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Consumer Perception, Nutritional, and Technological Properties of Bread Made with Chickpea Flour

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Abstract

Celiac disease (CD) is one of the most common intestinal diseases in humans today. The only "cure" for this disease is a strictly gluten-free diet. Bread is a highly accepted food product. But, bread is a product that owns its technological properties to the presence of gluten. Bread without gluten has different texture, palatability, and sensorial properties. Therefore, new products are needed to solve this problem. Chickpeas are an inexpensive source of protein for making gluten-free baked goods. In this study, we explored a gluten-free bread formula made with chickpea flour and examined the consumer profile of chickpea bread and its nutritional and technical properties. Results showed that chickpeas could be an alternative raw material for meeting the consumer needs of people who need (or prefer) gluten-free products/diets.

Keywords
Gluten-free; chickpea; functional foods; pulses; grabanzo

1. Introduction

Celiac disease (CD) is one of humas' most common intestinal disorders. Currently, the only effective treatment for CD patients is strict adherence to the gluten-free (GF) diet [1]. Celiacs consume a wide variety of gluten-free foods. However, bread is the most difficult to replace in their diets due to technological shortcomings, especially in texture and volume. Various formulations of this product have been developed to provide dietary alternatives to people with celiac disease [2].

Gluten-free bread is usually made with corn, rice flour, or starch from other sources, such as potatoes and cassava [3]. The specific organoleptic, volumetric, texture and taste characteristics of gluten-free bread and bread and crust characteristics, are the biggest manufacturing challenges. Acceptance of gluten-free bread is not only problematic from an industry perspective, but the product has also been shown to have a shorter shelf life [4]. There is a need to look for alternatives to improve the recipes and quality of gluten-free bread because, in addition to the factors above, the type and variety of gluten-free raw materials used to produce GF bread can certainly affect the properties of the product.

Chickpea (Cicer arietinum L.) is an important pulse cultivated [5] and consumed [6] all over the world. Chickpeas are an inexpensive protein source that contains valuable components such as carbohydrates (40-50 g/100 g), proteins (21-25 g/100 g), fats (4-6 g/100 g), vitamins and minerals [7]. It also has a highly digestible protein and a low glycemic index [8]. In addition, they have a high dietary fiber content, and unsaturated fatty acids such as linoleic acid and oleic acid [9]. Despite the presence of anti-nutritional factors, that can limit protein digestibility and nutrient bioavailability, chickpeas can be used if treated with various physical, biochemical, or heat treatments that increase nutrient levels and remove antinutritive constituents [10].

The objectives of this study are: 1) to develop a recipe for gluten-free bread made from chickpea flour, 2) to study the consumer perception of the formulated gluten-free bread, and 3) to evaluate its nutritional properties.

2. Materials and Methods

2.1 Materials

Commercially available chickpea flour was used for this study. All other materials and reagents were purchased from the market (Cuenca, Ecuador and/or Córdoba, Argentina).

2.2 Methods

2.2.1 Bread Preparation

The bread-making process is shown in Figure 1. The recipe for chickpea bread (CB) used in this study (on a flour-fwb basis) was: 100 g chickpea flour, 25 g egg, 10.5 g milk powder, 6 g caster sugar, 6 g soybean oil, 2 g salt, 0.8 g dry yeast, 0.3 g xanthan gum and 0.3 g carboxymethylcellulose. The bread was fabricated using a lab-scale procedure with the following steps: 1) mixing (Kitchen Aid, Model: Artisan, Argentina) of dry ingredients for 2 min (110 rpm), 2) addition of liquid ingredients and mixing for 4 min (110 rpm) [Steps 1 and 2 are summarized as MIXING INGREDIENTS in Figure 1], 3) panning, 4) proofing 45 min at 35°C (85% relative humidity) (Inox, Model L20, Argentina), and 5) baking 26 min at 150°C (Electrical Oven, Rational, Model SCC WE 101G, Argentina). Wheat bread (WB) was also prepared using standard method 10-10.03 of the AACC [11].

