Instrumental Assessment of Textural Parameters of Colombian Lemon Biscuits

José David Torres González, Ramiro Torres Gallo, Diofanor Acevedo Correa, Luis Alberto Gallo-García and Piedad Montero Castillo

Faculty of Engineering, Research Group Innovation Agricultural and Agroindustrial Development, University of Cartagena Av. El Consulado, St. 30 No. 48-152. Colombia

Department of Agroindustrial Engineering, School of Engineering University of Atlántico, km 07, Road to Puerto Colombia 232527 Atlántico, Colombia

Abstract

The objective of the research was to evaluate the textural parameters of biscuits from the municipality of Cereté (Cordoba, Colombia). The proximal composition of the samples was analyzed, unidirectional compression and three-point breaking tests were applied, using a texture analyzer, and a sensory evaluation was performed. A completely randomized experimental design and variance analysis were used to determine the influence of biscuit thickness on proximal, texture and sensual parameters. The thicker samples had lower moisture content; the thickness did not influence in protein, ash, fat, fiber, carbohydrates and calories content. The thicker biscuits had higher values of firmness, consistency, maximum strength and stiffness. There was a direct and highly significant correlation between firmness, consistency and fracturability. The thickness influenced the variation of texture parameters; these variations were explained by changes after heat treatment such as starch gelatinisation, protein denaturation and reduction of moisture content. The results coincided with those reported by other authors in cookies made from vegetable flours. The biscuits showed good sensory acceptance, the thicker ones had the best approval in hardness.

Keywords: Instrumental assessment; Textural parameters
1. Introduction

Texture is an important factor in food acceptability [1, 2, 3]. It includes a number of different physical sensations; although it is more convenient to use the term "textural parameters" [4]. Those which are the group of physical characteristics that depend on the structural elements of the material and are related to deformation, disintegration, flow by the application of a force and are objectively measured as a function of mass, time and distance [5].

According to Szczesniak [6], texture is "the mechanical, geometric and surface attribute set of a product that are perceptible by means of mechanical tactile, visual and auditory receptors". Texture parameters can be considered of great importance in food quality control [7]. Specifically, hardness in starch products indicates its freshness, while crispness gives information on its internal structure and compositional characteristics [8].

The determination of textural parameters in high carbohydrate food products is particularly difficult due to their heterogeneous composition and uneven structure [9]. Usually this type of food does not flow under pressure, but is fragile and brittle [10]. For the determination of instrumental textural parameters in this type of products, techniques such as compression and three-point crack test are used [7]; which are destructive techniques and are based on applying forces to the sample to obtain deductible graphical quantification derived from software installed in universal test sets and texturometers [3]. In these tests, the maximum force required to produce a breakage or total fracture of the product structure is evaluated, so at higher values of force it is understood that the greater the resistance of the food will be [7]. The three-point breakage test corresponds to bending tests, also known as a rupture bridge; in the food industry it is used to evaluate the hardness and fractureability of biscuits, chocolate bars and other starchy products [11]. Research by Mancebo et al., [12] evaluated the effect of the properties of gluten-free wheat flour and corn flour on the formulation of snap biscuits; these authors reported that particle size affected hardness, where thinner wheat flour biscuits required a significantly higher maximum strength than corn flour biscuits, the particle size being equal in both types of flour; this may be due to some functionality of wheat proteins compared to other types of proteins, which affects the texture of biscuits; cookie hardness is caused by the interaction of protein and starch by hydrogen bonds [13].

In the Colombian Caribbean Region there are several artisanal food products among them we find the lemon cookies, popularly known as hard biscuits; which are made with corn flour, water, milk, sugar, egg white, vegetable oil, cinnamon and lemon zest and are subjected to the baking process. Although lemon biscuits are characterized by high demand and are known, there are no scientific publications registered on their texture parameters being of vital importance from
the technological point of view. Therefore, the objective of this work was to evaluate through instrumental tests the texture parameters of lemon biscuits coming from the municipality of Cereté (Cordoba), analyze their proximal composition and evaluate them sensorially.

2. Methodology

2.1 Identification of inputs in the production of lemon biscuits

To know the procedure in the formulation of lemon biscuits, a family business was visited in the municipality of Cereté (Cordoba), it was observed that the ingredients used in the preparation of the biscuits were: corn flour, sugar, egg, lemon peel, milk, butter, cinnamon, and sodium bicarbonate. The biscuit formulation was diverse, but overall the proportion of water in the dough is low, and sugar and fat concentrations were high. Sugar competes with both starch and gluten to trap the small amount of water that is present [14].

