Gluten-Free Bread: A Case Study

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***Abstract*—Physicochemical and sensorial characteristics of a possible commercial Gluten-Free Bread (GFB) made with a new gluten-free flour were studied, as compared to a regular wheat bread, which was also analysed as Control sample. Results show that GFB presented high values of moisture and water activity, 36.56% and 0.96. This bread presented high density (0.38 g/ cm^3) comparing to regular bread (0.25 g/ cm^3), being these results reinforced by image analysis of alveoli. GFB was whiter, with less color intensity, meaning that a* and b* color parameters were lower than control, which was confirmed by sensorial evaluation results. GFB was soft and easily chewable (75.0 N and 70.0 N, respectively for hardness and chewiness), which, once again, was corroborated by the sensorial results. The overall assessment done by the consumer panellist to GFB was 4.1 (on a scale from 1 to 10), while the control bread presented 5.5. It could be concluded that the new flour formulation is suitable for GFB production, with characteristics comparable with the regular bread.**

***Index Terms*—wheat, gluten-free, bread, physicochemical characteristics, sensorial properties**

I. Introduction

Bread constitutes the basis of main food consumption. Recently, consumer awareness and interest by nutritive and healthy food is increasing [1]. Thus the development of healthy food, specifically Gluten-Free Bread (GFB) is very important since the number of celiac patient grows [2]. Moreover, this is also important for individuals with dermatitis herpetiformis, gluten ataxia, wheat allergies and gluten sensibility [3]. In these diseases and intolerances, people cannot eat food with gluten and the only way to overcome it is to avoid all such type of foods throughout their lives [4]. Despite the growth of gluten-free products in the market, it is still a problem to find them mainly due to the limited variety, availability, weak sensorial characteristics and high price, which leads a consumer hamper adherence and a general dissatisfaction of gluten-free products [5].

The production of high quality GFB is a big challenge to bread making industry, since gluten presents unique viscoelastic properties to enhance desirable volumes and textures in breads. Furthermore, gluten is also important for the appearance, texture, structure, and shelf life of breads [2], [6]. The replacement of gluten could be done by the combination of different ingredients, such as hydrocolloids, starches, non-wheat cereals flours, nutritional supplements and additives, in order to improve the technological, sensory and nutritional properties of the gluten-free products [6], [7]. Some authors mention that there are some specific considerations to take into consideration when a producer wants to develop gluten-free products; they are: avoidance of gluten-containing sources, alternative sources, ensure sensory characteristics, provide nutritional value of gluten-free product, meet recommended dietary allowances, economics, and compliance with the FDA guidelines [8].

Technical properties of GFB are important to the industry and consumer acceptability, and can affect the product's value [7]. Thus, it is important to evaluate the characteristics of GFB for assessing its quality, mainly the loaf volume, specific volume, color, and textural properties [9], [10] nutritional composition and sensorial attributes [11], [12], and also the crumb microstructure by using image analysis [13], [14].

The aim of this work is to evaluate the physicochemical and sensorial characteristics of a possible commercial GFB made with a new gluten-free flour, and compare it with a regular wheat bread conventionally and usually consumed, and which is available in the market.

II. Materials and Methods

A. Samples

Gluten-free flour was supplied by CREDIN enterprise, which wants to test a new gluten-free flour, in order to produce GFB. This flour is a mixture of several ingredients: gluten-free wheat starch, potato starch, rice flour, dextrose, psyllium fiber, fermented and dry rice flour, salt, stabilizers (guar gum, xanthan gum, hydroxypropylmethylcellulose), pH adjusting (calcium acetate) and enzymes. The discrimination of the ingredient's quantities is not allowed to be disclosed. A regular wheat flower type 65 (Cerealis, Lisbon, Portugal) was used to produce the regular wheat bread, which will be designated by Control.

All reagents were analytical grade.

B. Breads Production

A basic recipe was used to produce GFBs and Control breads (Table I).

The ingredients were mixed in a bread mixer Spiral Ferneto AE080 (Ferneto, Vagos; Portugal) during 8

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minutes to form a dough, which rested for 5 minutes. After that, the dough was cut into loaves (320 g), fermented during 40 minutes, at a relative moisture of 82-85% and 32 ℃. Following fermentation, dough was baked at 220 ℃ for 12 minutes in an electric oven model Modulram Classic with built in stove (Ramalhos, Aveiro, Portugal). Three breads of GFB and Control were produced.

