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Whole chickpea flour as an ingredient for improving the nutritional quality of sandwich bread: Effects on sensory acceptance, texture profile, and technological properties

Harina integral de garbanzos como ingrediente para mejorar la calidad nutricional del pan para sándwich: efectos sobre la aceptación sensorial, el perfil de textura y las propiedades tecnológicas

ABSTRACT

The inclusion of pulse flours with higher dietary fiber content in bakery products, such as chickpea (*Cicer arietinum* L) flour, has been exploited by the food industry due to its nutritional and sensory characteristics. This work aimed to develop a sandwich bread with a partial substitution (7.5%, 15%, and 30%) of refined wheat flour by whole chickpea flour (WCF) and also to evaluate the effects on sensory acceptance, physicochemical parameters, and texture profile during the shelf life. Four methods for obtaining WCF were assessed and the best condition was used to produce the sandwich bread. Sensory evaluation was carried out with 65 consumers using a 9-point hedonic scale and a purchase intention scale. Firmness, elasticity, cohesiveness, chewability, and fracturability was evaluated by the Texture Profile Analysis (TPA). The specific volume, total fungi count, pH, titratable acidity, and moisture content were also determined. The nutritional composition was estimated by mass balance. Data demonstrated that there was no difference ($p>0.05$) in sensory evaluation of the products elaborated with different concentrations of WCF, and all samples presented good acceptance. The addition of WCF did not cause negative effects on the texture and volume characteristics of the bread. The sample with 30% WCF had adequate technological characteristics, resulting in a product with higher nutritional value, especially dietary fiber, and was well accepted by the consumers. This formulation can be used by the food industry and also in domestic preparations, contributing to the diversification and nutritional enrichment of sandwich bread.

Keywords: Baking; Chickpea flour; Sensory analysis; Stability; Texture profile.

RESUMEN

La inclusión de harinas de granos no convencionales con mayor contenido de fibra dietética en productos de panadería, como la harina integral de garbanzo (HIG) (*Cicer arietinum* L), es utilizada por la industria alimentaria debido a sus características nutricionales y sensoriales. Este trabajo tuvo como objetivo desarrollar un pan para sándwich (PPS) con sustitución parcial (7.5%, 15% y 30%) de harina de

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trigo refinada por HIG así como evaluar la aceptación sensorial, parámetros físicoquímicos y el perfil de textura durante su vida útil. Fueron evaluados cuatro métodos para la obtención de HIG, utilizándose la mejor condición para producir el PPS. Sesenta y cinco consumidores realizaron la evaluación de aceptación sensorial e intención de compra con una escala hedónica de 9 puntos. La firmeza, la elasticidad, la cohesión, la masticabilidad y la fracturabilidad se evaluaron mediante el análisis de perfil de textura (TPA). También se determinó el volumen específico, el recuento total de hongos, el pH, la acidez titulable y el contenido de humedad. La composición nutricional se estimó por balance de masa. Todas las muestras presentaron buena aceptabilidad sin diferencias estadística. La adición de HIG

no causó efectos negativos en la textura ni el volumen del PPS. La muestra con 30% de HIG tubo características tecnológicas adecuadas, resultando en un producto con mayor valor nutricional, especialmente por la fibra dietética. Esta formulación podría ser utilizada por la industria alimentaria y también en preparaciones domésticas, contribuyendo a la diversificación y al enriquecimiento nutricional del pan para sándwich.

Palabras clave: Análisis sensorial; Estabilidad; Harina de garbanzos; Panadería; Perfil de textura.

INTRODUCTION

The classic sandwich bread is a traditional bakery product made with refined wheat flour and is widely accepted by different consumers. However, the search for a better life and changing consumer's behavior with respect to the nutritional quality of industrialized products have been increasing the demand for bakery products with whole ingredients, especially those with a higher content of dietary fiber^{1,2}. As a result, the food industry has sought to study possible whole flours that can partially replace refined wheat flour in bakery products, but without altering the sensory and technological characteristics desired by consumers³.

In this context, the inclusion of pulse flours, such as chickpea (*Cicer arietinum* L), in bakery products has been exploited due to its nutritional quality, good sensory characteristics, and adequate technological properties that allow its addition in bakery formulation⁴. Chickpea is the third most-produced grain legume worldwide⁵, is rich in dietary fiber, proteins, essential amino acids, such as lysine and tryptophan, and bioactive compounds⁶.