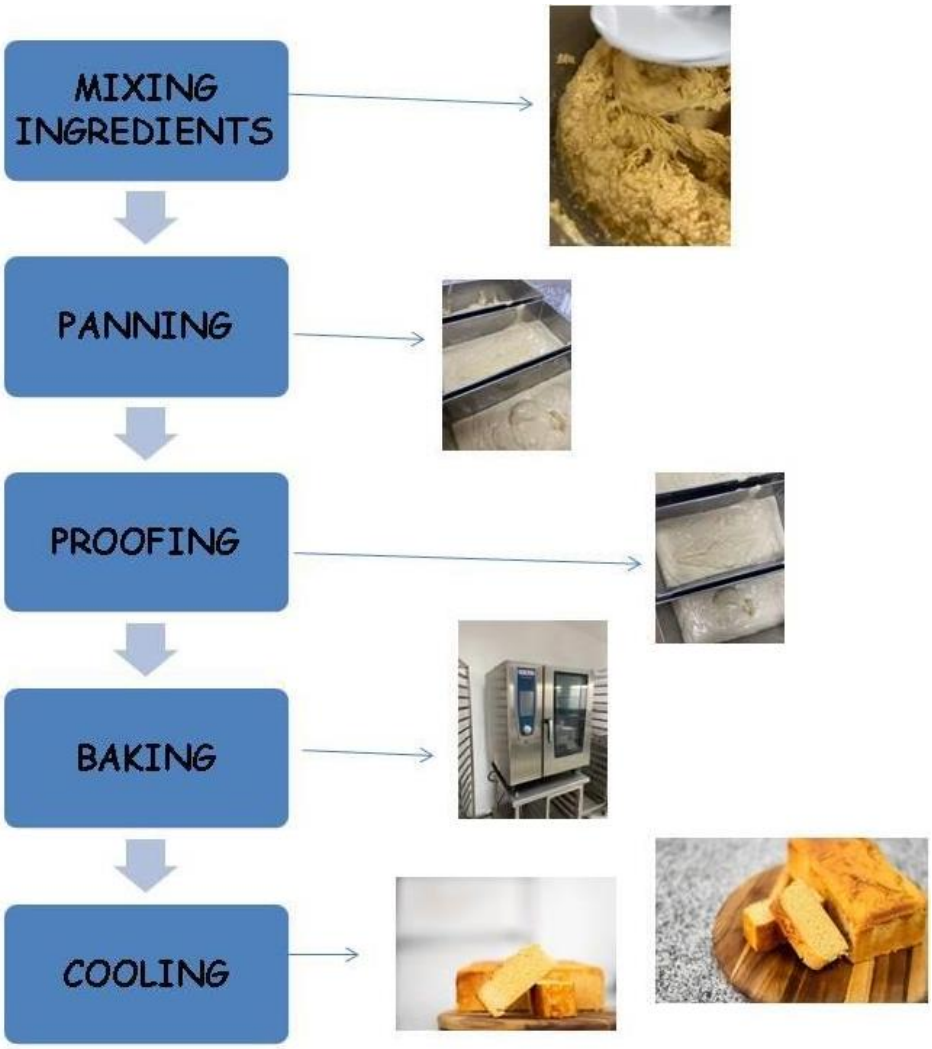

Figure 1 Schematic representation of chickpea bread manufacturing process (details can be read on materials and methods).

2.2.2 Physicochemical Properties

Crude protein, fat, fiber, ash, and moisture content were determined using official methods of the Association of Official Analytical Chemists [12]. The difference determines the carbohydrate content (Carb. Content = 100 - %Moisture - %Protein - %Fat - %Ash).

2.2.3 Physicochemical Characterization

Crude protein content, fat, fiber, and moisture were determined according to the Association of Official Analytical Chemists [12]. Carbohydrate content was determined by difference.

2.2.4 Technological Evaluation of Bread

Twenty-four hours after baking CB and WB were analyzed for: loaf volume (rapeseed displacement method, AACC [11], crumb moisture (weight loss in an oven at 105°C, AACC [11], and crumb firmness using a texturometer (TA. XT *plus*, Stable Micro Systems, United Kingdom), using official methods (# 44–15.02 and 74–09.019) of the AACC [11].

2.3 Sensory Evaluation

CB and WB samples were evaluated by 5 semi-trained panelists who tested the texture, flavor, color, aroma, and overall appearance and acceptability of slices using a 10-cm hedonic scale [13]. Additionally, an online Google Docs web interface was used to perform a word association technique. A total of 208 young consumers took part in the survey. 52.1% of those who responded to the survey were female, and 92% were aged between 18 and 23. No differences due to the effect of gender were observed. Participants were shown a picture of bread made from chickpea flour and instructed to write the first three words, phrases, or concepts that came to mind. Participants were also asked to answer sociodemographic and consumption questions. Experimental procedures involving humans were performed by the ethical principles for medical research involving human subjects of the Declaration of Helsinki.

2.4 Statistical Analysis

The Analysis of Variance (ANOVA) was used to explore the difference between CB and WB using the RStudio and R software [14]. All tests were performed in triplicate (texture measures were obtained in quintuplicate). In the word association test, only valid words relevant to the study were considered for data analysis by calculating the mentioned frequency of each word. Words mentioned by at least 10% of consumers were categorized based on the most important related words. Using inductive coding, words with similar meanings were grouped into different categories [15]. A sensory map of consumer perceptions associated with CB consumption was obtained using principal component analysis of the covariance matrices of the dimensions evaluated [14].