2.2 Biscuit preparation in the family business

First, the corn flour, butter and sugar were mixed in a homogeneous way; then lemon peel, egg, cinnamon and sodium bicarbonate were added, immediately it was added milk until to give consistency to the dough. Once this was obtained, molds were made in circular shapes of 5 cm in diameter to the biscuits. It is then baked in a conventional oven at 150 to 160 °C for 15 to 25 min. The biscuits were left to rest to be packed in plastic bags and marketed immediately. Table 1 shows the formulation used to make the lemon biscuits in the family business.

Table 1. Formulation of the biscuits made in the family business

<table>
<thead>
<tr>
<th></th>
<th>(%)</th>
<th>Amount (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn flour</td>
<td>80.00</td>
<td>1000</td>
</tr>
<tr>
<td>Water</td>
<td>5.00</td>
<td>62.5</td>
</tr>
<tr>
<td>Cow milk</td>
<td>10.00</td>
<td>125</td>
</tr>
<tr>
<td>Common sugar</td>
<td>2.00</td>
<td>25.0</td>
</tr>
<tr>
<td>Egg white</td>
<td>2.00</td>
<td>25.0</td>
</tr>
<tr>
<td>Vegetal oil</td>
<td>0.50</td>
<td>6.3</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>0.20</td>
<td>2.5</td>
</tr>
<tr>
<td>Grated lemon</td>
<td>0.15</td>
<td>1.9</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>0.15</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>1250</strong></td>
</tr>
</tbody>
</table>

2.3 Obtaining of the product

The baked lemon biscuits were purchased from small family businesses in the local market of the municipality of Cereté (Cordoba), considering that the minimum
hygienic and sanitary requirements were met and that the biscuits were packaged in sealed plastic bags of 25 units as sold by the vendors. To carry out the respective analyses, in this work, six whole bags were purchased for a total of 150 biscuits.

2.4 Bromatological analysis of biscuit samples

Biscuits samples were kept at 15°C. The methodology of the Official Association of Analytical Chemistry was followed (AOAC) [15] where moisture was determined by kiln drying to constant weight (934.01); ashes by total incineration at 550 °C (942.05); total proteins by the Kjeldahl method, using a factor N = 6.25 (990.03), fat content using ether petroleum as a solvent in Soxhlet extraction equipment (920.39); total dietary fibre would be dietary fiber by enzymatic-gravimetric method with amylase, protease and amyloglycosidase, by successive treatments (991.43) and carbohydrates by difference.

The caloric value was calculated considering the coefficients of 4 kcal/g for carbohydrates and proteins, 2 kcal/g for dietary fibre and 9 kcal/g for fats. A fully randomized uniform factorial experimental design (CAD) was used and a variance analysis (ANOVA) was applied to analyze the effect of biscuit thickness on proximal composition variation.

2.5 Texture tests

Whole samples of lemon biscuits were subjected to a unidirectional compression test to measure fracturability parameters: force at which the food started to break (kg. m\(^2\) s\(^{-2}\)); and hardness: maximum force at which the product completely broke (kg. m\(^2\) s\(^{-2}\)). A TA. TX2i\({\text{®}}\) texture analyzer was used. Plus, Stable Micro System, coupled with the Texture Expert Exceed version 2.64 software; equipped with an aluminum platform on which the samples were placed, with a load cell of up to 500 N; the process speed was determined by means of previous tests and set at 5 mm/sec.

2.6 Three-point breaking test

The test was made in whole lemon biscuits, using a texture analyzer; this is shown in Figure 1. The samples were placed on two parallel vertical supports, with rounded edges to minimize the tensions caused during the tests, separated at a distance of 4 cm; they were chosen in previous tests, taking into account the biscuit diameters; a third parallel axis moved vertically, at a previously set speed of 5 mm/s, exerting a force until a total break in the structure of the lemon crackers occurred. The textural parameters were determined from the force-time curves: firmness (F), maximum point of the linear section of the curve; consistency (g. s), area under the curve in the force-time graph; distance (mm), at which the product was displaced in each test; rigidity (N mm\(^{-1}\)), F\(_{\text{max}}\) / distance; maximum rupture deformation (N mm\(^{2}\)), stiffness/initial height.
2.7 Experimental and design