Chickpea flour has about 58% total carbohydrates, 21% protein, and a high level of dietary fiber (12.4%), and minerals (3.2%)^{7,8}. B-type saponins are presented at high levels and are associated with a decrease in cholesterol absorption⁹. Depending on chickpea variety, it can have 40% of resistant starch and up to 60% of Slowly Digestible Starch (SDS)¹⁰, resulting in a low glycemic index. Therefore, it is an interesting option for consumers with diabetes mellitus, cardiovascular diseases, and metabolic syndrome¹¹.

Different types of chickpea flours can be produced, such as whole, germinated, and fermented, as described by Shrivastava and Chakraborty¹². After grain processing, the particle size of chickpea flour must be standardized through sieves with a specific mesh, resulting in a flour able to form a cohesive dough which can be introduced in the formulation of various bakery products, such as bread¹³, pasta¹⁴ and extruded products¹⁵.

However, whether such modifications in product formulation lead to negative sensory and technological changes should be evaluated, which can be done either by sensory methods with consumers or by instrumental methods. In this sense, the texture profile analysis (TPA) has been widely used to evaluate quality attributes that directly interfere with food acceptance. Through TPA it is possible to obtain fast results on firmness, elasticity, cohesiveness,

chewability, among other properties, making it adequate for the characterization of new food products^{16,17}.

This work aimed to develop a more nutritious sandwich bread with partial substitution of refined wheat flour by whole chickpea flour and to evaluate its sensory acceptance, nutritional composition, texture profile, and shelf life.

MATERIAL AND METHODS

Materials

The chickpea (*Cicer arietinum* L.) grain and other ingredients such as salt (União), sugar (União), refined wheat flour (Badotti), maize starch (Pachá), biological instant dry yeast (Fleischmann), powdered milk (Itambé), margarine (Qualy), emulsifier (Emustab), and calcium propionate (Fleischmann) used for bread formulation were purchased from the local market.

Chickpea grain processing

Four methods for processing chickpea grains to produce whole chickpea flour (WCF) were tested: F1: grinding of raw grains followed by sieving through a 10 mesh stainless steel sieve (1.70 mm); F2: grinding of raw grains followed by roasting in a stainless steel pan for 10 min, followed by sieving (1.70 mm); F3: immersion of the grains in water (5 °C; 3 parts of water: 1 part of grains) for 12 h and then drying at 180 °C for 1 h in an electric oven (G.PANIZ FTE 120) followed by grinding and sieving (10 mesh) and; F4: immersion of the grains in water (5 °C) for 12 h, followed by cooking at 121 °C for 15 min and then drying at 180 °C for 1 h, followed by grinding and sieving (10 mesh). Such conditions were evaluated because Brazilian consumers use them in domestic preparations of chickpea grains. It was verified which condition was more applicable in the production of WCF, considering the practicality of the process and the flavor and aroma of the flour (evaluated by the authors in a non-statistical way).

Sandwich bread production

For bread formulation, three different concentrations of whole chickpea flour (WCF) were tested, replacing 7.5%, 15%, and 30% of refined wheat flour (samples B1, B2, and B3, respectively). A control sample (C), without WCF, was also produced. Table 1 shows the ingredients and quantities used for the preparation of 800 g dough, which produced a 680 g bread after baking.

The production occurred manually, as follows: the yeast was activated by the formation of an aqueous paste composed of yeast, sugar, and part of the flour. This mixture was placed in a B.O.D. oven at 33 °C for 20 min. Afterward, the remaining ingredients were added and the dough was developed. Salt, margarine, and WCF were incorporated into the dough at the end of the process. The dough was fermented at 33 °C for 15 min and then was molded manually with a cylinder and added to a rectangular loaf pan with cover, performing a second fermentation at 33 °C for 30 min. The products were baked in the electric oven

Table 1. Formulations of sandwich bread (%)*.

