the quality of the baked products. A lower falling number (<300) is associated with high enzyme activity, resulting in sticky crumbs and brown crusts. The falling number was 414 s, which may be associated with a weak amylase activity. Sliwinski et al.

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(2004) reported lower falling numbers for European and Canadian wheat flours used in puff pastry production. The dodecyl sulfate sedimentation index is related to the quantity and quality of gluten proteins. The commercial flour had a dodecyl sulfate sedimentation index of 14.00 ± 0.00 cm^3. Guttieri et al. (2004) reported lower values of dodecyl sulfate sedimentation index (6.1–7.2 mL) for soft white and red wheat samples, and Colombo et al. (2008) found a dodecyl sulfate sedimentation index range of 11.75–19.25% for Argentinian hard wheat samples. The solvent retention capacity profile was about 97.80 ± 4.66% for sucrose, 99.47 ± 0.93% for lactic acid, 73.29 ± 0.29% for sodium carbonate and 84.11 ± 0.33% for water. The solvent retention capacity values for sucrose and water were consistent with the values obtained by de la Horra et al. (2015) for hard wheat flours suitable to produce yeast-leavened laminated salty products. The alveograph test provided relevant information to relate flour characteristics to dough behavior during fermentation and the early stage of baking. The P/L value was 1.82 (p value: 120.12 mm; L value: 66 mm)—higher than that obtained by de la Horra et al. (2012) for a set of Argentinian wheat flours (0.43–1.62). The deformation energy was 320×10^{-4} J. Cuniberti et al. (2003) found a W range of $120–562 \times 10^{-4}$ J for a set of Argentinian wheat flours. The flour sample presented high proteins and gluten contents, and the presence of a certain level of hydrophilic components which imparts the necessary viscosity in this kind of systems. Therefore, the obtained dough presented extensibility properties that allowed the lamination and the layers formation.

Physical characterization of shortenings

Shortenings and margarines are composed of a solid phase of fat crystals intimately mixed with a liquid phase of fluid oil. The proportion of the material in the solid phase is the factor that most directly influences fat consistency (O'Brien 2004). The melting points (MP) in the analyzed shortening samples were significantly different ($p < 0.05$). The MG1 sample presented an MP of 46.94 ± 0.08 °C, which is in accordance with the melting range (45.0–57.2 °C) reported for shortenings used in puff pastry production (O'Brien 2004; Stauffer 1996). The MP in MG2 and MG3 (42.77 ± 1.29 and 39.09 ± 0.18 °C, respectively) was similar to the MP of Danish pastry shortenings (39 °C) (O'Brien 2004).

The SFC profile of the samples declined with higher temperature (Fig. 1a). Sciarini et al. (2013) showed the same tendency with the temperature increment in fats with different SFC values. The decreasing tendency was most pronounced for MG1 and MG2, whereas MG3 showed a flatter profile. In the temperature range of 15–35 °C (production process of baked products), the SFC in MG1 dropped by 135 and 160% in MG2, whereas in MG3 it declined by 11%. At the temperatures evaluated, MG1 showed the highest SFC ($p < 0.05$), followed by MG2 and MG3. Simovic et al. (2009) reported SFC values of low-trans margarines similar to MG1 and MG2 (ranges of SFC at 10 °C: 60.1–54.8%; 20 °C: 47.1–40.1%; 25 °C: 38.6–30.9%; 30 °C: 26.3–22.3%). Doerry (1996) reported that a relatively high solid fat content was optimum for puff pastry shortenings, e.g. an SFC of 16% at 40 °C. MG1 with an SFC of 18% at 40 °C should be suitable to produce baked products with a laminated structure. Studies about consistency and spreadability properties of chemically and enzymatically modified dairy fats, palm oil, cocoa butter, bovine and porcine fat have been found (Rousseau et al. 1996, Rousseau and Marangoni 1998). These authors reported different rheological properties despite the fact that the samples under study had the same SFC. Therefore, the understanding of fat three-dimensional network structure should not be conceived only through fatty acid composition and SFC. It is essential to evaluate the mechanical properties and geometric characteristics of the fat structure (Narine and Marangoni 1999).