Unidirectional compression and three-point breaking tests used a fully random (cookie thickness) all-random (DCA) unifactor design, with four levels (4 mm, 6 mm, 8 mm and 10 mm) and nine repetitions, for a total of 36 experimental units in each type of test. A variance analysis (ANOVA) and Tukey's HSD test were performed, with a significance level of 5 %, to determine the influence of biscuit thickness on texture parameters. In addition, a correlation was made from the r-Pearson test between each of the instrumental texture parameters. The correlation was considered highly significant at the level of 0.01 (bilateral). Data were processed using the Minitab Inc. statistical program® version 16.0, on a personal computer.

2.8 Sensory analysis of lemon biscuits samples

The tests were conducted with 15 untrained panelists in a suitable room with adequate light and moisture. A 5-point preferential hedonic scale (5 = excellent, 4 = good, 3 = neutral, 2 = regular, 1 = bad) was used to evaluate the product for odour, colour, taste and hardness. A completely randomized experimental design, where a variance analysis (ANOVA) was applied, was used to assess the effect of sample thickness on specimen acceptability. Data were collected on a spreadsheet, then transformed into numerical scores for analysis.

3. Results

3.1 Proximal composition of biscuit samples

Table 2 shows the proximal analysis of the biscuits, taking into account their thickness, comparing them with a sample of commercial biscuit made from 100 % wheat flour (used as a standard).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>4 mm</th>
<th>6 mm</th>
<th>8 mm</th>
<th>10 mm</th>
<th>7 mm</th>
<th>p-valor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>9.55±1.02a</td>
<td>8.75±1.05ab</td>
<td>8.41±1.07ab</td>
<td>8.18±0.66b</td>
<td>8.11±1.19b</td>
<td>p=0.02&lt;0.05</td>
</tr>
<tr>
<td>Ash</td>
<td>1.56±0.62a</td>
<td>1.98±0.54a</td>
<td>1.92±0.63a</td>
<td>1.97±0.70a</td>
<td>2.05±0.62a</td>
<td>p=0.88&gt;0.05</td>
</tr>
<tr>
<td>Protein</td>
<td>7.19±1.05a</td>
<td>7.16±0.56a</td>
<td>7.21±0.67a</td>
<td>6.89±0.60a</td>
<td>7.15±0.64a</td>
<td>p=0.97&gt;0.05</td>
</tr>
<tr>
<td>Fat</td>
<td>8.23±0.25a</td>
<td>8.14±0.23a</td>
<td>8.38±0.17a</td>
<td>8.52±0.30a</td>
<td>8.68±0.51a</td>
<td>p=1.83&gt;0.05</td>
</tr>
<tr>
<td>Fibre Crude</td>
<td>3.54±0.12a</td>
<td>3.48±0.04a</td>
<td>3.52±0.13a</td>
<td>3.37±0.10a</td>
<td>2.96±1.13a</td>
<td>p=2.55&gt;0.05</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>70.03±2.39a</td>
<td>70.49±2.43a</td>
<td>70.56±2.34a</td>
<td>71.07±3.39a</td>
<td>71.41±2.67a</td>
<td>p=1.77&gt;0.05</td>
</tr>
<tr>
<td>Caloric (Kcal)</td>
<td>343.67±5.69</td>
<td>345.87±6.32</td>
<td>348.79±6.26</td>
<td>359.42±4.46</td>
<td>442.43±2.2b</td>
<td>P=0.04 &lt; 0.05</td>
</tr>
</tbody>
</table>
About moisture, it was observed that it was higher in the samples of lower thickness, presenting statistically significant differences (p<0.05) in the samples of 4 mm, compared to those of 10 mm and commercial samples. This probably influenced the lower hardness of these biscuits, as the water molecules being present in the food matrix possibly caused a softening and softening of the structure.

Samples of biscuits showed a low-fat content, similar to the commercial one; that is, between rows there was no statistically significant difference in the different thicknesses (p>0.05). Results that coincided with those reported by Chim et al., [16], who formulated biscuits with low fat content; noting that this characteristic is of importance not only from the point of view of preservation of the product, due to the lower tendency to oxidative rancidity during the storage period, but also in processing, considering that the low fat content favors the formation of an adequate texture in baked biscuits. These results do not coincide with those presented by Rebolledo et al., [17], where fat presented a value of 21.01%, while Cori and Pacheco [18] found fat values of 16.90% in sweet biscuits based on wheat flour and sunflower flour. Maldonado and Pacheco [19] reported fat values of 9.42% in biscuits with a mixture of wheat flour and green banana; Garcia and Pacheco [20] also found fat values of 0.56%, evidently lower than those obtained in this study.

