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ANALYSIS OF TEXTURAL PROPERTIES OF GLUTEN FREE BREADS

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Abstract

Bread is one of the most important gluten-free foods, and it is usually connected with crumbling texture, poor colour, low volume, unsatisfactory taste and a short shelf-life, probably due to the lack of the viscosity network formed by gluten. Thus, some defects of gluten-free bread are related with inefficient gas retention and expansion during dough leavening, which results in a reduced volume and low crumb softness of the breads. The current challenge is for the industry to overcome these limitations. Furthermore, the texture is a characteristic that depends on the structure of the food, but also on the complex oral manipulation that aims to grind the food. In the present work the textural properties were analysed in breads made with special flours without gluten produced industrially, and the reproducibility of the results between breads from different batches was also evaluated.

Two formulations of gluten-free flour were tested, provided by Germen (Portugal) (designated as A) and Credin (Denmark) (designated as B), and were also produced samples of bread with wheat flour type 65 (sample called Control), produced by CEREALIS (Portugal) - designated as A, B and Control samples, respectively. For analysis of the textural characteristics, a texturometer was used and perforation and compression tests were performed. The properties measured by the perforation test were: crust firmness, crumb firmness, adhesiveness, and stickiness. In the compression test, the characteristics evaluated were: hardness, elasticity, cohesiveness, resilience and chewiness. To evaluate the reproducibility, the breads were produced in four different batches, for each type of bread (A, B and Control), to assess whether the characteristics were maintained on the different days of manufacture.

The results obtained for the perforation test showed that the loaves produced with gluten-free flours are less firm (in the crust and in the crumbs) and less adhesives when compared to bread made with type 65 flour (with gluten). Regarding stickiness, it can be said that there are not many apparent differences between the breads analysed, however bread B is more similar to Control bread. Bread A has a greater discrepancy between the top and the bottom in terms of stickiness, being more intense on the top of the bread. The compression tests showed that in the crumb the values are identical in all studied samples, including the control sample. However, when analysing the complete slice, it appears that samples A and B are considerably less hard than the Control, due to the crust contribution. The gluten-free breads presented lower resilience than the Control sample, with Sample B showing the highest concordance between the crumb and the complete slice. Moreover, the results showed both gluten-free breads had similar elasticity and chewiness values, both for the crumb and for the whole slices, and higher than the wheat bread. Regarding the reproducibility of the results, it was possible to observe that the perforation tests are preferable to those of compression, and that on the other hand the samples made with the flour without gluten type B are more uniform between batches.

The results obtained in this study showed that the type of flour, its composition and the presence or absence of gluten significantly influence the texture of the breads produced. Breads made with gluten-free flours were less firm on the crust and crumbs when compared to wheat bread. On the other hand, gluten-free breads tend to be less sticky and slimy. Moreover, the two tests to evaluate the texture proved to be complementary, since they allow to evaluate different characteristics, and thus obtain a more complete profile of textural characteristics of the breads. The reproducibility of the results was higher for perforation tests compared to compression tests, and on the other hand the samples manufactured with type B gluten-free flour showed to be more constant in their texture characteristics, when different batches of bread were compared.

Key words: *Flour, Gluten free, Bread, Texture analysis, Compression test, Perforation test.*

1. Introduction

Bread is one of the most consumed foods in the world. It is considered of high nutritional value, as it is rich in starch and has an important supply of proteins, in addition to containing some components beneficial to health, such as phenolic compounds, phytic acid and dietary fiber [1]. Nowadays, consumers are more aware of the benefits of healthy eating, with the aim of improving their quality of life, and therefore are more demanding about food nutrients and their functionality [2]. Euromonitor International [3], through the Global Consumer Trends Survey report, showed that consumers prefer foods whose labels show that the food contains added vitamins or fibers.

Wheat (*Triticum aestivum* L.) is commonly used in the manufacture of bread, and is one of the main constituents of the human diet, due to its nutritional and functional properties. Gluten proteins are recognized as one of the crucial components that determine the quality of bread and many of its properties [4]. However, gluten is an important allergen, and many people cannot consume it, even when in small amounts.