The frequency sweeps under isothermal conditions showed the rheology behavior of the shortenings (in stress terms) when they were subjected to a constant cyclic strain, whose frequency changed over time. There were no significant increments in the storage (G') and loss (G'') moduli with a higher frequency, which indicates that the viscoelastic behavior was poorly dependent on frequency (Fig. 1b). The analyzed samples presented a predominance of G' over G'' in the studied frequency range. This revealed a system behavior more similar to a viscoelastic solid, where deformations are essentially elastic and recoverable (Rao 1999b). The observed behavior is typical of plastic shortenings and fat blends (Buldo and Wiking 2012). The macromolecular structure and distribution of fats is determined by the tendency of the solid particles to interlock. Fats have a high capacity to be molded (plasticity) as long as the interlocking effect is strong enough to make them highly resistant to small deformation processes. When stress increases, a point is reached where the fat structure will yield to allow plastic flow. The relative consistency of fats is hence a measure of the stress required to cause plastic flow or movement. The internal strength of the material is determined by the number of contact points among crystal particles (O'Brien 2004).

The elastic response to stress by MG1 and MG2 was significantly higher ($p < 0.05$) than the MG3 response. The level of the G'-curve coincides with the number of cross-links along the original chain molecules (Schramm 2000). Therefore, MG1 and MG2 structures were associated with more entangled systems because of a high number of

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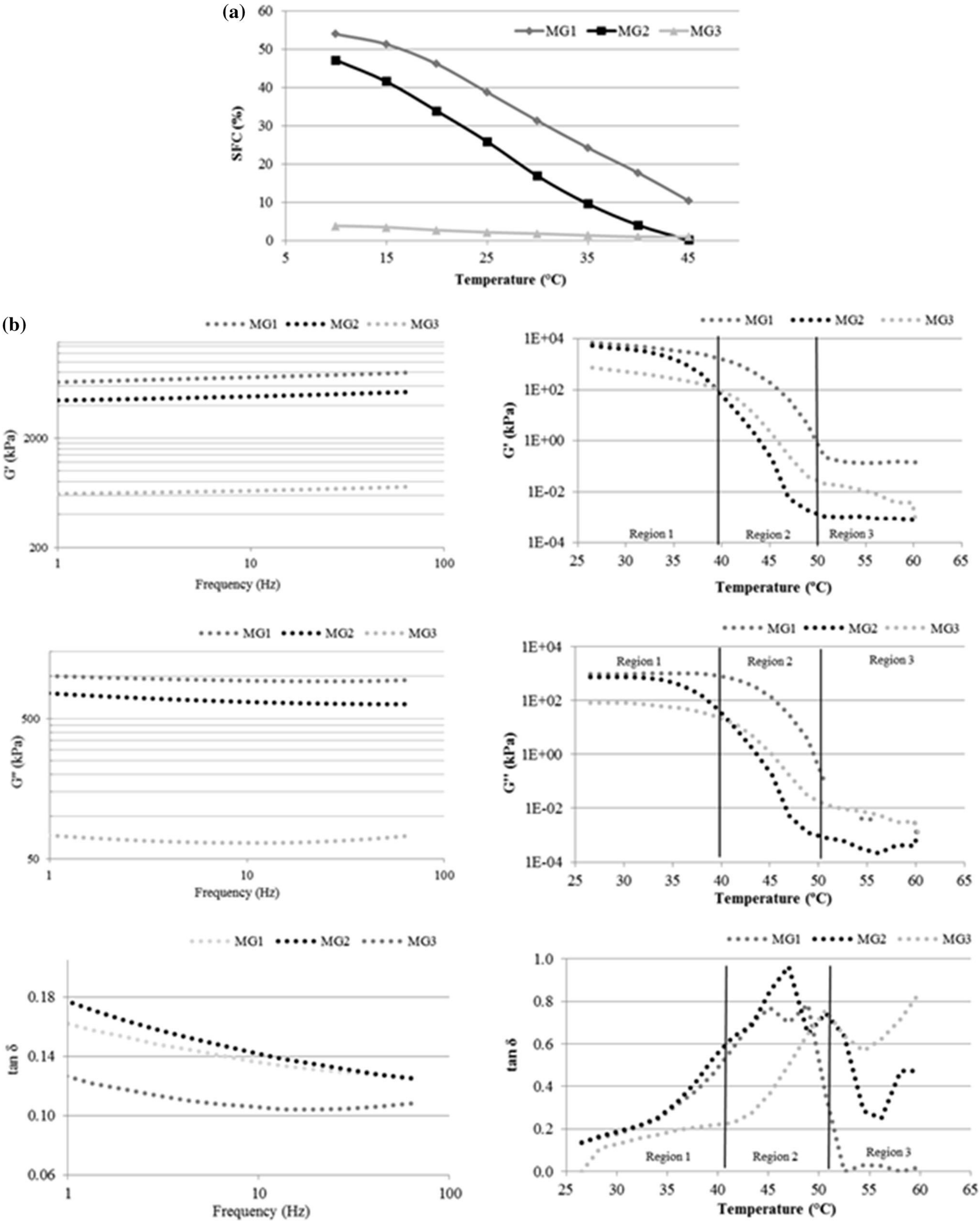