Ingredients	BC	B1	B2	B3
Refined wheat flour	50.2	46.4	42.7	35.1
WCF	----	3.8	7.5	15.0
Maize starch	3.8	3.8	3.8	3.8
Cold mineral water	37.5	37.5	37.5	37.5
Salt (NaCl)	1.0	1.0	1.0	1.0
Sugar (crystal)	1.5	1.5	1.5	1.5
Biological instant dry yeast	1.0	1.0	1.0	1.0
Powdered milk	1.5	1.5	1.5	1.5
Margarine	2.5	2.5	2.5	2.5
Bread improver (ascorbic acid and alpha amylase)	0.5	0.5	0.5	0.5
Emulsifier	0.5	0.5	0.5	0.5
Calcium propionate	0.1	0.1	0.1	0.1
Total dough	100	100	100	100

*Control (BC) and samples elaborated with partial substitution of wheat flour by whole chickpea flour with 7.5% (B1), 15% (B2) and 30% (B3).

(G.PANIZ FTE 120) at 160 °C for 30 min, then the covers were removed and kept at 180 °C for 10 min.

Nutritional composition estimation

The nutritional composition of control and WCF bread were calculated by mass balance using Dietwin® software. Data on nutritional composition data of each raw material used, as well as the quantities and yields of the process were entered into the software.

Sensory evaluation

Sensory tests were previously approved by the Research Ethics Committee of the Federal University of São João del-Rei (CAAE: 96380118.8.0000.5151) and were performed to select the WCF bread with the best acceptability. Samples C, B1, B2, and B3 (sliced to be approximately 15 g) were served on three-digit coded disposable dishes and presented in a random order, according to Stone and Sidel¹⁸.

A sensory acceptance test was performed with 65 consumers to determine if there was a difference among samples and which one was more accepted ($p < 0.05$). For this, consumers were asked to respond to a nine-point hedonic scale ranging from 1 ("extremely dislike") to 9 ("extremely like") for the following attributes: color, aroma, texture, flavor, and overall acceptance. A purchase intention scale ranging from 1 ("I would certainly not buy") to 5 ("I would certainly buy") was also applied. Sensory acceptance was used as a criterion for selecting the best formulation, and this formulation was then used in the study of product stability.

Evaluation of bread stability during storage

Physicochemical and microbiological stability were evaluated until 15 days of storage. For this, total fungi count, pH, titratable acidity, and moisture content were performed one day after bread production (Time 1: T1), on the seventh day of storage (T2), and the 15th day of storage (T3). Texture profile analysis and specific volume were also evaluated on the first and 15th day of storage.

Physicochemical analyses

Analyses were performed in triplicate according to the procedures of the Adolfo Lutz Institute¹⁹. pH was determined using benchtop potentiometer (GEHAKA PG 2000) (method 17/IV). Total titratable acidity according to the method 016/IV, using 0.1 NaOH solution. Moisture was determined in an automated infrared moisture analyzer (OHAUS MB35) at 105 °C until constant weight.

Texture Analysis and specific volume

The texture profile was evaluated using a Texturometer (TA.XT plus, Stable Micro Systems), according to AACC method 74-09²⁰ with six repetitions, using a 36 mm diameter cylindrical probe (P/36R), a 50 kgf load cell and two slices of bread (2.5 cm thickness) with double compression at 1.66 mm s⁻¹. Firmness, elasticity, cohesiveness, chewability, and fracturability were evaluated.

The specific volume of bread was measured in triplicates, according to AACC method 10-05.01²¹ (rapeseed displacement method), using proso millet seeds. Results were expressed as cm³ g⁻¹.

Total fungi count

The fungal count was analyzed in duplicates using 25 g samples, as described in Trombete et al²². Surface plating was carried out in acidified PDA agar, with 0.1 mL inoculum. Plates were incubated without reversing at 25 °C for five days in a B.O.D. incubator. After this period, total colonies were counted and results were expressed in CFU g⁻¹ of bread.

Statistical analysis

Data were evaluated by descriptive statistics, ANOVA and Tukey test, at 5% probability level, using Sisvar 5.0 software.

RESULTS

WCF obtained from F1 and F2 processing methods presented an undesirable aroma of “raw grains” (not experimentally evaluated), which remained in the bread after baking. F3 method produced a flour with pleasant aroma and flavor and was easy to be applied. The chickpea flour obtained from F4 also had pleasant aroma and flavor, but it was considered more difficult to produce. In this way, the WCF selected for bread making was obtained from the F3 method. From this flour were produced three formulations of bread: B1, B2, and B3 (7.5%, 15%, and 30% of WCF, respectively). Figure 1 shows the loaf bread slices obtained from the three formulations.

