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Production of a new gluten-free bread and comparison with a regular wheat bread
Produção de um novo pão sem glúten e comparação com um pão de trigo usual

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Abstract

The main purpose of this work was the assessment of physicochemical and sensorial characteristics of a new gluten-free bread (GFB), in comparison with regular wheat bread (RWB). The gluten-free bread was produced from one baking flour mixture provided by a national company. Water activity (aw), moisture and gluten content, texture, colour, density and alveolar characteristics were used to evaluate the GFB, and also a sensory evaluation was performed. There were some differences between the GFB and the RWB, mainly in density, springiness, chewiness, and in the alveolar properties. However, the colour coordinates, moisture and aw presented similar results for both breads analysed. The sensorial results showed some differences, mainly in the texture and flavour. The global score was the same for both breads, 5.6 points, which was an encouraging result. It was also evaluated the stability of bread properties between production lots, being evaluated 4 independent GFB lots. In general, and considering only the determinations made, it can be said that the produced GFB presented quite good and promising results. Thus, the flour used by this Portuguese enterprise is suitable for production of GFB, giving bread with quality, with healthy benefits.

Resumo

O principal objetivo deste trabalho foi a avaliação das caraterísticas físico-químicas e sensoriais de um novo pão sem glutén (GFB), comparando-o com o pão de trigo usualmente consumido (RWB). O pão sem glutén foi produzido a partir de uma farinha de mistura de uma fábrica nacional. Foram avaliadas a atividade da água (aw), o teor de humidade e de glutén, a textura, cor, densidade e as caraterísticas alvéolares, bem como as caraterísticas sensoriais. Existiram algumas diferenças entre o GFB e o RWB, principalmente na densidade, na elasticidade, na mastigabilidade, e também nas características alvéolares. No entanto, as coordenadas da cor, a humidade e a aw apresentam resultados semelhantes para ambos os pães avaliados. Os resultados da análise sensorial mostraram algumas diferenças, principalmente na textura e no flavour. A avaliação global foi a mesma para os dois pães, 5.6 pontos, sendo um resultado promissor. Foi também avaliada a estabilidade das caraterísticas dos pães entre diferentes lotes, tendo sido avaliados 4 lotes independentes de GFB. De um modo geral, e considerando só as propriedades avaliadas, pode dizer-se que o GFB apresentou bons resultados e promissores. Deste modo, a farinha usada pela empresa Portuguesa é adequada para a produção de GFB, originando um pão com qualidade, com benefícios para a saúde.

Keywords

Gluten free-bread; Texture; Colour; Alveoli properties; Alveoli properties

Production of a new gluten free bread and comparison with a regular wheat bread

1. Introduction

Nowadays, the consumer interest by nutritive and healthy food is increasing [1]. Thus, the development of healthy food is very important due to the growing number of celiac patients [2], but also owing to people who suffer from nonceliac gluten sensitivity and an increasing number of consumers who want to avoid gluten-free products due to their lifestyles [3]. The quantity of gluten-free products in the market is growing, but it is still a problem to find them mainly due to the limited variety, availability, weak sensorial characteristics and high price, which leads to a weak consumer adherence and a general low satisfaction [4]. Thus, when a producer wants to develop some gluten-free products, he must avoid gluten-containing sources, chose alternative sources, ensure sensory characteristics, provide nutritional value of gluten-free product, meet recommended dietary allowances, consider economical aspects, and compliance with the FDA (Food and Drug Administration) guidelines [5].
Among gluten-free foods, bread is the most important 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 [6]. Several studies have been carried out considering the improvement of gluten-free bread (GFB), and important aspects are the development of nutritive and technological quality of breads, because in comparison the GFB has poorer aspect, structure and nutritional value than its gluten counterparts [7, 3, 8, 9]. Generally, the GFB is characterized by a heterogeneous recipe, mainly the combination of rice and/or corn starch and flours, as well as proteins, fibres, fats, hydrocolloids, and sometimes specific enzymes [10, 11, 9]. The most common defects of GFB are related with inefficient gas retention and expansion during dough leavening, which results in a reduced volume and low crumb softness of the breads. Furthermore, since GFB contain a great percentage of starch, it undergoes a fast stalling [12]. The sensory properties are also important to consider, like the bread appearance, taste and aroma, because they play a key role in consumer´s choices [13]. Thus, the variety of ingredients used in GFB production affects the organoleptic characteristics of breads, but also its technological and nutritional properties, resulting in very different products [14].
To the industry and consumer acceptability the technical properties of GFB are important aspects, and they can affect the product's value [15]. Thus, it is important to evaluate the characteristics of GFB for assessing its quality, mainly the colour, loaf and specific volume, as well as textural properties [16, 17], nutritional composition and sensorial attributes [18, 19], and finally crumb microstructure by using image analysis [20, 21, 9].
The aim of this work was to evaluate the physicochemical and sensorial characteristics of a commercial gluten-free bread made with a new gluten-free flour, and compare it with a regular wheat bread (RWB), to decide if this GFB has possible acceptance by the market.