Fig. 1 Solid fat content profile and rheological profiles of shortening samples. **a** SFC: solid fat content. **b** G′: elastic moduli; G″: viscous moduli; tan δ: G″/G′ ratio

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intermolecular points of interactions. The lower G′ for MG3 was related to a weak structure formed by a lower number of interactions. MG1 showed the highest viscous component (G″), followed by MG2 and MG3. These results were in agreement with Vreeker et al. (1992), whose showed that the G′ of fat network varied with the SFC and its fractal or tortuous nature. During fat production the SFC decreased, hence a sample that initially had a higher SFC showed a more viscous response. The lower particles mobility during heating promotes the formation of smaller crystal microstructures. In the fat network the intra-microstructural interactions are stronger than the inter-microstructural. Consequently the elastic response of the system is dominated by the elastic behavior of the interactions established between the crystal microstructures. This generates a less rigid structure with a greater G′, as in the case of MG1 and MG2. On the other hand, a system with a lower SFC presented a lesser viscosity and when is heating the molecules mobility grow. This promotes the formation of large crystal structures, whose intra-microstructural interactions are weaker than the established between the different microstructures. In this case, the storage modulus of the system is dominated by the elastic behavior of the microstructures, due to the forces between the intra-microstructural entanglements. Consequently the network had a lesser elastic behavior than the one formed by smaller crystals (Shih et al. 1990, Sciarini et al. 2013).

At 1 Hz of frequency, the observed results for tan δ were not significantly different (Table 1). However, MG2 and MG1 showed tan δ values closer to 1, attributable to a relatively more viscous reaction of the systems to the applied strain. A lower tan δ value for MG3 can be related to a more elastic response. Fats with a higher SFC (MG1 and MG2) presented more entangled structures and globally dissipated in a viscous fashion the energy used to deform them.

The rheological behavior of the shortenings was evaluated in terms of temperature at a fixed frequency. The samples showed different rheological profiles when subjected to the heat treatment. The G′ values were higher than G″ for the three samples along the entire temperature sweep (Fig. 1b). In a first region (Region 1: 0–39 °C) the elastic compound slightly declined with higher temperature. MG1 had the greatest elastic response, followed by MG2 and MG3. These revealed that during the heating process to 39 °C, MG1 showed a more entangled structure than MG2 and MG3. The G′ of MG2 started to decrease at a lower temperature (35.9 °C) compared with MG3 (38.7 °C) and MG1 (41.5 °C). Therefore, MG2 began to suffer a destructuration at a lower temperature in comparison with MG3 and MG1. MG1 presented the highest viscous component, followed by MG2 and MG3. The tan δ curves of all the samples rose with higher temperature. This tendency was related to a sharper decrease in the elastic component than in the viscous component.

The greatest rheological changes took place in a second region (Region 2: 39–45 °C), where a great decrease was observed in both moduli with the higher temperature, caused by the shortening melting. Destructuration of the systems was greater than the one produced at lower temperatures. MG1 showed the highest elastic component, followed by MG2 and MG3 (Table 1). The highest viscous component appeared in MG1, followed by MG3 and MG2 (Table 1). The tan δ curves showed the same tendency as under lower temperature. However, MG1 and MG2 tan δ values (Table 1) were significantly higher and closer to 1 than MG3. This can be associated with an MG1 and MG2 reaction more similar to a viscoelastic liquid than MG3. At temperatures over 45 °C (Region 3), the elastic component of the samples remained constant, whereas G″ showed a slight decrease. The tan δ profiles showed a maximum, which decreased with the temperature increment.