Celiac disease (CD) is an autoimmune enteropathy that causes damage to the mucosa of the small intestine when gluten, present in wheat, is ingested. This condition occurs in genetically susceptible individuals. The innate, adaptive and autoimmune sensitivity to gluten is crucial in the development of CD [5]. Gluten-free products have been the target of increasing demand, due to the increasing incidence of CD or other allergies associated with gluten. Thus, the replacement of gluten becomes a necessity in order to avoid the occurrence of such pathologies. The elimination of gluten, however, is associated with an important technological challenge, since while it aims to minimize the prevalence of any disease-causing factor, nonetheless can give rise to products with a possible compromised quality. It is, therefore, imperative to try to adopt methods that can produce gluten-free cereal products with technological properties comparable to their gluten-containing counterparts, while at the same time with minimal commitments in terms of quality. Thus, the replacement of gluten becomes a necessity in order to avoid the occurrence of such pathologies [6].

Chewing aims at preparing solid foods for swallowing and subsequent digestion, and it is also essential for sensory perception, including the perception of texture, which is dynamic. This results from the continuous perception of changes in food properties through oral mechanoreceptors, as well as from the strength and position of the jaws. The texture depends on the structure of the food, but also on the complex oral manipulation that aims to grind the food [7, 8].

Taking in consideration the previous comments, the objectives of this work were to analyse the texture of breads made with special gluten-free flours and compare them with a control sample containing gluten, as well as to evaluate the reproducibility of textural properties between the different breads produced in different batches.

2. Materials and Methods

2.1 Flour samples

Two new formulations of gluten-free flour were tested for bread production. Flours were supplied by the companies Germen (Portugal) and Credin (Denmark). The flour formulations used were as follows:

- Credin: wheat starch (gluten free), potato starch, rice flour, dextrose, psyllium fiber, fermented and dehydrated rice flour, salt, thickeners (E412, E415), emulsifier (E464), acidity regulator (E263) and enzymes.

- Germen: starch (gluten free), rice flour, sugars, potato protein, thickeners (E415, E412), emulsifiers (E464, E472e, e471), salt, locust bean flour and antioxidant (E330).

The proportion or quantity of each ingredient is not shown for reasons of industrial confidentiality. A common wheat bread was also produced using a type 65 wheat flour, which was produced by the company Cerealis (Portugal).

The codes of the breads manufactured are A, B and Control, respectively for the flours produced by the companies Credin, Germen and Cerealis.

2.2 Bread production

The quantities of the ingredients used in the production of all the breads studied are shown in Table 1.

Table 1. Amount of ingredients used in bread production: A, B and Control

Ingredients	Amounts (kg)		
	A	B	Control
Flour	5	5	5
Vegetable oil	0.25	0.25	0.25
Yeasts	0.25	0.25	0.25
Water	3.75	3.75	3.75
Propionate	0.035	-	-
Ascorbic acid	0.010	-	-
Bread flavor	0.010	-	-

2.3 Texture evaluation

To analyse the texture characteristics, a TA-XT2 texturometer (Stable Microsystems, UK) was used. A perforation and a compression test were performed (Figure 1). The analyses were carried out the day after the bread was baked.

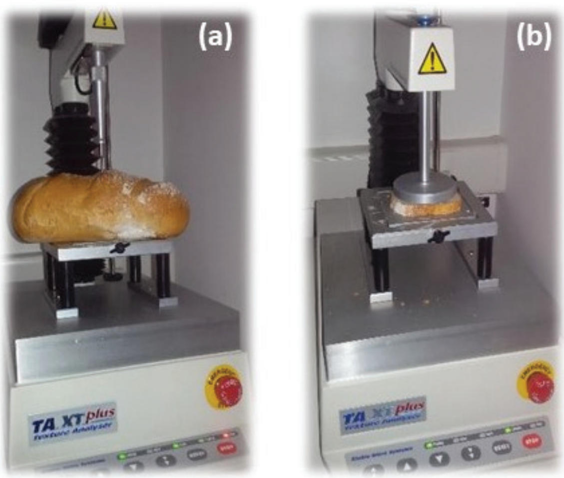

Figure 1. Texture analysis: (a) Perforation test; (b) Compression test

For the perforation test, a 2 mm diameter drilling probe was used. In this test, whole loaves were used, with 12 perforations distributed over the upper and lower sides of the bread. The test conditions were as follows: pre-test speed of 2 mm/s; post-test speeds of 1 mm/s; perforation distance 20 mm; trigger force of 0.1 N. The properties measured with this test were: Crust firmness (strength at the highest peak); Crumb firmness (average threshold strength); Adhesiveness (negative area); and Stickiness (minimum negative force), as shown in Figure 2 (a).