In the protein content there were no statistically significant differences between the biscuit samples, taking into account the thickness (p>0.05), so it is inferred that the processing to which this product is subjected does not affect the amount of protein. The average protein values of the biscuits in this work were basically contributed by the incorporation of whole milk into the formulation, rather than by the contribution of egg yolks or cornmeal. These results were similar to those obtained by Rebolledo et al., [17], which reported 12.7% protein, while Maldonado and Pacheco [20] found a protein percentage of 9.68%, while Cori and Pacheco [18], in sweet biscuits, reported a protein content of 9.35%; while Roman and Valencia (2006) found values of 8.15%; Garcia and Pacheco [20] obtained 4.38% protein, which are below those recorded in the present investigation.

In the protein content there were no statistically significant differences between the biscuit samples, taking into account the thickness (p>0.05), so it is inferred that the processing to which this product is subjected does not affect the amount of protein. The average protein values of the biscuits in this work were basically contributed by the incorporation of whole milk into the formulation, rather than by the contribution of egg yolks or cornmeal. These results were similar to those obtained by Rebolledo et al., [17], who reported 12.7% protein, while Maldonado and Pacheco [19] found a protein percentage of 9.68%, while Cori and Pacheco [18], in cookies, reported a protein content of 9.35%; while Roman and Valencia [21] found values of 8.15%; García and Pacheco [20] obtained 4.38% protein, which are below those recorded in the present investigation.
Badui [22], affirms that the importance of proteins in food systems is due to nutritional properties since their components are obtained from nitrogenous molecules that allow the structure and growth of the consumer to be preserved. They can also be ingredients of food products that, due to their functional properties, help to establish the structure and final properties of the food. In relation to the above, it is evident that the biscuits in this paper are an important source of protein; therefore, they can be consumed on a regular basis by those who lack these nutrients.

As for the ash content of biscuits, there were no statistically significant differences between the different thicknesses, similar to that reported in the literature for biscuits made from wheat flour and other cereals [23]. These coincide with those registered by Maldonado and Pacheco [19], with a percentage of 2.69%, in wheat flour biscuits and green bananas, and with those of Cori and Pacheco [18] who found 1.47% in sweet biscuits with wheat flour and sunflower. Garcia and Pacheco [20] recorded values of 0.86% ash. From a nutritional point of view, it was observed that the formulation under study had a mineral content similar to that of commercial biscuits made from 100% wheat flour. At the processing level, this content favours functional changes because minerals can slow down the gelatinisation and retrogradation of starch [19]. Raw dietary fiber in biscuits was in the range of 3.37 to 3.54%, relatively higher than those reported for the standard sample of wheat flour 2.96%. Research indicates that fiber has several implications for cookie making. On the one hand, given its influence on viscosity and dough requirements for biscuit formation and texture during baking, a higher fibre content in cereal flour tends to vary rheological properties by increasing water absorption, thickening and reducing mass volume, as evidenced by Pacheco and Testa [24] in a formulation for biscuits with flour composed of green banana and wheat, as found by Villarroel et al., [25], in the formulation of fiber-enriched bakery products.

On the other hand, the contribution of fiber can have positive effects on the well-being of consumer health by its intervention in the processes of constipation control, improved control of blood glucose, protection against colon cancer, lower risk of cardiovascular disease [26]. Other studies suggest that dietary fiber intake of 20 to 35 grams per day in children, adolescents and adults may decrease the risk of digestive system-related health problems [26]. Garcia and Pacheco [20] found a dietary fiber percentage of 3.09%, while Cori and Pacheco [18] recorded a value of 3.95% in dietary fiber present in wheat biscuits supplemented with sunflower flour. This study showed that an increase in thickness led to a higher carbohydrate content, although it was not statistically significant (p>0.05). These results were higher to those reported by Rebolledo et al., [17], which recorded values of 49.8% of soluble carbohydrates in sweet biscuits enriched with corn germ. Commercial biscuits in this paper had higher caloric value because they were possibly made from wheat flour with higher carbohydrate content.
3.2 Texture testing of biscuit samples

Table 3 shows the variance analysis of the texture parameters of the biscuits. The 10 mm thick samples showed greater firmness and consistency. For the fracturability data, these showed that 4mm thick biscuits required less breaking strength. In addition, it was observed that the 10 mm thick lemon biscuits had the highest hardness and the highest stiffness. This indicates that the thickness in this foodstuff does have a significant influence on the resistance of external loads and forces (p<0.05).