Viscosity changes with temperature can be described by an Arrhenius-type relationship. The samples presented different activation energies (Table 1), although the observed tendencies were not significantly different. In Region 1, which included the temperature of dough production and lamination, MG3 was the most sensitive sample to temperature changes (higher activation energy values), with a destructuration rate of the system higher than MG1 and MG2. Igwe (2004) found the same tendency in vegetable oils (in solution), where the samples with

Table 1 Rheological and Arrhenius parameters of shortening samples

Sample	Frequency sweep			Temperature sweep						Activation energy (kcal mol^{-1})	
	G′ (kPa)	G″ (kPa)	tan δ	G′ (kPa)		G″ (kPa)		tan δ			
				39 °C	45 °C	39 °C	45 °C	39 °C	45 °C	Region 1	Region 2
MG1	6500a	1009a	0.16a	1765.0a	168.0a	818.5a	129.5a	0.47a	0.77a	0.24a	4.14a
MG2	4435a	763b	0.17a	92.1b	0.2b	49.3b	0.2b	0.53a	0.87a	0.20a	3.20a
MG3	619b	74c	0.12a	108.8b	2.0b	24.8b	1.0b	0.23b	0.51b	0.26a	3.75a

Rheological measurements at 1 Hz. G′: elastic moduli; G″: viscous moduli; tan δ: G″/G′ relationship. Values in each column followed by a different letter are significantly different ($p \leq 0.05$)

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higher values of Ea showed the lowest values of intrinsic viscosity. In a laminated system composed of alternate dough and fat sheets, the fat capacity to be deconstructed and flow with rising temperatures influenced the final structure of the baked product. In Region 2, MG1 was the least resistant to temperature changes, followed by MG2 and MG3.

Dough evaluation

In order to evaluate the effect of shortenings with different structural properties on the organization and distribution of the dough structural elements, micrographs were taken from dough laminated pieces (Fig. 2). In the images the starch granules are in green, while the proteins in red and the dark regions are associated with the shortening. The micrographs of dough sheet sections (Fig. 2a) showed that there had been a gluten network development in all the samples. However, dough pieces with MG2 and MG3 presented a greater gluten development than MG1. Shortenings with intermediate and low SFC interfered to a lesser extent in the established interactions between proteins during the dough development.

The greatest differences in the distribution of the structural elements were observed in the dough|fat|dough intersections (Fig. 2b). Although the three samples were penetrated by the fat sheet in the dough section, the level of penetration was different in each sample. The dough sheet in the dough sample with MG1 showed clearly defined limits, and the fat section included isolated starch granules. While the fat section of the sample with MG2 showed starch granules and proteins belonging to the edge of the dough sheet. The dough piece with MG3 presented the highest level of penetration. Micrographs of MG3 revealed a continuous starch phase throughout the fat section and a dough sheet with irregular edges. The dough pieces which showed the most orderly structures were produced with fats bearing a higher SFC and a viscous response (MG1 and MG2). Therefore, the more entangled structures of MG1 and MG2 did not allow a great penetration of the fat into the dough sheet.

The laminated dough pieces showed different behaviors when subjected to a great deformation. The MG1 sample