For the compression test, four slices (10 mm thick) were cut per sample, then a cube (of core) with approximately 40 mm on each side was removed from each slice. The analysis of the texture profile consisted of two compression cycles using a cylindrical probe with a 75 mm base diameter (the probe being larger than the sample), spaced by an interval of 5 seconds

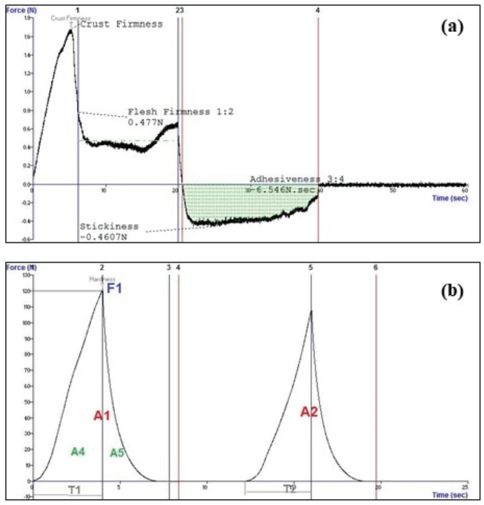

Figure 2. Force (N) versus time (sec) curves: (a) Perforation test; (b) Compression test

between cycles. A 30 kg load cell was used and the test and post-test speeds were 1 mm/s. The compression distance was 4 mm, the trigger force was 0.5 N and the acquisition rate was 50 readings per second. The texture attributes: hardness, elasticity, resilience and chewiness were calculated using the equations below, considering Figure 2 (b) [9]:

$$Hardness\ (N) = F1 \quad (1)$$

$$Elasticity\ (\%) = \frac{T2}{T1}\, x\ 100 \quad (2)$$

$$Resilience\ (\%) = \frac{A5}{A4}\, x100 \quad (3)$$

$$Chewiness\ (N) = F1\ x\ \frac{T2}{T1}\ x\ \frac{A2}{A1} \quad (4)$$

2.4 Reproducibility

In order to assess whether the characteristics were maintained in the different days of manufacture (reproducibility), using the same conditions of bread manufacture and the same tests, the differences that could exist between different batches of the same type of bread were evaluated. For this, the breads were produced in four different batches, for each type of bread (A, B and Control), with three loaves being removed from each of these batches for analysis, following the procedures described earlier.

3. Results and Discussion

3.1 Perforation test

The results for the firmness of the crust and firmness of the crumb, as well as the stickiness and adhesiveness are shown in Figure 3.