TABLE I. INGREDIENT QUANTITIES FOR BREAD PRODUCTION

Ingredient	Quantity (Kg)
Main Flour	5.000
Vegetable oil	0.250
Yeast	0.250
Water	4.000
Calcium propionate	0.035
Sorbic acid	0.010
Bread aroma	0.010

C. *Physicochemical Analysis of Breads*

Water activity was determined by a hygrometer (Rotronic), at 25 ℃, and five determinations were made. Moisture content was accessed by mass loss until constant weight in a stove at 100-105 ℃, and also five determinations were made [15].

The Ridasecreen® Gliadin plate kit (R-Biopharm, Darmstad, Germany), including the R5-antibody, was used for sandwich Enzyme-linked immunosorbent assay (ELISA), according to the manufacturer ́s instructions.

For the density determination was used the relation between mass and volume. For that pieces of bread were carefully cut in the form of parallelepipeds (3x3x1 cm), which were then weighed on a precision balance. Fourteen replications were done.

The color parameters were evaluated using a colorimeter Chroma Meter (Konica Minolta) and the results are expressed in CIELab coordinates system, where L* is the lightness of the sample, and ranges from 0 (black) to 100 (white), a* ranges from -60 (green) to +60 (red) and b* ranges from -60 (blue) to +60 (yellow).

For the analysis of textural properties it was used a texturometer TA-XT2 (Stable Microsystems, UK) which compresses the sample twice to simulate the action of chewing. The compression is usually 80% of the original length of the sample [16]. For the analysis it was necessary to cut the sample into slices (10 mm thick), removing a cube of side 30 mm from the crumb. Fourteen replicates were performed. The probe used was cylindrical with 75 mm diameter base (being the pressure probe greater than the sample) at a temperature of about 20 ℃. The test parameters were:

- Compression speed: 1.0 mm/s;
- Compression distance: 4 mm (corresponding to a deformation of 40% of the height of the sample);
- Recovery time (pause) between the two compressions: 4 seconds;
- Acquisition rate: 50 readings taken per second.

The textural properties evaluated were hardness, springiness, cohesiveness and chewiness.

For the alveolar characterization, was undertaken the analysis of slices using the program “Image J” developed by Wayne Rasband from the National Institute of Mental Health of the United States of America. Five 10 mm thick slices were scanned, and a slice cut was made in the central zone eliminating the crust (Fig. 1). The software of the Image J provide the number and size of the alveoli, the total area and the alveolar percentage on that area.

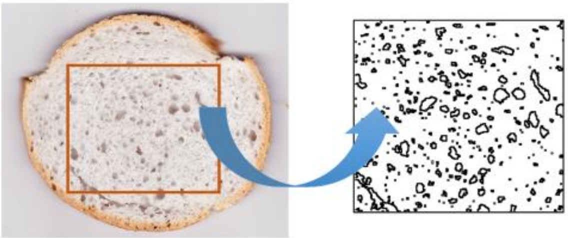

Figure 1. Methodology for alveolus characterization.

The analyzed properties were determined in the same day of bread production. At least 3 determinations of each parameter were done in each bread produced.

D. *Sensorial Evaluation*

Sensory analysis was performed in a laboratory prepared for that purpose, on the day of delivery of the samples, by a panel of 25 untrained tasters, aged between 18 and 54 years, who were asked to rate the following attributes:

- Appearance: color of crumb and crust, roughness, alveolar (uniformity and dimensions).
- Aroma: bread, fermented.
- Taste: bread, salt, fermented.
- Texture: Springiness, density.
- Overall appreciation.

In this test the taster expressed the intensity of each attribute through a scale where verbal hedonic expressions are translated into numeric values in order to allow statistical analysis. The scale of values varied from 1 (less intensity) to 10 (high intensity).

III. RESULTS AND DISCUSSION

A. *Physiccchemical Properties of Breads*

The moisture and water activity (a_w) are important factors for food storage. The results showed that moisture content and water activity values are quite high for both breads, being the GFB the one with higher values of moisture and a_w , 36.6% and 0.96 respectively (Table II). These two factors are important in food storage, thus the results showed that the water present is available to react with other components of bread matrix and also the fungi development is a possible concern.

According to Neto *et al.* [17] most of the microorganisms grow in the range 0.90 to 0.99 (medium and high values of a_w), and hence the studied breads may be susceptible to the growth of microorganisms.

TABLE II. MOISTURE, WATER ACTIVITY, AND DENSITY OF BREADS

Sample	Moisture (%)	a_w	Density (g/ cm^3)
GFB	36,58 ±0,66	0,96 ±0,00	0.38±0.01
Control	34,70 ±0,21	0,91 ±0,01	0.25±0.00

Table II also showed the density values of breads. The GFB presented high density when compared with the Control bread. However, the encountered difference is not noticed by the consumers, as shown further ahead in the results of the sensorial evaluation of breads.