Table 3. Variance analysis of the textural parameters of lemon biscuits

<table>
<thead>
<tr>
<th>Texture parameters</th>
<th>Biscuit thickness</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 mm</td>
<td>6 mm</td>
</tr>
<tr>
<td>Firmness (g)</td>
<td>6900.95±1450</td>
<td>10826.91</td>
</tr>
<tr>
<td></td>
<td>±36a</td>
<td>±1332.02b</td>
</tr>
<tr>
<td>Consistency (g*s)</td>
<td>5744.35±1790</td>
<td>8609.18±1152.7</td>
</tr>
<tr>
<td></td>
<td>±0.24a</td>
<td>96b</td>
</tr>
<tr>
<td>Fracturability (N)</td>
<td>3.58 ±0.86a</td>
<td>5.55 ±0.54b</td>
</tr>
<tr>
<td>Maximum strength (N)</td>
<td>6.97 ±1.38a</td>
<td>10.94 ±1.27b</td>
</tr>
<tr>
<td>Stiffness (N/mm)</td>
<td>3.78 ±0.79a</td>
<td>5.93 ±0.73b</td>
</tr>
<tr>
<td>Breaking deformation (N/mm²)</td>
<td>0.94 ±0.19a</td>
<td>0.98 ±0.12a</td>
</tr>
</tbody>
</table>

Analysis of variances showed that the product thickness had a significant effect (p<0.05) on firmness, consistency, fracturability, maximum strength and stiffness, meanwhile rupture deformation had no significant effect (p>0.05) and maximum values were observed at levels 2 and 3, while minimum values were observed at the thickest product. Baked biscuits are most often tender and crunchy because little or no gelatinization of starch and sugar is produced [14].

Figures 1, 2, 3, 4, 5, and 6 outline the behaviour of each of the textural parameters v. the thickness of the lemon biscuits. It was observed that in firmness, maximum strength (hardness) and stiffness there was a similar trend, i.e. an increase proportional to the thickness of the sample; being the biscuits of 10 mm which presented, in all cases, the highest values, while showing a similar dispersion. On the other hand, the behaviour of consistency and fracturability were similar to those previously mentioned, i.e. higher in biscuits 10 mm thick, although more dispersion was observed in the data with respect to averages when comparing box sizes. Regarding the deformation, there was a great dispersion of the values, especially in the 4 mm thick biscuits, where it was observed that some samples
required less force per unit area to be deformed; but in general there was no definite tendency as to the influence of thickness on this textural parameter. The textural characteristics of lemon biscuits can be attributed to the manufacturing process, baking, the ingredients used during the preparation of the biscuits and the variation in the proximal composition, especially the moisture of the samples. Data on the hardness, fracturability and firmness of the lemon biscuit samples indicated a good degree of freshness of the product, while consistency evidenced information on the internal structure of baked biscuits [8]. Other studies have reported cutting stress values of 38.41 N on average for biscuits made with black skipjack (*Euthynnus Lineatus*), being lower when the samples contained a lower protein content and a higher proportion of lipids [27].

Figure 1. Firmness vs. biscuit thickness  
Figure 2. Consistency v. biscuits thickness.  
Figure 3. Fracturability vs. biscuit thickness  
Figure 4. Maximum strength vs. biscuit thickness  
Figure 5. Stiffness vs. biscuit thickness  
Figure 6. Breaking deformation vs. biscuit thickness
In table 4, the correlations made between the texture parameters of the lemon biscuits are outlined. It was observed that between firmness, consistency, fracturability and maximum strength (hardness) there was a direct and highly significant correlation (p<0.01). Between stiffness with firmness, consistency, fracturability and maximum strength (hardness) there was a slight direct correlation, but not statistically significant (p>0.05).