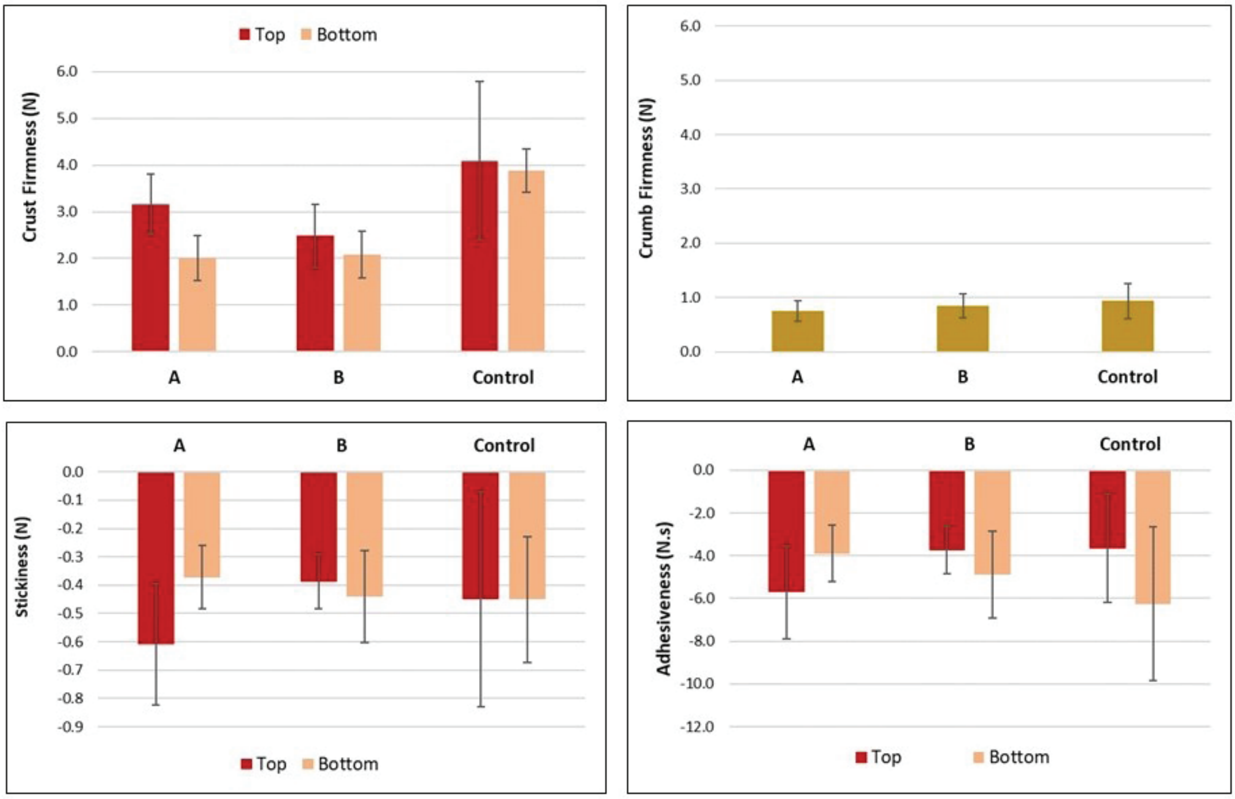

Figure 3. Results of perforation texture tests: firmness of the crust, firmness of the crumb, stickiness and adhesiveness

With regard to the firmness of the crust, it can be concluded that the control sample is the one with the greatest firmness of the crust, both on the top and bottom of the bread, which is to be expected since they are breads made with flours with different characteristics. Regarding the breads under study, sample A is the one with the highest firmness in the upper part of the crust. However, at the bottom of the bread, the firmness in both loaves is similar. Regarding the firmness of the crumb, bread B has a firmer crumb than A, but even so, the control bread is the firmer when compared to the other 2 types of bread. From the results obtained, it is evident that the absence of gluten significantly reduced the firmness of the breads under study, which was already expected given the fundamental role of gluten in defining the viscoelastic properties of bread dough [10]. In general, the development of gluten-free bread involves the use of various ingredients and additives in order to replace the viscoelastic properties of gluten and, consequently, obtain bakery products with acceptable and desirable properties for the consumer [11]. Thus, gluten-free formulations often use gluten-free flours (quinoa, buckwheat or amaranth), leguminous flours (soy, chickpeas or peas), starches (corn, potatoes or manioc), or ingredients such as hydrocolloids, emulsifiers or combinations of these with other products, with a view to improving technological, sensory and nutritional properties while aiming to increase shelf life [12 - 15].

Regarding stickiness (Figure 3), it can be said that there are not many apparent differences between the breads analysed, however bread B is perhaps more similar to control bread. Bread A presents a greater discrepancy between the top and the bottom in terms of stickiness, the latter being more intense on the top of the bread. The adhesiveness (Figure 3) shows a tendency similar to the stickiness with respect to the samples A and B under study, however in the control sample there was a greater difference between the two sides of the bread, with the greatest adhesiveness being verified in the bottom face.

3.2. Compression test

The values obtained for the textural properties by the compression test are shown in Figure 4. As for the hardness, which represents the force necessary to compress a food between the teeth or between the tongue and the mouth, that is, the force necessary to cause the deformation [16], it can be seen that in the crumb the values are identical in all studied samples, including the control sample. However, when analysing the complete slice, it turns out that samples A and B are considerably less hard than the control, most likely due to the crust, since the crumb is similar. These results agree with those previously found for the firmness of the crust through the perforation test.