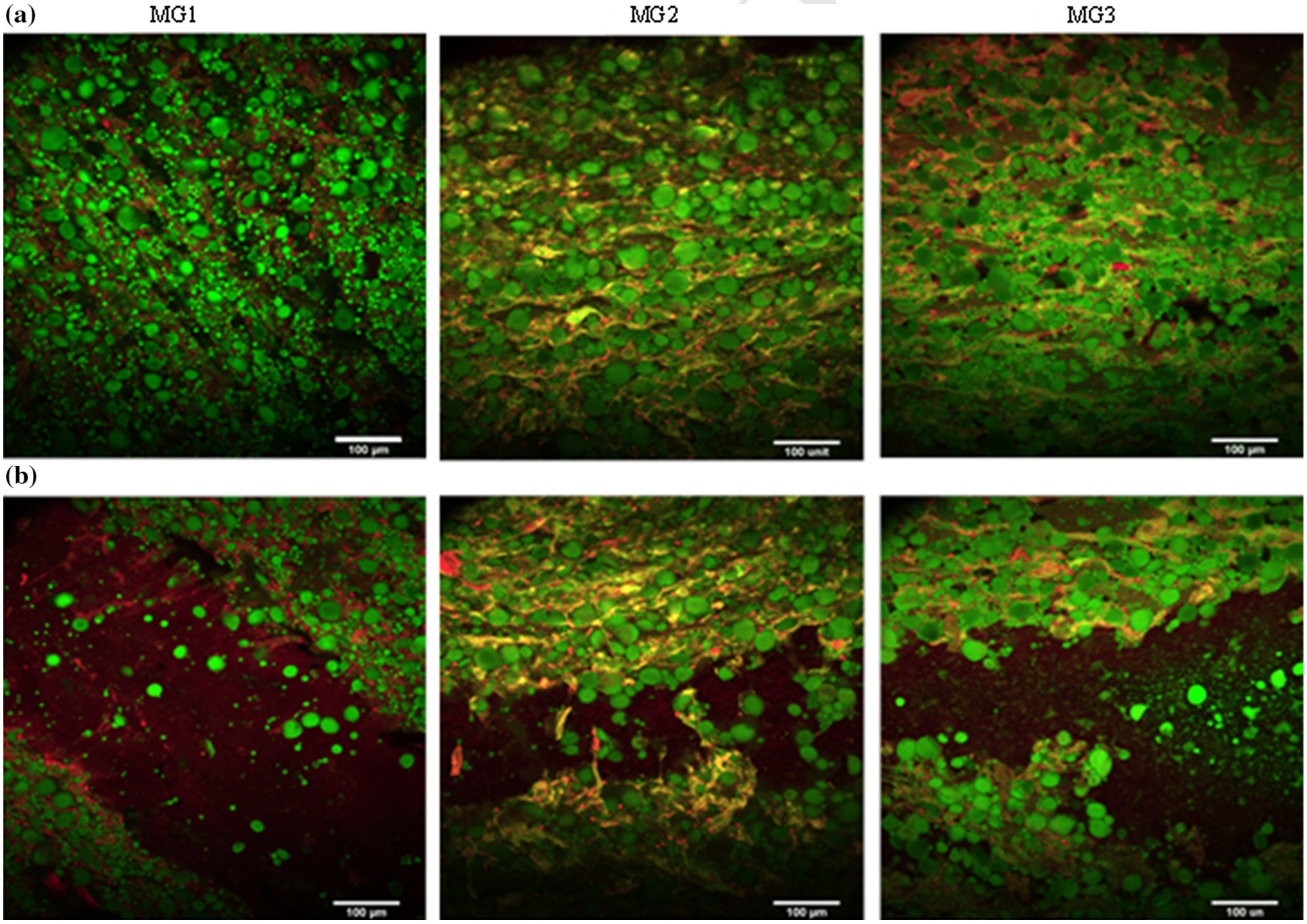

Fig. 2 Confocal microscopy of laminated dough pieces without fermentation. **a** Dough sheet section; **b** dough|fat|dough section. In *green*: starch granules; in *red*: protein; dark regions: fat

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proved to be more resistant to deformation (18.951 ± 2.368 N; $p < 0.05$) than MG2 and MG3 (12.259 ± 0.452 and 5.900 ± 0.002 N respectively; $p < 0.05$). Mamat and Hill (2012) also found that biscuit dough made with fat of higher solid content had higher breaking force. These results revealed that the structural characteristics of the fats were different and they influenced the capacity of the laminated system to withstand deformation. The laminated dough prepared with MG1 was least deformed during compression and the micrograph of the dough|fat|dough intersection revealed a more structured distribution of the components of the system. The viscous nature of MG1 prevented the flow and irruption of the fat during the formation of the laminated structure and its consequent alteration. On the other hand, MG3 with a greater gluten development in the dough layer was lesser resistance to deformation. These was related to a lesser viscous behavior, which produced a dough pieces with poorly stratified inner layers as a result of a higher flow capacity. The general behavior of the system when is subjected to a great deformation, like in the lamination step, is strongly influenced by the properties of the shortening layer and in a lesser extent to the fat contained in the dough layers. Lagendijk and van Dalfsen (1965) studied the inner structure of puff pastry dough samples made with margarine. The authors observed in dough pieces more resistant to extension a laminated inner structure, with some intersections points between fat and dough layers. While in dough samples with lower resistance to extension, they reported that sheeted structure was absent.