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Firmness (g)</th>
<th>Consistency (g*s)</th>
<th>Fracturability (N)</th>
<th>Maximum strength (N)</th>
<th>Stiffness (N/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firmness (g)</td>
<td>r-Pearson 1</td>
<td>p-valor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistency (g*s)</td>
<td>r-Pearson 0.933**</td>
<td>p-valor 0.010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracturability (N)</td>
<td>r-Pearson 0.973**</td>
<td>0.983**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum strength (N)</td>
<td>p-valor 0.001</td>
<td>0.000</td>
<td>0.983**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Stiffness (N/mm)</td>
<td>r-Pearson 0.432</td>
<td>0.565</td>
<td>0.405</td>
<td>0.232</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>p-valor 0.356</td>
<td>0.210</td>
<td>0.344</td>
<td>0.335</td>
<td></td>
</tr>
</tbody>
</table>

The rupture deformation data were not considered in the correlations, since as found the thickness of the samples of lemon crackers did not influence this textural parameter. The lemon biscuits, being a baked product, had a structure with little moisture which made them very resistant, hard, rigid and compact. Similar results were found Gani et al., [28], in baked biscuits, which indicated that among the factors that most contributed to and influenced the textural parameters were gelatinisation of starches, reduction of moisture content of the product during heat treatment, denaturation of proteins and crystallization of sugar at baking temperature. In figures 7, 8, 9, and 10, the behaviour of a random sample of lemon cracker for each thickness was observed in detail during the respective three-point cracking tests. Thus, the highest peaks were in the thickest samples, while the highest consistency was found in the 8 mm biscuit sample.
Velásquez et al., [29], state that one of the most representative characteristics that a flour for biscuit making must have is that of being very extensible for processes without fermentation. This parameter can be measured in laboratories and industries with robust equipment, but under practical conditions it is proposed to
use a usual methodology in gels (linear extension), as a reference linked to texture, which should be measured because replacing wheat flour with other flour can obtain biscuits with better texture. Bastardo et al., [30] indicated that the retrogradation and gelatinisation of cornstarch starch increased the stiffness, firmness and consistency of the biscuits; this may explain the increase of these textural parameters in baked lemon biscuits of different thicknesses in the present investigation. In accordance with these results, De Simas et al., [31] evaluated instrumental hardness in baked biscuits and found that samples with higher moisture content were more easily fractured, while those with lower moisture content were harder.

In this work, variability was found in the rupture deformation data, especially in biscuits with a thickness of 4 mm, where different maximum points within the curve of the texture analyzer were observed. This was mainly attributed to the irregularity of the surface of the samples whose diameter ranged between 4 and 6 cm, as well as to the air content inside the structure of the product, which possibly opposed a partial resistance to the forces exerted on the respective biscuits and produced important fluctuations in the graphs corresponding to the results of the texture measurements. Similar results were reported by Park et al., [32], who found that the error and variability of data in the textural parameters of fermented and baked biscuits was mainly related to air pockets present in the internal structure of the products; they also pointed out that if during the fracture tests the force exerted on the samples is not appropriate and if it is not exerted on the central part of the product, this may lead to biscuits experiencing inadequate breaking, leading to a greater dispersion of values in the textural parameters calculated in the universal test kits. Duta and Culetul [33] evaluated the rheological, physico-chemical, thermal and mechanical properties of gluten-free oatmeal biscuits with an oat bran (OB) share of 30, 50, 70 and 100%. Regarding texture measurements, biscuits prepared with 100% OB showed less hardness than other formulations, while those with less OB did not show statistically significant differences in relation to control.

The control structure was more compact and homogeneous due to the higher proportion of smaller porridge fractions; both types of biscuits showed less breaking strength compared to control. Reduced hardness could be attributed to structural deformation of starch and germination-induced protein. The degradation of macromolecules contributed to the formation of a weaker matrix in the biscuit resulting in a softer texture, results that were similar to those found by Chung et al., [34].
3.3 Sensory analysis of biscuit samples

Table 5 shows the average data from the sensory tests on the biscuit samples and compares them to a commercial 100% wheat flour commercial.