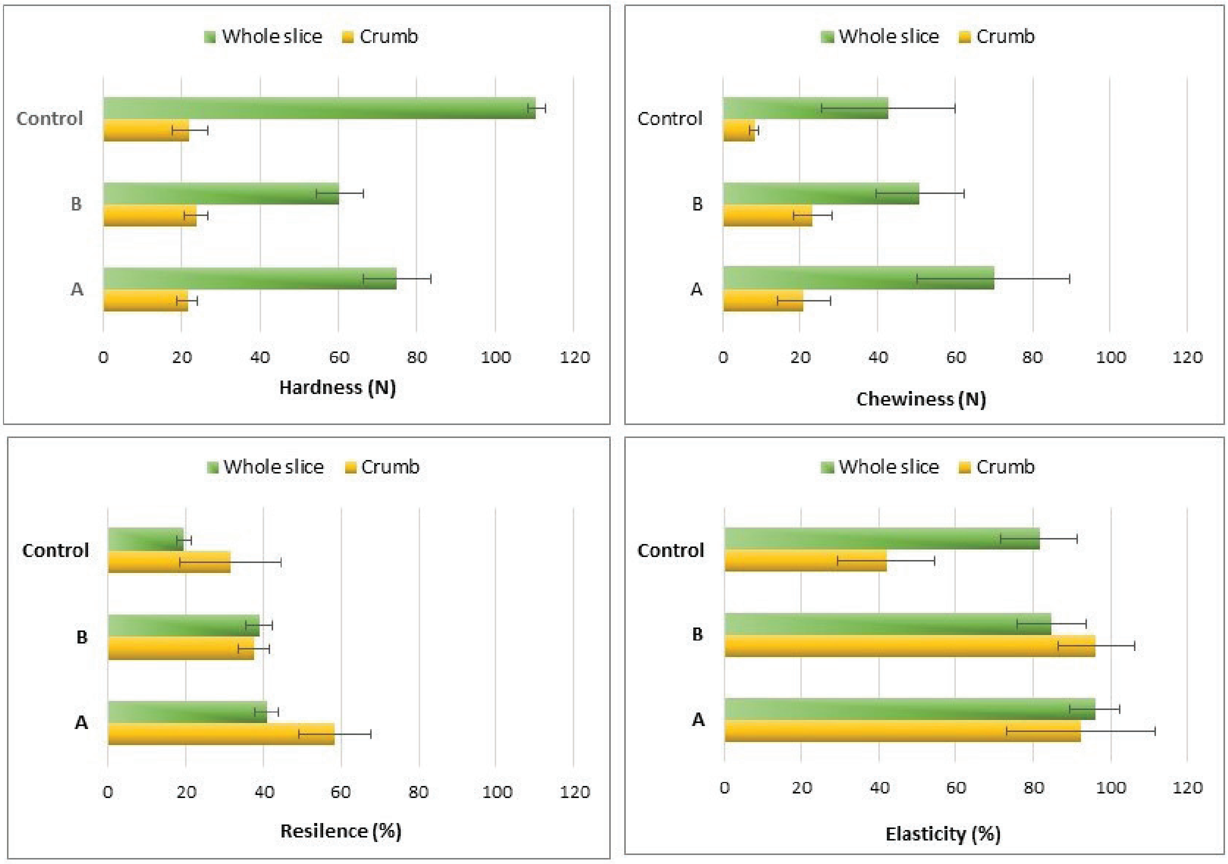

Figure 4. Results of texture tests by compression: hardness, chewiness, resilience and elasticity

Resilience is the deformation energy per unit volume up to a limit of proportionality, that is, the energy used when applying a force to a material without rupture, with or without any residual stress [16]. In the gluten free bread samples under study, resilience was considerably lower than the control sample, with sample B being the one with the highest concordance between the crumb and the complete slice (Figure 4).

Elasticity is the ability to recover shape after compression and measures the speed of return to the initial state after removing the force that caused the deformation [16]. It was found that both types of bread produced with gluten-free flour, A and B, the results are relatively similar, both for the crumb and for the whole slices. However, Control bread has a much lower elasticity, particularly for the crumb (Figure 4).

Chewiness measures the energy needed to disintegrate a food to the point of being swallowed (Guiné *et al.*, [16]), and it is similar for both gluten-free bread samples, A and B, however the crumb of B is easier to chew than sample A (Figure 4). Comparing these with the Control, the values are somewhat different, the Control being easier to disintegrate to swallow, either for the crumb or for the whole slice.