Physical and textural attributes of the baked product

The effect of shortening properties on the development of the laminated baked structure was assessed by the product elaboration and its quality evaluation. The lateral view of the products made with MG1 and MG2 revealed a laminated structure with horizontally aligned thin layers (Fig. 3b). The sample made with MG3 showed a layered structure with disruptions in some areas; the layers were less separated and a coarse, uneven stratum appeared in the upper section of the product. The upper view of the products revealed that samples made with MG1 and MG2 had maintained the desired shape, whereas products with MG3 had lost symmetry during the baking process.

In order to evaluate the magnitude of the vertical and horizontal growth of the dough pieces from the beginning of the fermentation to the end of the baking, the height and width ratios were determined (Fig. 3a). The products prepared with MG1 and MG2 showed the highest values for the height ratio and lower values for the width ratio in comparison with instead, MG3. Dough pieces with MG1and MG2 experienced a greater growth in vertical direction, while sample with MG3 expanded mainly in horizontal direction. The yeast-leavened laminated salty dough will keep its symmetry and shape, if during the

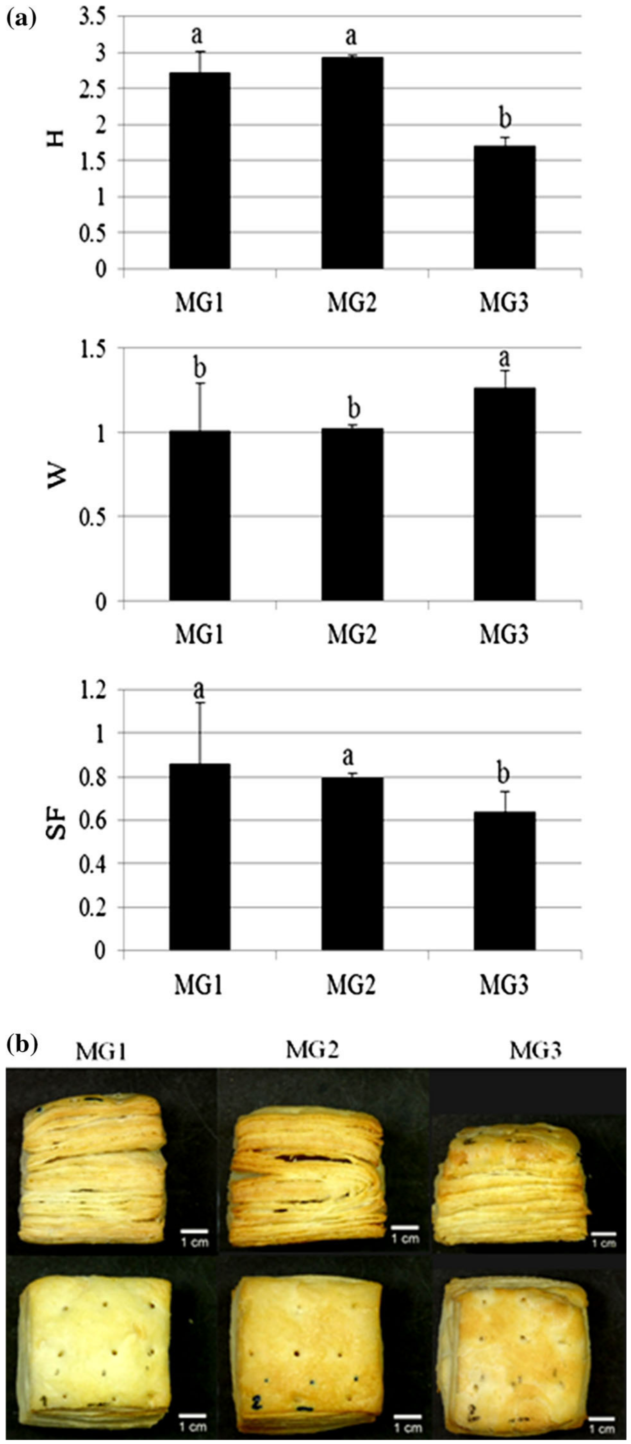

Fig. 3 Conformational evolution of the yeast-leavened laminated salty products. **a** H: height relationship; W: width relationship; SF: shape factor. Columns with a different letter are significantly different ($p \leq 0.05$). **b** Yeast-leavened laminated salty products elaborated with the three fat samples

