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Sensory profile of gluten-free breads based on alternative commercial flours †

Karen Irigoytia [1,2], María Belén Parodi [3], Nancy Espósito [1,2], Marina de Escalada Pla [3,4] and Carolina Genevois [*1,2]

[1] Institute of Food Science and Technology of Entre Ríos (ICTAER-UNER-CONICET), Gualeguaychú, Entre Ríos, Argentina; direccion.ictaer@uner.edu.ar
[2] National Research Council of Argentina (CONICET); info@conicet.gov.ar
[3] Faculty of Bromatology, National University of Entre Ríos (UNER), Gualeguaychú, Entre Ríos, Argentina; investigacion.fb@uner.edu.ar
[4] Institute of Food Technology and Chemical Processes (ITAPROQ-UBA), Buenos Aires, Argentina; dir.itaproq@di.fcen.uba.ar
* Correspondence: carolina.genevois@uner.edu.ar
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Abstract: Gluten-free baked goods (GFBG) are based mainly on refined flours and starches, being characterized by a poor nutritional profile. The use of alternative flours rich in protein and dietary fibre, and with good sensorial profile in the formulation of GFBG could improve either nutritional or sensorial properties. The objective of the study was to evaluate the global differences/similarities, and the overall acceptability of gluten-free breads (GFB) formulated with alternative flours in regular consumers and with gluten-related disorders. The results showed four well-differentiated groups of GFB with descriptors related to texture, odour, flavour, colour and crumb, and most of the samples received a punctuation in a range of 5.9-7.3 in a 9-point hedonic scale. The identification of descriptors in GFB formulated with flours with good nutritional profile could be a useful tool in the design of baked goods for the food industry.

Keywords: Consumers; alternative flours; sensory profile

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1. Introduction

GFBG have become a growing trend in the food industry, mainly because consumers with gluten-related disorders are looking for healthier options. Over the last years the supply of gluten-free products has significantly increase. However, these products are often associated with lower-quality compared to wheat-containing counterparts, mainly explained due to a lower sensorial acceptability, less flavour, lower nutritional profile, and a shorter shelf-life [1]. They are also notable for being less available and affordable [2]. These challenges in the quality and availability of gluten-free products reinforce the need for continuing the research and the development in this food segment.

In this context, sensory analysis by regular consumers plays a critical role in GFB characterization. Scientists and producers strive to find the perfect combination of ingredients that deliver appealing taste, texture, and aroma while maintaining a high standard of technological and nutritional quality. This involves a comprehensive sensory evaluation process to ensure that GFBG are as flavourful and attractive as their gluten-containing counterparts. Furthermore, consumers are increasingly interested in local and sustainable food options [3]. This has led to a growing demand for GFB that not only meet dietary intake needs but are also produced locally and environmentally friendly. In this work, the use of Napping® in the description of the sensory characteristics of GFB formulated with novel flours would provide the opportunity to identify the descriptors related to the most

important attributes commonly recognized by the consumers of these products. The objective of the study was to evaluate the global differences and similarities, and the overall acceptability of GFB formulated with alternative flours in regular consumers, with and without gluten-related disorders.

2. Materials and Methods

2.1. Materials

Alternative gluten-free flours were purchase locally: brown rice (Ying Yang, Argentina), rice bran (Cooperative Villa Elisa S.A., Argentina), lupine (Épicos, Argentina), millet (Yin-Yang, Argentina), carob (native species from Argentina, manually collected), quinoa (Aiken, Argentina), sorghum (Celidarina, Argentina), teff (Épicos, Argentina), and buckwheat (Celidarina, Argentina). Other ingredients used in breadmaking were rice flour from long-grain rice (Cooperative Villa Elisa S.A., Argentina), corn starch (Maizena, Argentina), sunflower oil (Natura, Argentina), hydroxypropyl methylcellulose (HPMC; Methocel K4M, Dow Chemical, USA), salt (Celusal, Argentina), sugar (Ledesma, Argentina), and dry yeast (LEVEX, Argentina).