The significantly different values that were found between bread types A and B and the control bread are probably due to the different characteristics of the raw materials used to make them. Furthermore, several authors state that generally gluten-free breads have a texture that disintegrates more easily and a lower specific volume, as well as a less pleasant colour, which does not satisfy the taste of consumers, in addition to a short shelf life, probably as a result of the lack of the viscoelastic network formed by gluten [17, 18].

3.3 Reproducibility

Figure 5 presents the values of the textural properties determined by the perforation test considering the 4 samples of each gluten-free bread (A and B) produced under similar conditions, but from different batches. It is observed that while for sample A there is a great variability in the firmness of the crust (both above and below), in sample B the results shown a good repeatability with regard to the firmness of the crust on both analysed faces. Regarding the firmness of the crumb, here too, sample B presents a constancy in the values obtained for breads made on different days, once again in sample A there was a slight variation, although not as clear as in the case of the crust. Looking at the results for stickiness and adhesiveness (Figure 5), once again the results show that breads made with gluten-free flour B are more constant from batch to batch than type A breads.

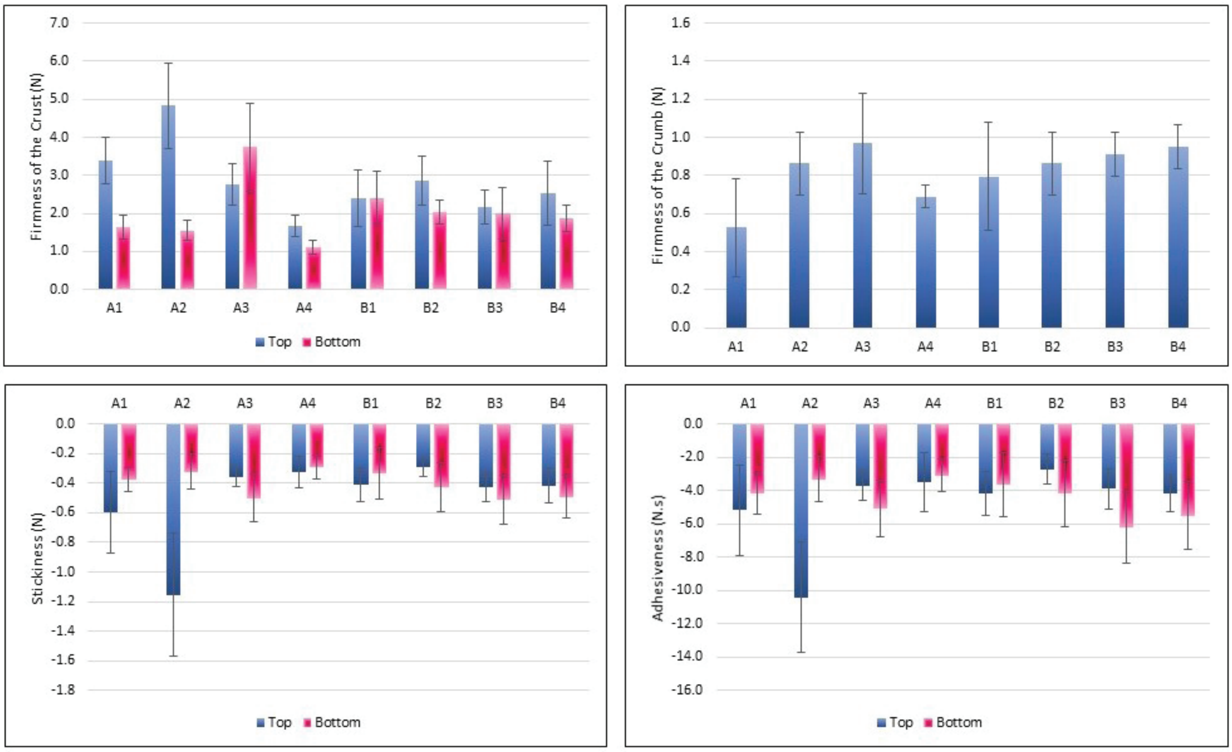

Figure 5. Reproducibility of the results of texture through the perforation test

Figure 6 shows the textural properties that were observed when the compression test was performed, also considering 4 units of each sample, from different lots. The results obtained show that the hardness presented a great variation both in samples A and also in samples B, and this has a very direct influence on chewiness, since these two properties are directly related, as indicated by equation (4). In general, resilience presents a higher value, with the exception of sample A3, the remaining evaluations are relatively