2. Experimental Procedure

2.1. Flour samples

A new gluten-free flour was supplied by GERMEN a mill cereal enterprise, to be tested. The ingredients of the flour are: gluten-free wheat starch, rice flour, sugars, potato protein, stabilizers (guar gum and xanthan gum), emulsifiers [hydroxypropylmethylcellulose, mono- and diacetyl tartaric acid esters of mono- and diglycerides of fatty acids, mono- and diglycerides of fatty acids (glyceryl monostearate, glyceryl distearate)], salt, carob flour and citric acid. The proportion or quantity of each ingredient was not allowed to be disclosed.
A regular wheat bread was produced with regular wheat flower type 65 (Cerealis, Lisbon, Portugal) to be the control, which will be designated by RWB.

2.2. Breads production

A basic recipe was used to produce GFB and Control breads, using the ingredients presented in Table I, resulting in a production of 31 breads. A sample of 5 breads was taken for analysis.

Table 1-Ingredient quantities for bread production

Ingredient	Quantity (Kg)
Main Flour	5.000
Vegetable oil	0.250
Yeast	0.250
Water	3.750

To form the dough, all the ingredients were mixed in a bread mixer Spiral Ferneto AE080 (Ferneto, Vagos; Portugal) for 8 minutes. The dough rested for 5 minutes, then it was cut into loaves (320 g). The loaves fermented for 40 minutes (RH 82-85% and 32ºC). After the fermentation, dough was baked in an electric oven model Modulram Classic with built in stove (Ramalhos, Aveiro, Portugal) at 220 ºC for 12 minutes.

2.3. Physicochemical analysis of breads

A hygrometer (Rotronic) was used to access the water activity (a_w) values, at 25ºC. Five measurements were made for each sample.
Moisture content was determined by mass loss until constant weight in a stove at 100-105ºC, and also five determinations were made [22].
The relation between mass and volume were used to calculate the density of breads. Fourteen pieces of bread were carefully cut in parallelepipeds (3x3x1 cm), then they were weighed on a precision balance
The gluten content was determined by the Ridasecreen® Gliadin plate kit (R-Biopharm, Darmstad, Germany), including the R5-antibody, which was used for sandwich Enzyme-linked immunosorbent assay (ELISA), according to the manufacturer´s instructions manual.

2.4. Evaluation of colour

The colour was evaluated using a hand tristimulus colorimeter Chroma Meter - CR-400 (Konica Minolta), which was calibrated with a white standard tile. The areas evaluated are showed in Figure 1. 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). Twenty determinations were made per type of bread.

Figure 1. Areas considers for evaluation of breads colour parameters.

2.5. Textural properties

A texturometer TA-XT2 (Stable Microsystems, UK) was used to do the textural analysis of the samples. A compression text, which compresses the sample twice to simulate the action of chewing, was made. The compression is usually 80% of the original length of the sample [23].
The samples were cut in slice (10 mm thick), then it was taken a cube of side 30 mm from the crumb. The measurements were done fourteen times per type of bread.
The probe used was cylindrical with 75 mm diameter base (being the pressure probe greater than the sample) at a temperature of about 20 ºC (Figure 2A). A compression test was performed

(Figure 2B). 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 (N), springiness (%), adhesiveness (N.sec), and chewiness (N) [24].