2.2. GFB formulation and preparation

Nine different GFB were formulated using a modified recipe reported by Genevois et al. [4]. where refined flours and starch were partially replaced by alternative flours (20%; (see section 2.1)). Briefly, all ingredients rice flour (22.5%), corn starch (57.5%), alternative flour (20%), sunflower oil (6%), sugar (5%), HPMC (2%), and salt 2% were mixed. Then, the dry yeast (3%) was hydrated in ¼ of the total water volume and mixed with the rest of ingredients using a professional stand mixer (AEB-105, Alhias, China) equipped with a dough hook for 2 minutes at speed 1 (in a scale of 1 to 5 of the mixer). The optimal fermentation time of dough (OFTD) and the optimal hydration level were previously determined to achieve the ¾ increase in dough volume during proofing and the maximum specific volume after baking, respectively. Approximately 200 g of dough were placed into disposable aluminium pans (23x6x4.5 cm) and fermented in a proofing chamber at 30°C, 90% relative moisture (Memmert-HPP 108, Schwabach, Germany) according to the OFTD of each GFB. The breads were baked in an electric convector oven (Beta 21L, Pauna, Argentina) at 180°C for 30 minutes and cooled at room temperature for 1 h. Finally, loaves were packed in sealed polypropylene bags and stored at room temperature (25°C) for 24 h until sensorial analysis were carried out.

2.3. Ultra-Flash Profiling, Projective Mapping (Napping®) and Affective Test

Nine samples of GFB (25 g of each formulation) were evaluated by the panellists in accordance with ISO 8589. Samples were coded with three-digit number and evaluated at room temperature in individual cabinets. The participants of study were randomly recruited from social networks with the following inclusion criteria: 1) age >18 years-old; 2) regular consumers of GFB, with or without gluten-related-disorders. Consumers were instructed to taste each sample of GFB from left to right and clean their mouths with water between samples to avoid carryover effects. They were asked to define each sample using words to describe objective attributes, preventing the use of hedonic descriptors. Then, the panellists were instructed to draw the samples on a sheet (dimensions map of 40cm x 60cm) in a way that distance between them would be perceived as similar or difference. For each consumer map, the X and Y coordinates of each sample were recorded in cm considering the left bottom corner of the sheet as origin of the coordinate system.

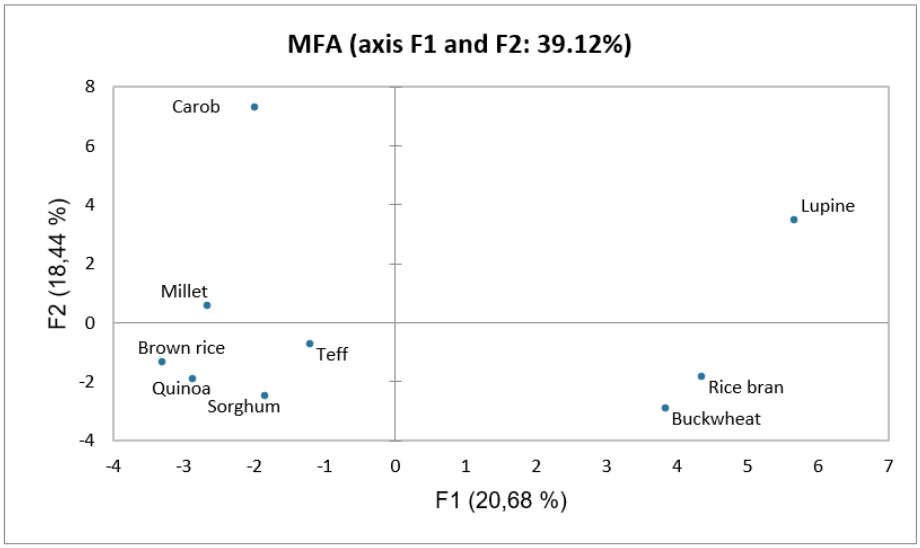
At the end of the projective mapping test, all panellists were asked to complete an affective test for overall acceptance using a 9-point structured hedonic scale (1-dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike a little, 5-neither like nor dislike, 6-like a little, 7-like moderately, 8-like very much and 9-like extremely) for each sample.

2.4. Statistical Analysis

The words defining objective attributes provided by consumers in the projective mapping were first qualitatively analysed following the ultra-flash profiling methodology described by Ares et al. [5]. Terms with similar meaning were grouped into categories and frequency of mention was determined by counting the number of consumers that used those words to describe each sample. The categories mentioned by more than 10% of the consumers were considered in data analysis. The coordinates from the consumer map, considered as active variables and the absolute frequency of sensory descriptors projected as supplementary variables, were analysed using multiple factor analysis (MFA) to obtain the sensorial profile of each GFB [6]. Analysis of variance (ANOVA) was used to determine significant differences between means with a level of significance (α) of 0.05 followed by LSD Fisher *post hoc* test. All statistical analysis was performed using XLSTAT system software (V1.5.1409, 2023, Addinsoft™).