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production process the lateral expansion is minimizing and the vertical growth is enhancing (de la Horra et al. 2015). The shape factor is a quality parameter which magnitude is determined by the three dimensions that characterize the baked product and is related with its symmetry. The products with MG1 and MG2 presented the highest values for the shape factor; these results can be associated with baked products bearing greater height values and lower width and length values than products with MG3. The baked products prepared with the fats showed no significantly different specific volume values (Table 2). Pimdit et al. (2008) did not report significant differences in the specific volume values of reduced-fat puff pastries.

The crust lightness of the yeast-leavened laminated salty products was significantly affected by fat. Products made with samples with higher SFC showed lighter crust (Table 2), with higher L* values, while when MG3 was used the crust obtained was lesser light. The samples showed positive values for a* and b* parameters. Products with MG3 showed crusts with the highest yellow and red intensities, followed by MG2 and MG1. Products with MG1 presented the highest value of firmness, followed by products with MG2 and MG3. This revealed that the structural properties of MG1 impart to the laminated structure a great capacity to resist against a deformation. Devi and Khatka (2016) highlighted that textural properties of cookies, baked products made from laminated dough, are significantly influenced by physical, chemical and rheological properties of fats and oils.

The texture image analysis of the cross-section images of the products was used to evaluate and quantify differences in the inner structure of the systems prepared with the three fats. Four textural features were used to describe the inner surface (Table 2). The images of the products with MG1 showed the highest contrast, which was attributed to greater local variations in the gray level values of the image pixels. No significant differences of contrast were detected between products made with MG2 and MG3. Homogeneity is a measure of the textural uniformity of the image (Arzate-Vázquez et al. 2012). The product with MG2 presented a more uniform inner surface than MG3 and MG1. The randomness of the intensity distribution in the image is measured through entropy. Products with MG1 presented the highest value of entropy, which was related to more complex images. No significantly different entropy values were found for MG2 and MG1 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). Products with MG3 showed the lowest values of fractal dimension, attributed to a lesser tortuosity inner surface due to the presence of pores. The

Table 2 Technological quality parameters and Friedman Test of yeast-leavened laminated salty products

Sample	L*	a*	b*	SV (cm^3)	Firmness (N)	Contrast	Homogeneity	Entropy	FD	Appearance		Odor		Flavor	
										Sum of ranks	Mean of ranks	Sum of ranks	Mean of ranks	Sum of ranks	Mean of ranks
MG1	71.8 ± 1.2a	5.1 ± 0.9b	31.5 ± 1.5b	3.4 ± 0.0a	44.0 ± 5.1a	68.9a	0.2c	7.7a	1.8a	188.5	2.22b	172.5	2.03a	180.5	2.12b
MG2	67.8 ± 1.2ab	8.6 ± 2.5ab	37.9 ± 1.2a	3.8 ± 0.7a	35.1 ± 4.3b	41.9b	0.4a	7.2b	1.8a	190.5	2.24b	178	2.09a	185.5	2.18b
MG3	63.2 ± 2.6b	12.5 ± 1.9a	41.2 ± 1.2a	3.8 ± 1.4a	20.3 ± 4.6c	44.5b	0.3b	7.0b	1.6b	131	1.54a	159.5	1.88a	144	1.69a

SV specific volume, *FD* fractal dimensionValues in each column followed by a different letter are significantly different ($p \leq 0.05$)

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samples with MG1 and MG2 showed higher values of fractal dimension, associated with a more complex arrangement of layers and pores of extended conformation, and with a greater morphological roughness. Farrera-Rebollo et al. (2011) observed that the inner structure of Danish pastry had a higher fractal dimension value than muffin and yeast-sweet bread, whose inner crumbs are characterized by the presence of pores instead of layers. The inner structure of the products was significantly affected when different fats were used. Products made from fats with a higher SFC, more entangled structures and a resultant more viscous behavior (MG1 and MG2) showed more complex structures with layers. Conversely, when a fat with a lower SFC and a higher destructuration rate under heat was used, the yeast-leavened structure was characterized by the presence of pores and a less complex surface.