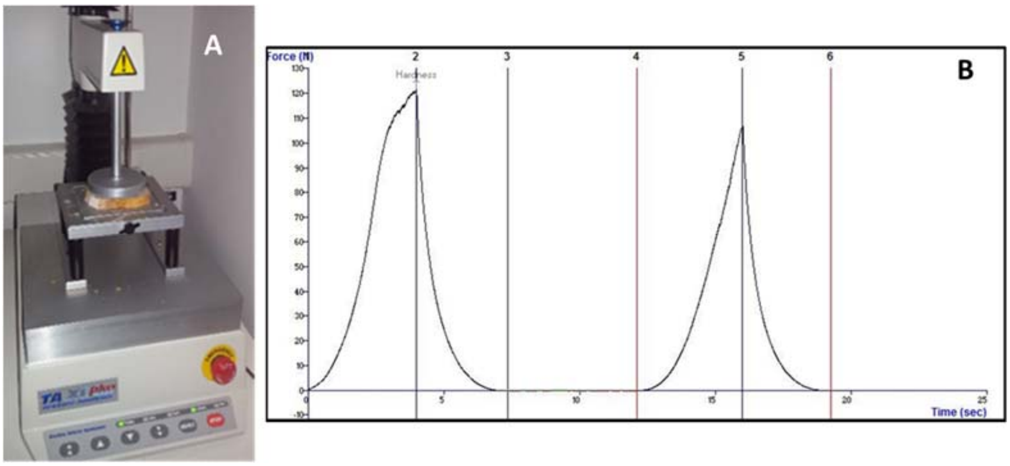

Figure 2. Texture analysis. A – Compression test; B- Curves Force (N) versus time (seconds) for compression test.

2.6. Alveolar characterization

The program "Image J" developed by Wayne Rasband from the National Institute of Mental Health of the United States of America was used for the alveolar characterization. Five 10 mm thick bread slices were scanned, and a slice cut was made in the central zone eliminating the crust (Figure 3). The number and size of the alveoli, the alveolar percentage and the total area on the analysed area were provided by the software of the Image J.

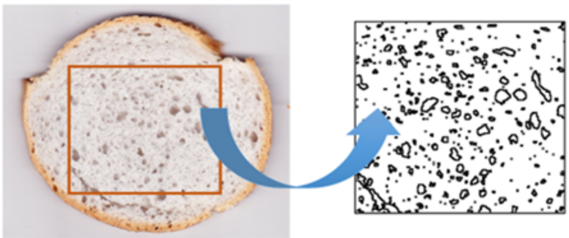

Figure 3. Methodology used for alveolus characterization.

2.2. Sensorial Evaluation

Sensory analysis was performed in a laboratory prepared for that purpose, and a panel of 25 untrained tasters, aged between 18 and 54 years. The intensity of each attribute in evaluation was represented in a scale, where verbal hedonic expressions were translated into numeric values to allow statistical analysis. The scale of values varied from 1 point (less intensity) to 10 points (high intensity). The tasters evaluated the samples according to the following attributes:

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

All the analysed properties were determined in the same day of bread production.

3. Results and Discussion

Both analysed breads presented similar and quite high values for moisture content and water activity (Table 2). Considering that these factors are important in food storage, the results showed that the fungi development is a possible concern since the water present in breads matrices is available to react with other components of the breads. Neto et al. [25] mention that most of the microorganisms grow in the range 0.90 to 0.99 (medium and high values of a_w).

Table 2-Moisture, water activity, and density of breads

Sample		Moisture (%)	a_w	Density (gcm^{-3})
GFB		34,05±0,64	0,91±0,01	0,41±0,01
RWB		34,70 ±0,21	0,91 ±0,01	0.25±0.00

From the results, it is also possible to notice that the GFB presented higher density when compared with the regular wheat bread. Nevertheless, as shown ahead in the results of the sensorial analysis, this difference was not noticed by the consumers. Some authors mention that the volume of the loaves is affected by the bread formulation and the ability of the internal structure to retain gases formed during fermentation and baking [9].
According to the US Food and Drug Administration and EC regulation, the products labelled "gluten-free" must be limited to 20 ppm or 20 mg gluten/Kg [26, 27]. Thus, the average value for gluten content in the GFB was 1.93 ppm, meaning that it is clearly a gluten-free product. However, considering the need to produce a completely gluten-free bread makes ways for other challenges, since gluten is a structural protein complex, exhibiting unique functional properties [10].
Colorimetric parameters measured on both crumb and crust of tested breads are reported in Figure 4. Generally, the GFB presented higher values for L* and lower values for a* and b* coordinates, meaning that this bread was whiter, less red and yellow and lighter, comparing to RWF bread, probably due to the ingredients present in the flour used for its production. Several authors mention that the different formulations significantly affect the crust and crumb colour, the volume and crumb grain of breads [14].
For both breads, the crust presented low values of L*, meaning that it was dark, and it was even darker in the lower side of the loafs. Furthermore, the GFB showed a whiter crumb. The a* coordinate showed apparent differences, mainly in the crumb. The crumb in RWB presented the lower negative value of a* meaning that there was a predominance of the green coloration in detriment of the red. In opposition, the crust presented greater values, which means that the red colour was stronger on the surface, being greater in the crust lower part of the RWB bread. Considering the b* coordinate, it also showed a higher value in the crust, indicative of a stronger yellow colour, which was more intense in the regular wheat bread. Furthermore, it is possible to say that the crust was browner than the core, which was a result of the browning occurring in the surface of the bread due to Maillard reactions, which occur during cooking in the oven [14].