The average value encountered for gluten content in the GFB was 2.24 ppm. The products labeled "gluten-free" according to the US Food and Drug Administration and EC regulation is limited to 20 ppm or 20 mg gluten/ Kg [18], [19].

Both breads presented similar tendencies for color properties of crust and crumb (Fig. 2). The crust is darker, with lower L*, and it is darker in the lower part of the loaf for both breads. It is also possible to notice that the GFB showed a whiter crumb. With respect to parameter a* it is also greater in the crust than in the crumb, which means that the red color is stronger on the surface, being greater in the crust lower part of the Control bread. The b* coordinate also shows a higher value in the crust, indicative of a stronger yellow color, which is more intense in the regular bread. These results indicate that the crust is browner than the core, which was a result of the browning occurring in the surface of the bread upon cooking due to Maillard reactions. Thus, the lightness of the breads is similar but the GFB crumb is whiter. Furthermore, the GFB is less yellow and less red, both for crust and crumb, probably due to the ingredients present in the flour used for its production.

The textural properties of bread are shown in Fig. 3. The GFB presented lower values of hardness, and higher values for chewiness and for springiness (elasticity). The results for cohesiveness were 0.76±0.06 and 0.47±0.05 for GFB and Control, respectively.

Hardness corresponds to the maximum force applied during the first cycle of compression, and represents the force required between the molars for chewing a food, being in most cases related to the tensile strength of the sample. Chewiness represents the energy required to disintegrate a solid material in order to swallow it [20].

Springiness or elasticity is the ratio between the times in the two deformations, and represents the ability to regain shape when the deforming stress is removed or reduced, i.e., expresses the percentage of recovery of the sample [21].

Cohesiveness represents the ratio between the work done in the second compression and the work done in the first compression, and reflects the ability of the product to stay as one [22].

Considering these properties, it is possible to notice that the produced GFB presented a fluffy texture, closely-knit and with high force required to chew in the mouth.

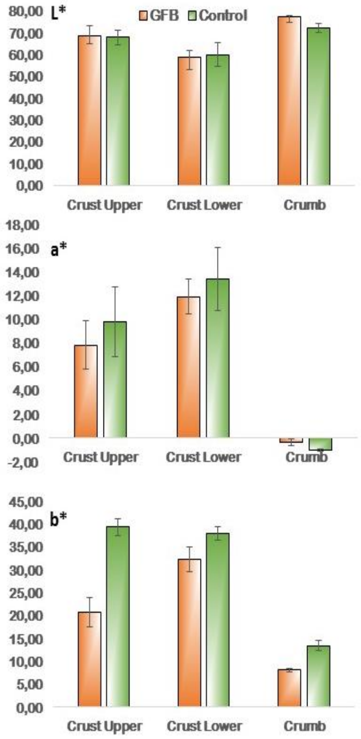

Figure 2. Color coordinates for crust (upper and lower) and crumb of gluten-free (GFB) and control breads.

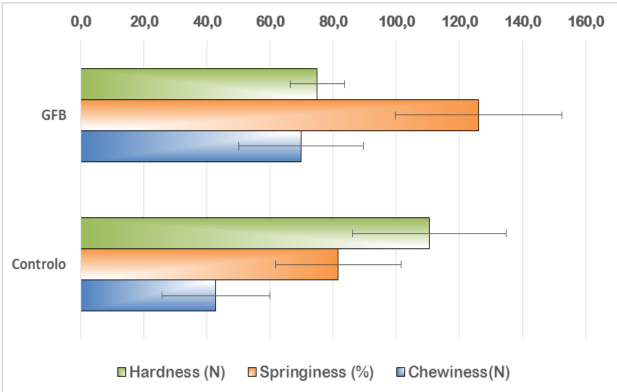

Figure 3. Texture characteristics of gluten-free (GFB) and control all breads.

The alveolar characteristics are showed in Table III. It is possible to observe that the GFB presented lower number of alveoli and alveolar percentage, with similar total alveolar area, and high alveoli dimensions, comparing with Control bread. This means that GFB is a denser bread, which is slightly corroborated by the results obtained for bread density evaluated by sensorial analysis.