Sensory evaluation of the baked product

The yeast-leavened laminated salty products elaborated with the three fats were subjected to an acceptability analysis. The products made with MG1 and MG2 obtained significantly higher values of average range for flavor and appearance than samples with MG3 (Table 2). This revealed that yeast-leavened laminated salty products with MG1 and MG2 were the most widely preferred in terms of flavor and appearance. No significant preferences were reported when assessing the samples in terms of odor. Baardseth et al. (1995) found that the roll-in shortening type used in Danish pastry had an influence on flavor and odor.

In the multiple discrimination test (Fig. 4), products with MG1 were found to be more symmetric than MG2 and MG3 ($p < 0.05$). There were significant differences in the level of crust flakiness. Products made with MG2 had crusts with higher flakiness than products with MG3 and MG1. When pore and sheet distribution in the inner structure was evaluated, MG3 proved to be the most uniform sample, followed by MG2 and MG1. Products with MG2 and MG1 showed higher values of lamination than MG3 ($p < 0.05$). This revealed that products with MG2 and MG1 had a laminated inner structure with more layers than MG3. There were no significant differences in the results for porosity levels, although pore content in the MG1 sample tended to be higher than in MG2 and MG3. Among the attributes evaluated by mouth manipulation, differences were detected for firmness of the product only. Samples with MG3 showed higher values of firmness than MG1 and MG2. According to the observed tendency, panelists had a higher fat perception during mastication of products with MG2 than when they tested the MG1 and MG3 samples. The sensory analysis revealed that the highest ranking samples in the acceptability analysis (products with MG1 and MG2) were symmetric and presented very flaky crusts; pore and sheet distribution was heterogeneous, with a higher level of lamination. The sensory analysis showed that symmetry and level of lamination may be considered positive attributes. The higher the symmetry and level of lamination, the better the quality of the baked product. Firmness and structure uniformity, instead, may be considered negative attributes. The lower the firmness and structure uniformity, the better the quality of yeast-leavened laminated salty products.

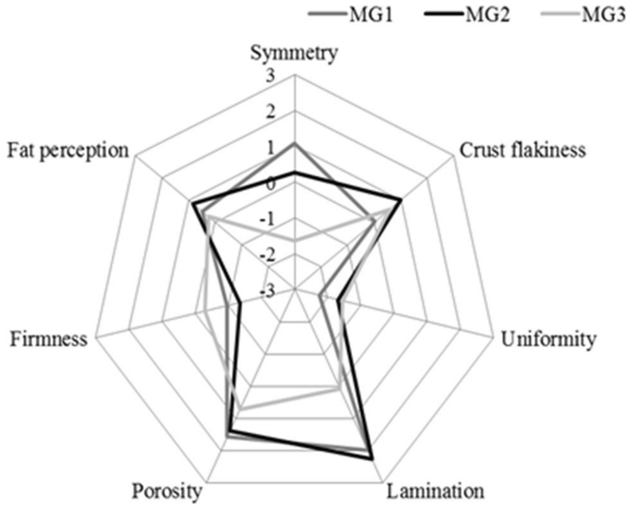

Fig. 4 Representation of the sensory attributes analyzed in the multiple discriminative test

Conclusions

Sensory, physical and textural attributes of yeast-leavened laminated salty baked products are related to the structural properties of the used fat. The fat solid content profile and the rheological behavior influenced the structure of the laminated dough system. Fats with a SFC over 20% at a temperature range of 15–35 °C (production and lamination processes) were more viscous and less sensitive to temperature changes. Consequently, the obtained dough pieces had a fat and dough layers structuration more regular and homogeneous, which prevented the collapse of the sheets during the production process. This rendered the system highly resistant to deformation and promoted vertical growth rather a lateral expansion, thus maintaining symmetry during the fermentation and baking processes. After the baking step the products were higher, with an inner crumb characterized by a tortuous surface due to the presence of layers. The products were the most widely preferred in the acceptability analysis and were mainly characterized by their symmetry and a more laminated inner structure.

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