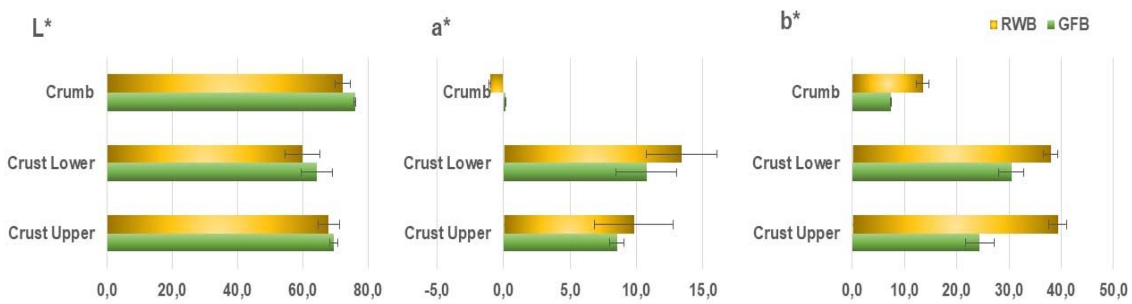

Figure 4. Colour parameters for crust (lower and upper side) and crumb of gluten-free (GFB) and regular wheat (RWB) breads

Figure 5 presents the textural characteristics of the breads. The GFB showed lower values of hardness and higher values for springiness (elasticity), but the chewiness was slightly higher. The breads presented adhesiveness values between -0,004 N.sec and -0,001 N.sec, meaning that the force required to remove the material adhering to a specific surface, like mouth or teeth was weak [28]. Moreover, hardness represents as the force required between the molars for chewing a food, being in most cases related to the tensile strength of the sample, and chewiness the energy required to disintegrate a solid material to swallow it [29]. Springiness is another important parameter of bread texture [9]. Springiness or elasticity also represents the ability to regain shape when the deforming stress is removed or reduced, i.e., expresses the percentage of recovery of the sample [30]. Considering these properties, it is possible to notice that the produced GFB presented a fluffy texture, and with low force required to chew in the mouth.

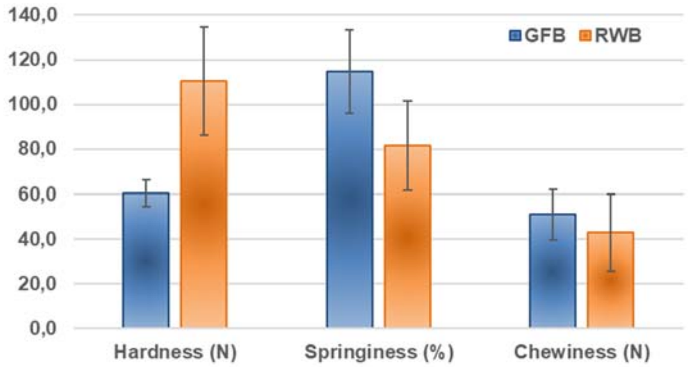

Figure 5. Texture properties of gluten-free (GFB) and regular wheat breads

The results presented in Table 3 show that the GFB presented lower number of alveoli and alveolar percentage, however this bread had slightly low value for total alveolar area, and alveoli dimensions, comparing with RWB bread. This means that GFB seems to be a denser bread, but this is not corroborated by the results of the sensorial analysis, as shown further ahead.