3. Results and Discussion

3.1 Physicochemical Characterization

The chemical composition of gluten-free bread showed statistically significant differences ($p < 0.05$) in moisture content, and protein content (Table 1). The moisture content of both pieces of bread was under 48%. Chickpea bread had higher protein content, approximately 9.7%, while wheat bread was 8.0%. No differences were observed in fat and ash content (Table 1).

Table 1 Physicochemical properties of CB and WB.

155 Physicochemical property	Chickpea Bread (CB)	Wheat Bread (WB)
Moisture (%)	47.44a ± 0.19	46.68b ± 0.04
Ash (%)	2.43a ± 0.03	2.50a ± 0.02
Fat (%)	6.79a ± 0.20	6.97a ± 0.26
Protein (%)	9.97a ± 0.08	8.01b ± 0.05
Available carbohydrates (%)	33.37a ± 0.23	35.84b ± 0.43

3.2 Technological Evaluation of Bread

Table 2 shows the technological properties evaluated for CB and WB. WB had a higher specific volume value than CB. This is directly related to gluten in WB and the lack of gluten in CB. As noted before, the volume of gluten-free bread is one of the main obstacles to the acceptability of gluten-free bread [4]. Crumb firmness was also higher for CB and although statistically significant, the difference was not excessively higher. No statistically significant difference was observed in crumb moisture between both pieces of bread.

Table 2 Technological properties of CB and WB.

	Chickpea Bread (CB)	**Wheat Bread (WB)**
Specific volume (cm^3/g)	**1.80a ± 0.10**	**3.01b ± 0.12**
Crumb firmness (N)	**24.65a ± 1.86**	**19.21b ± 1.55**
Crumb moisture (%)	**50.26a ± 0.55**	**50.35a ± 0.72**

3.3 Sensory Analysis

Five semi-trained panelists evaluated the texture, flavor, color, aroma, and overall appearance and acceptability of CB and WB (data not shown). No significant differences were observed. This evaluation showed no significant differences in the overall appearance and acceptability of CB and WB. The color of CB was well accepted even though it was different from WB. Interestingly, aroma acceptability did not impair the CB aroma. CB samples obtained the lowest acceptability scores in the bread made with chickpea flour. We used the word association test for the chickpea bread because it shows promise for researching consumers' perceptions [16]. A word association test responses are relevant to understand how people make their choices [17]. Totally, 223 words

(significant to the study) were extracted from the test. These words were categorized into six dimensions (sensory-related, hedonic-related, food-related, health/nutrition-related, consumer-related, and unknown). Frequencies of mention of the dimensions and categories were calculated. Table 3 shows the results of such analysis.

Table 3 Frequency of mentions of the word association test.

Dimension	Categories	Frequency (%)
Sensory-related	Appearance (color, size, yellow, intense color)	
	Texture (soft, dense, crumbly)	61.4
	Characteristics (fluffy, light, pale, short)	
Hedonic-related	Positives (lovely, appetizing, tasty)	24.1
	Negatives (ugly, tasteless, colorless, looks weird)	
Food-related	Food (bread, gluten free, flour, cake, muffin, gluten)	8.1
Health/nutrition-related	Physiological (well-being, health, healthy, nutritious)	3.0
Consumer-related	Consumer (coffee, tea, butter, fruit jam, sweet)	2.6
Not known	Unknown (strange, different)	0.4

Individually, the most frequently mentioned words were soft, with a frequency of 20.0%, followed by dense (14.5%), tasty (13.2%), yellow (12%), crumbly (11.9%), and healthy (4%). As observed, all of these words are related to the quality characteristics of bread and baked goods.

The dimension "sensory-related" had the highest frequency of mention by participants in the word test. Words describing the texture, appearance, and properties of the bread are the most frequently mentioned when looking at the product image. Thus, consumers have these properties very present when trying a bread product. The absence of gluten directly affects crumb, crust and volume properties. The word test confirms that consumers of GF-bread therefore find these properties very important for the quality of the final product.

Words associated with the dimension “hedonic related” were the second most frequently mentioned (Table 3). In this dimension we found positive attitude/feeling words and negative attitude/feeling words. Positive words highlighted presumably positive aspects related to the improvements in the bread's characteristics due to using chickpea flour. The negative words could be seen as drawbacks implicit in a gluten-free product (as seen by consumers) due to avoiding products made from pulses and non-cereal grains which are uncommon in bread manufacture. Within the “food-related” dimension (third most frequently mentioned), the terms that appeared the most were “bread, “flour," and “gluten-free." The consumer-related dimension had words related to consumption, that is, how panelists perceive how the CB could be consumed, perhaps with butter, fruit jam, and coffee.