3. Results and Discussion

Thirty-four untrained consumers, where 56% were females and 44% were males between 29 and 70 years-old, and 29% were regular consumers of GFB and 71% were consumers with gluten-related disorders The qualitative analysis of ultra-flash profiling was carried out to unify criteria in relation to the terms suggested by regular consumers of GFB, with or without gluten-related-disorders. Consumers used between one and five words to describe each sample of GFB giving as result seventy descriptors which were grouped into 42 descriptors, the synonyms used by different panellists were combined into one term. The latter were re-grouped in 17 categories to carry out the MFA analysis. In Figure 1 is shown the first two dimensions of the MFA of the projective mapping data for the nine GFB formulated with alternative flours. Meanwhile in Figure 2 is shown the biplot obtained by MFA with all descriptors recorded from sensorial evaluation of GFB with alternative flours. The statistical analysis of MFA localizes the samples based on the results of the projective mapping, and relates the dimensions with the attributes in order to describe which are the responsible for the differences or similarities between the samples (Figure 1 and 2). As can be observed in Figure 1, the sensorial map shows fourth defined groups according to their inherent characteristics along the vertical and horizontal coordinates, suggesting that consumers used all sheet space to place the samples: 1) carob and millet; 2) lupine; 3) rice bran and buckwheat; and 4) rice brown, teff, sorghum and quinoa. The biplot obtained from the MFA explained the 39.12% of the total data variability with the two first axis, where the first dimension (F1) represented the 20.68% and the second dimension (F2) the 18.44% of variability. The resulting sensory space map was built as follows: the GFB formulated with carob flour has a comparatively greater contribution to the observations in F2 than the rest of the samples (59.5%), and it was described with descriptors as *spicy*, *acid* and *intense flavour*. In F1, GFB added with lupine flour has a contribution of 31.9 % and the main descriptors were *moist*, *creamy* and *soft crumb*.



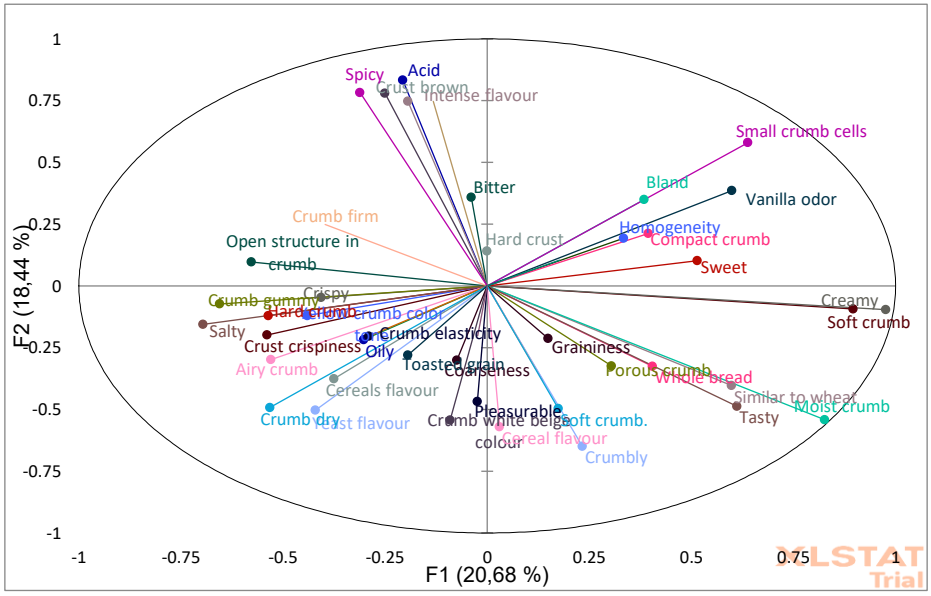


Figure 1. a. Biplot representation of the GFB formulated with different alternative flours (n=9), in the first two dimensions of the MFA of data from projective mapping. **1b**. Biplot representation of the nine samples of GFB formulated with different alternative flours, in the first two dimensions of the MFA of data from projective mapping.

Considering consumer's descriptions, the sensory profile of GFB samples were successfully characterised. GFB elaborated with carob and millet flour were located at negative values of the first dimension (F1) and positive values of the second dimension (F2) characterized mainly for attributes as *acid*, *spicy*, *crust brown*, *crumb firm,* and *open structure in crumb*, and *intense flavour*. The GFB formulated with lupine flour was located at the positive values of the first and second axis (F1 and F2), being its sensory profile characterized by *small cells in crumb*, *vanilla odour* and *sweet*. The third group of samples composed by GFB with rice bran and buckwheat were localized at the positive values of F1 and negative values of F2. These breads were mainly perceived by consumers as *creamy*, *soft*, *moist crumb*, *tasty*, *crumbly* and *similar to wheat*. The last defined group of GFB with quinoa, brown rice, teff and sorghum flours were located at negative values of both axis, being described with sensorial attributes as *salty*, *crumb dry*, *crumb gummy*, *yeast flavour* and *crumb with beige colour*, showing a clearly different sensory profile.