Table 3- Alveolar characteristics of gluten-free (GFB) and regular wheat breads

Sample	Number	Total area (mm^2)	Average size (mm)	Alveolar %
GFB	104.5 ±43,9	149,2 ±13.1	2.9±0.3	22.9±5.2
RWB	207.2± 58.2	167.1 ±1.0	3.2±0.6	26.5±4.4

Several authors mention that to obtain a desirable volume, texture, and appearance, but also a good crumb structure of breads the presence of gluten is very important, mainly for the gas retention [2, 31]. When bread is produced with gluten-free flour, and to achieve such desired properties, several raw materials could be used to replace the gluten properties, such us hydrocolloids [32], like xanthan and guar gum, which are present in the gluten-free flour used to produce the tested bread. Moreover, it is known that in gluten-free breads which are formulated with rice flour as ingredient, as it is the present case, and with xanthan-guar gums, these will improve the dough structure, enhancing the specific volume and the firmness [33]. Furthermore, the amount of starch and the botanical origin of flour also affect the crumb quality. Thus, some authors noticed that GFB produced with rice and cassava starch had better crumb properties than potato starch and maize [34]. Moreover, the porosity of bread was significantly influenced by potato protein, generally the porosity decreased with the increasing of protein and it was also observed that the distribution of pores changed at the same time [9]. According to a report of [35] emulsifiers improve porosity and number of alveoli.
Sensory analysis is a very important tool in development of new products, because it allows the identification of important attributes to the acceptance of a product [36]. Thus, the results of this analysis inform about bread attractiveness for consumers, revealing its market potential [9]. Several authors mention that colour, texture and aroma are attributes of consumer preference [11]. Figure 6 presents the results of the sensorial evaluation of the studied breads. Generally, the breads were quite different when considering the appearance, alveoli characteristics and aroma. The roughness and the dimensions of the alveoli were higher in GFB. However, as mentioned above for image determination of the alveoli dimension, this last result did not match, since the average size was low. Moreover, regarding the alveoli uniformity, it is

possible to observe that the tasters gave high score for RWB. Regarding the colour characteristics of breads, the crumb colour was similar in both breads, but the crusts were quite different. Still, the colour evaluation mentioned above revealed that there were relevant differences between breads, both for crust and for crumb.
The fermented and bread aroma are attributes which presented different scores for GFB and RWB, which were higher for regular bread, but the taste of breads (salt and fermented) were similar. Also, springiness and density presented almost the same punctuation. However, the result for the density was not in accordance with the results showed by instrumental texture analysis. Thus, although the analytical results showed high values for density in GFB, the consumer did not distinguish the difference, probably because the panel was not a trained one and this attribute could not be unequivocally evaluated. Moreover, it could also be possible that 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 was not perceived by the consumers.
The consumer judges gave similar punctuation for the overall appreciation, both with a score of 5.6. This result, allowed to conclude that the produced GFB is a promising gluten-free product and appealing to the consumer, since it had similar overall score as the regular wheat bread produced and usually consumed.

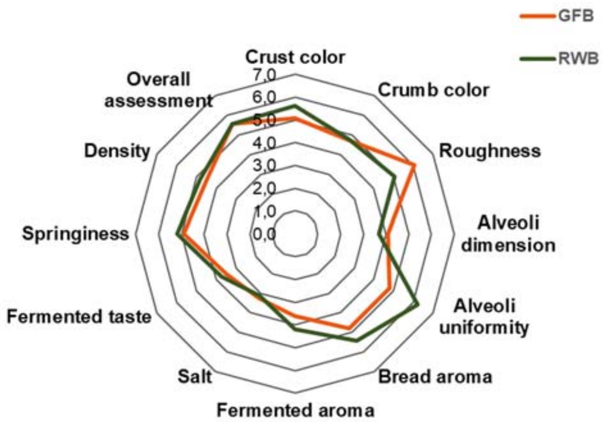

Figure 6. Sensorial results of gluten-free (GFB) and regular wheat breads

4. Conclusions

A GFB produced using commercial gluten-free flour was characterized focusing on the relation between quality parameters (moisture, water activity, density, colour of crust and crumb, texture, alveoli properties) and sensory acceptation.
The results obtained with the present work allowed to conclude that the produced GFB, which is made with a new gluten-free flour, presented good physicochemical and sensorial characteristics compared to wheat bread regularly consumed, which is available in the market. GFB and RWB showed similar moisture content, 34%, and a_w, 0.91, which means that they can be susceptible to the growth of microorganisms. The GFB presented higher density value, 0,41 gcm^{-3}. Generally, the GFB and regular bread tested presented different colour parameters, also with considerable differences in textural characteristics. The gluten-free bread was whiter, with lower values for a* and b* parameters. This bread showed higher values for chewiness and springiness, but was less hard than regular bread. Furthermore, the crumb of GFB presented low number and percentage of alveoli, and low total alveoli area and dimension. Despite of these, the results further showed that the overall assessment of sensorial characteristics revealed that consumers had similar preference for both breads. Regarding the formulation of this gluten-free flour, it is also worth noticing 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 GFB a good alternative to wheat-based counterparts.

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