**Table 5.** Sensory analysis of lemon biscuit samples from a commercial sample

<table>
<thead>
<tr>
<th>Biscuit thickness</th>
<th>Color</th>
<th>Odor</th>
<th>Taste</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 mm</td>
<td>3.57±1.09a</td>
<td>3.43±0.97a</td>
<td>4.14±0.38a</td>
<td>3.14±0.21a</td>
</tr>
<tr>
<td>6 mm</td>
<td>3.71±0.75a</td>
<td>3.58±0.78a</td>
<td>4.29±0.34a</td>
<td>3.57±0.92a</td>
</tr>
<tr>
<td>8 mm</td>
<td>3.86±0.89a</td>
<td>3.75±0.75ab</td>
<td>4.43±0.77ab</td>
<td>3.71±0.11a</td>
</tr>
<tr>
<td>10 mm</td>
<td>4.15±0.69ab</td>
<td>4.04±0.37ab</td>
<td>4.58±0.53ab</td>
<td>4.57±0.54b</td>
</tr>
<tr>
<td>Commercial (7 mm)</td>
<td>4.67±0.52b</td>
<td>4.62±0.71b</td>
<td>4.74±0.48b</td>
<td>4.66±0.83b</td>
</tr>
</tbody>
</table>

It can be seen that there was a good acceptance for the characteristics of colour, smell, taste and hardness, exceeding the minimum threshold of 3.0. Therefore, it is inferred that the baking process did not significantly affect these characteristics of cornmeal biscuits. In general the panelists indicated that the color, smell, taste, were better in the samples of greater thickness, that is to say those of 10 mm. Likewise, in terms of hardness, statistically significant differences were observed (p<0.05) given that panelists pointed out that it was better in the 10 mm samples; this was possibly caused by the lower water content in these samples and a higher content of solids such as carbohydrates.

Similar results to those found in this work were reported by Bello et al., [35] during sensory evaluation of two types of biscuits made from banana starch, as found by Canett et al., [36] during the sensory characterization of crackers made from grape marc husk. While Cori and Pacheco [18] also sensory evaluated sweet wafer-like biscuits with defatted sunflower flour and found good acceptability in terms of odor, color, flavor and hardness parameters. Along the same lines, Garcia and Pacheco [20] sensorially evaluated several formulations of wafer biscuits based on Arracacha flour and compared it to a standard made with commercial wheat flour. These authors indicated that the new formulations were pleasantly perceived in terms of smell, colour and taste by the panelists consulted. These authors reported that the use of Arracacha flour in a ratio of 12% was an appropriate ingredient in the production of biscuits with high sensory preferences, constituting a food alternative.

4. Conclusions

Thicker samples had lower moisture content. The thickness did not influence the content of protein, ash, fat, fiber, carbohydrates and calorie intake. The thickest
biscuits had the highest values of firmness, consistency, billability, maximum strength and rigidity. There was a direct and highly significant correlation between firmness, consistency, fracturability and maximum strength. The thickness of the samples significantly influenced the variation in texture parameters of baked lemon biscuits. Variations were explained from product changes after baking heat treatment such as starch gelatinisation, protein denaturation and reduced moisture content. The biscuits showed good acceptance in terms of smell, taste and colour characteristics, exceeding the minimum threshold of 3.0 on the scale used. The thicker samples presented the best sensory approval by the panelists, especially in hardness.

References


Instrumental assessment of textural parameters


https://doi.org/10.1590/s0101-20612009000100011


https://doi.org/10.1016/j.meatsci.2014.05.003

https://doi.org/10.4067/s0718-07642011000300003

https://doi.org/10.1016/j.lwt.2015.05.057

https://doi.org/10.1016/j.fbp.2010.07.005


https://doi.org/10.1002/0471740039.vec0284


[27] K. Delgado-Vidal, E.D. Ramirez-Rivera, J. Rodríguez-Miranda, R.E. Martínez-López, Elaboración de galletas enriquecidas con barrilete negro (euthynnus lineatus): caracterización química, instrumental y sensorial,
Instrumental assessment of textural parameters


[29] L. Velásquez, V. Aredo, Y. Caipo, E. Paredes, Optimización por diseño de mezclas de la aceptabilidad de una galleta enriquecida con quinua (Chenopodium quinoa), soya (Glycine max) y cacao (Theobroma cacao L.), Agroindustrial Science, 4 (2014), no. 1, 35-42.


[32] J. Park, I. Choi, Y. Kim, Cookies formulated from fresh okara using starch, soy flour and hydroxypropyl methylcellulose have high quality and nutritional value, LWT-Food Science and Technology, 63 (2015), no. 1, 660-666. https://doi.org/10.1016/j.lwt.2015.03.110


Received: March 23, 2018; Published: April 24, 2018