These differences and similarities between samples perceived by the consumers in terms of descriptors could be explained by physicochemical characteristics of GFB formulated with different alternative flours as can be appreciated in Figure 3b. Although the hydration level and optimal fermentation time were optimized to standardize the effect of alternative flour addition and maximize the final quality of GFB, it is important to consider that each flour has different chemical composition, colour, odour and flavour, giving as result a unique sensorial profile. For instance, a study carried out to compare sensorial aspects of industrial and artisanal GFB give as result a significant number of terms that could be obtained in these products. In addition, highlighted that moisture and texture plays a crucial role in how consumers assess GFB and the wide variety of descriptors that could be used to describe them [7]. Another study reported that celiac consumers (N=205) expected a GBF characterised by a soft and moist crumb, tasty, similar to a homemade wheat bread, and with a lower price and better availability [8].

In Figure 3a are shown the mean values corresponding to the overall acceptability of the nine GFB evaluated by the untrained panel (N=34). Is noteworthy that products that obtain high scores in the Affective Test are more likely to be successful in the market [4]. In the present work it was possible to observe that the GFB formulated with alternative flours received a high score in the hedonic test (mean value >6±2). The overall acceptability showed values between 2.9 and 7.3 in a 9-point hedonic scale. The GFB formulated with 20% of carob flour was the sample with the lowest ($p<0.05$) punctuation (2.9±2.5 in the 9-point hedonic scale) and was mainly assessed as *extremely disliked* by the consumers (47%). Meanwhile, the breads formulated with rice bran and buckwheat flours received the highest score (7.3±2.0 and 6.9±1.8 in the 9-point hedonic scale, respectively) and were categorized as *like moderately* by consumers (relative frequency of 34% and 25%, respectively).

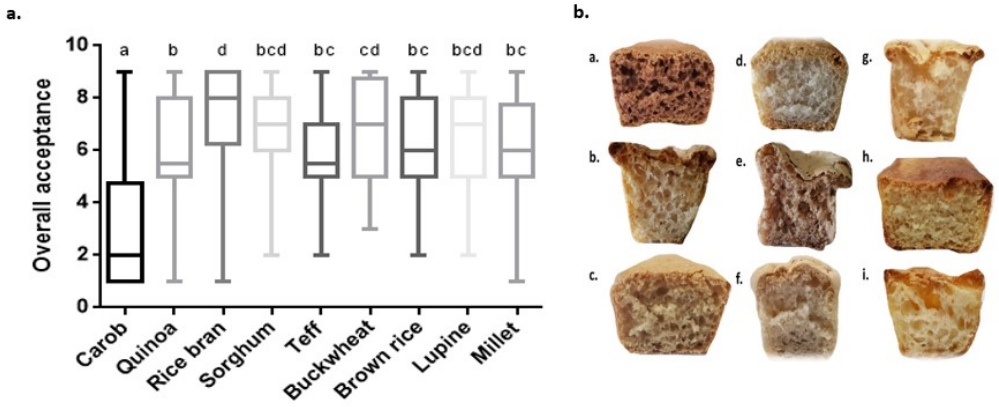


Figure 3. a) Boxplot of the overall acceptability in regular consumers of GFB. Different letters indicate significant differences ($p>0.05$) between mean values of samples. **b)** Gluten-free breads formulated with carob (a), quinoa (b), rice bran (c), sorghum (d), teff (e), buckwheat (f), brown rice (g), lupine (h) and millet (i) flours.

4. Conclusions

The GFB formulated with alternative flours such as the proposed in the present study received a punctuation >6 in a 9-point hedonic scale for overall acceptance, except for the GFB with carob flour. The main descriptors obtained for each alternative flour are based on the opinions and expectations of regular consumers, with and without gluten-related disorders, and have been related to attributes as texture, odour, flavour, colour, alveolar structure and humidity of crumb. The sensorial profile obtained could serve as guide in the successful design of GFBG with good technological and nutritional properties to satisfy the consumer´s expectations. These techniques could also complement the quantitative descriptive analysis in sensorial trained panel in GF baked products.

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Institutional Review Board Statement: the study was conducted in accordance with the Declaration of Helsinki, and approved by Ethics Committee of the Faculty of Bromatology, National University of Entre Ríos, protocol number 2, March 13th, 2023.

Informed Consent Statement: informed consent was obtained from all subjects involved in the study previously to the sensorial evaluation.

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