Figure 2 shows the principal component analysis performed in the covariance matrix of the mean values of the dimensions evaluated by the participants. The two components explained almost 100% of the variation, with Factor 1 responsible for 91.69% and Factor 2 for 8.01%.

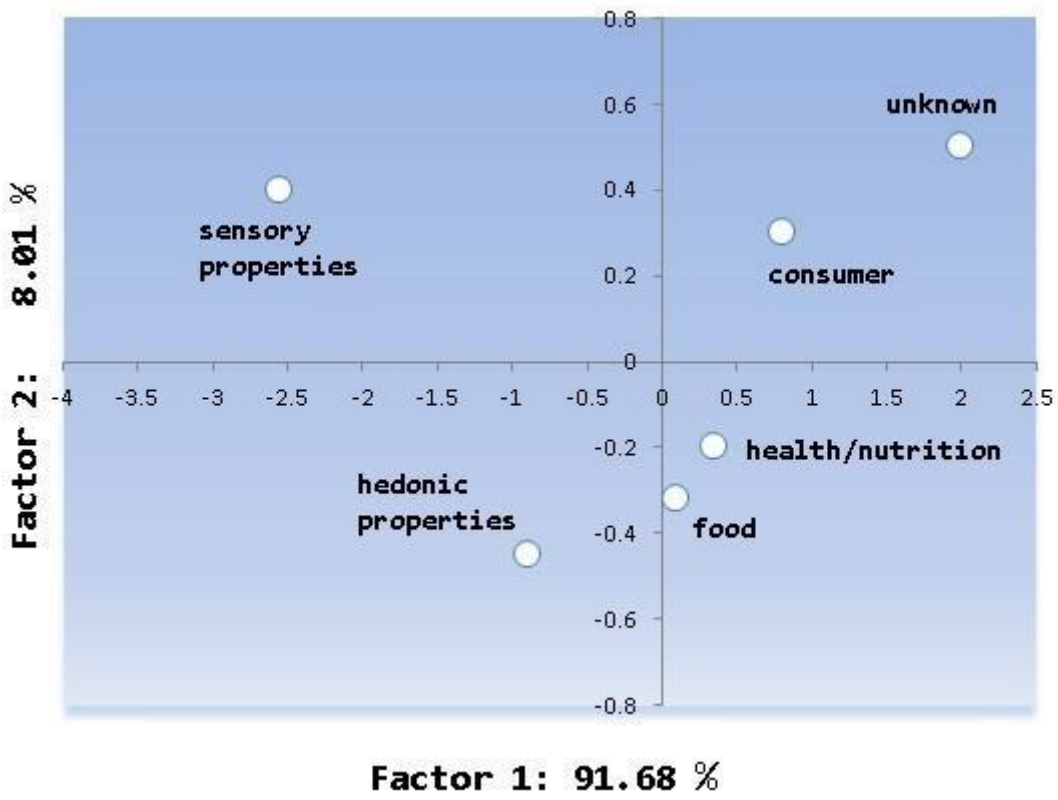

Figure 2 Principal component analysis.

Using the scatter plot, we can visualize the relationship between the dimensions classified by word associations (Figure 2). Consumption of gluten-free goods is more closely linked to product knowledge than to sensory qualities (appearance and texture) and hedonic attitudes (positive and negative aspects). These traits are negatively correlated because consumers with celiac disease tend to consume gluten-free foods and believe these foods have undesirable qualities, especially in volume and texture [2].

4. Conclusion

Demand for new, better-tasting, healthier gluten-free bread varieties is rising. This study investigated a gluten-free bread formulation made with chickpea flour (CB). This CB formulation resulted in bread with good acceptability and palatability, higher firmness and less specific volume than wheat bread. All these changes were expected when making bread with no gluten. We made a word association test to study the consumer perception of our CB formulation. We found that the most frequently mentioned words were soft (20.0%), followed by dense (14.5%), tasty (13.2%), yellow (12%), crumbly (11.9%), and healthy (4%). The sensorial-related characteristics were the most elicited in the word association test meaning that consumers of gluten-free baking products place high importance on these organoleptic properties. Second in importance were the hedonic-related properties. We also think that the incorporation of materials such as chickpea flour in

gluten-free breadmaking needs to be further investigated but results from this study show that chickpea flour could be an alternative for meeting the consumer needs of people who need (or prefer) gluten-free products/diets.

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Author Contributions

Dr. Aguirre, Dr. El Khori, and Dr. Borneo contributed equally to the design, data collection, statistical analysis, data discussion, funding, and writing of this work.

Competing Interests

The authors have declared that no competing interests exist.

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