TABLE III. ALVEOLAR CHARACTERIZATION OF GLUTEN-FREE (GFB) AND CONTROL BREADS

Sample	Number	Total area (mm^2)	Average size (mm)	Alveolar %
GFB	99.8 ±50.1	164.2 ±12.8	3.7±0.7	21.3±3.9
Control	207.2±58.2	167.1 ±1.0	3.2±0.6	26.5±4.4

Several authors mention that gluten is important to gas retention in order to obtain a desirable volume, texture, and appearance, but also for crumb structure [2], [23]. To replace the gluten properties several raw materials could be used, being the most common ones hydrocolloids [6], such as xanthan and guar gum, and methylcellulose, who are present in the gluten-free flour tested in this work. It was proved that in the GFB formulated with rice flour, as it is the present case, and xanthan-guar gums improve the dough structure, enhancing the firmness and the specific volume [24]. Several authors also proved that the botanical origin and amount of starch affect the crumb quality, they noticed that GFB produced with cassava and rice starch had better crumb properties than maize and potato starch [25].

B. Sensorial Evaluation of Breads

The results of the sensorial profiles of the studied breads are presented in Fig. 4. The attributes evaluated related to appearance, aroma, taste, texture and finally the global appreciation, translated into a scale of 10 points. The GFB presented lower scores for color evaluation, both in the crust and crumb, and lower roughness. This bread presented higher alveoli dimensions, which is correlated with the alveolar characterization results done by image analysis. In spite of this, the alveoli of GFB were less uniform in comparison with regular wheat bread. To highlight, the alveolar properties evaluated by the panelists are in accordance with the image analysis. Furthermore, the other evaluated parameters presented also lower values for GFB. Considering the texture characteristic evaluated by the tasters, it is possible to notice that the results are not in accordance with the results showed by instrumental texture analysis. This could be due to the fact that the panel was not a trained one and this attribute could not be unequivocally evaluated. Furthermore, the tasters were not able to clearly identify the differences in density, meaning that the high density of GFB determined by analytical methods compared to regular bread is not perceived by the consumers.

Regarding the aroma and taste of breads, the main differences are in bread aroma, which was higher for regular bread, and the GFB presented higher fermented taste. Some authors found that the observed differences between GFB and wheat bread are mainly related to the volatile compounds existing in the crust of the bread, being the most important difference due to the absence of pyrazines in the aroma of the gluten-free breads, which could be replaced by adding of aroma precursors of Maillard reaction in the dough before baking, like the pair proline and glucose [26].

When asked about the preference, the consumer panelists scored the regular bread with a score of 5.6 and the GFB with a score of 4.1. Because differences are still noticeable between the two types of bread, it means that more work must be done in order to improve GFB properties to make it more appealing to the consumer. However, considering that the regular bread is the common one and the highest score is 5.6, it could be concluded the GFB was well evaluated, when compared with it.

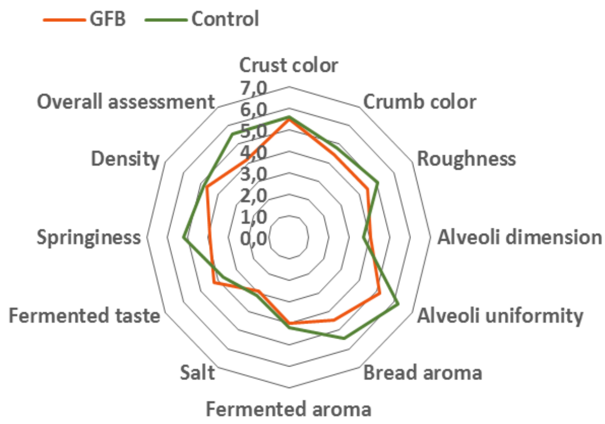

Figure 4. Sensorial profile of gluten-free (GFB) and control breads.

IV. CONCLUSIONS

The results of the current study show that the produced GFB, which is made with a new gluten-free flour presented good physicochemical and sensorial characteristics compared to wheat bread conventionally and daily consumed, which is available in the market. GFB showed a moisture content of 36%, with an a_w of 0.96, which means that it can be susceptible to the growth of microorganisms. Generally, the GFB and regular bread tested presented similar color parameters, with appreciate differences in texture characteristics, with high density (0.38 g cm^2), chewiness and springiness, and less hard than regular bread. The crumb presented low number and percentage of alveoli, but with high dimensions and similar total alveoli area. The overall assessment of sensorial characteristic revealed that consumers preferred the regular wheat bread. The results allowed to conclude that more improvements and experiences must be done in order to achieve the standards that consumers want, mostly in texture. Regarding the formulation of this gluten-free flour, it is also noticed that it is nutritionally more complete and healthier. Thus, individuals who must face the daily challenges imposed by a strict gluten-free diet treatment could find in this bread a good alternative to wheat-based counterparts.

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