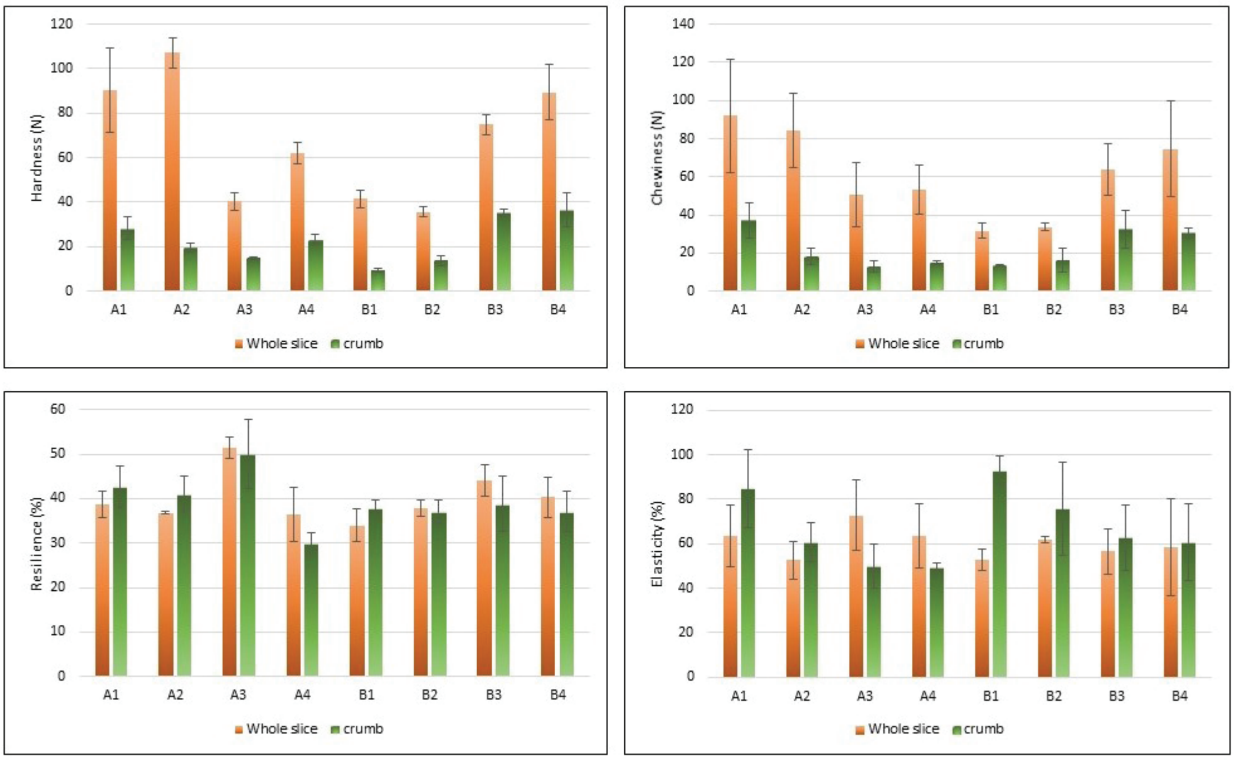

Figure 6. Reproducibility of the results of texture through the compression test

similar between samples A and also among samples B. The elasticity is also highly variable, except for the values obtained for complete slices of type B bread.

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4. Conclusions

- The results obtained in this study showed that the type of flour, its constitution and the presence or absence of gluten considerably influence the texture of bread, and the breads obtained by using gluten-free flours are less firm on the crust and also on the crumb, when compared with bread made from gluten-free flour. On the other hand, they tend to be less adhesive and viscous, which means less dry.

- Another conclusion is related to the performance of the two types of tests to evaluate the textural properties, and it was observed that the tests are complementary, since they allow to evaluate different characteristics, and thus obtain a more complete profile of textural characteristics of the breads.

- Finally, with regard to the reproducibility of the results, it was possible to observe that the reproducibility is higher when perforation tests are performed as compared to compression tests, and that on the other hand, samples manufactured with type B gluten-free flour are more constant in their textural characteristics when different batches are analysed.

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