The sensory evaluation by hedonic scale demonstrated that there was no difference ($p>0.05$) between samples for color, aroma, taste, and texture. In this way, all samples formulated with whole chickpea flour were widely accepted. The overall acceptance for all attributes was located between 7 and 8, which corresponds to the terms “Like Moderately” and “Like Very Much”. The purchase intention also did not differ ($p>0.05$) for the three products and was equivalent to the term “I would

probably buy”. As there was no difference between samples in sensory acceptance, the B3 formulation (30% WCF) was selected for the continuation of the study because it had more WCF in its composition.

When comparing the nutritional value of the control sample (without WCF) and B3 sample (with 30% of WCF), B3 had higher values of protein and fiber content. Dietary fiber was more than two times higher than control, as presented in table 2.

Data obtained from moisture content, pH, total titratable acidity, and total fungi count are shown in table 3. The pH value and moisture content showed no difference ($p>0.05$) between samples, and the total titratable acidity was higher in the 30% WCF sample. The values of total fungal count showed that all samples had a low presence of yeasts and molds. The highest total fungal count corresponded to 5.4×10^3 CFU g⁻¹ (after 15th days of storage), demonstrating that the good manufacturing practice procedures used in the preparation of loaf bread allowed to obtain products with good hygienic quality.

Firmness did not differ ($p>0.05$) between the control and 30% WCF sample, but it was higher ($p<0.05$) on the 15th day for both samples, demonstrating that they became harder over time, which was expected due to the retrogradation of starch. Springiness and chewiness did not differ between samples ($p>0.05$), and cohesiveness was lower in both control and 30% WCF sample after 15 days of storage, indicating that the samples become more fragile over time. The texture profile is shown in figure 2.

The specific volume and texture characteristics observed during shelf life are presented in table 4. Specific volume was similar in both samples ($p>0.05$), but after 15 days of storage, the products had less volume than on the first day of storage, demonstrating that shrunk in volume.

Figure 1: Sandwich bread developed with partial replacement of wheat flour by whole chickpea flour (WCF) a) B1 (7.5% of WCF); b) B2 (15% of WCF) and; c) B3 (30% of WCF).

Table 2. Nutritional information of sandwich bread (control sample) and elaborated with 30% of whole chickpea flour.

Nutritional Information				
50 g portion (2 slices bread)	Control		30% WCF	
	Amount per serving	%DV (*)	Amount per serving	%DV(*)
Energy	121 kcal= 508 kJ	6%	124 kcal= 521 kJ	6%
Carbohydrates	25 g	8%	24 g	8%
Protein	3.7 g	5%	4.6 g	6%
Total fat	0.7 g	1%	1.1 g	2%
Saturated fat	0.25 g	1%	0.32 g	1%
Trans fats	0 g	**	0 g	**
Total dietary fiber	0.73 g	1%	1.61 g	6%
Sodium	233 mg	10%	233 mg	10%

*Daily values based on a 2000 kcal or 8400 kJ diet. Your values may be higher or lower, depending on energy needs. **%DV not established. 1.

Table 3. Average results (mean $\pm$ standard deviation) from physicochemical and microbiology analysis of sandwich bread control (BC) and elaborated with a partial substitution (30%) of wheat flour by whole chickpea flour.

Samples	Days	Parameters analyses			
		Moisture (%)	pH	Acidity (mL NaOH 0,1 M)	Microbiology
Control	Day 1	37.3a	5.74a	2.93b	<1.0 x 10 ¹ UFC/g
	Day 7	37.8a	5.71a	2.60b	3.3 x 10 ³ UFC/g
	Day 15	37.0a	5.55a	2.96b	5.4 x 10 ³ UFC/g
Bread with 30% FW	Day 1	36.7a	5.85a	4.63a	<1.0 x 10 ¹ UFC/g
	Day 7	36.5a	5.79a	3.53a	<1.0 x 10 ¹ UFC/g
	Day 15	37.2a	5.46a	4.00a	4.5 x 10 ² UFC/g

Mean followed by different letters in the same row indicate a significant difference ($p < 0.05$) between the control sample and WCF sample (for the same day of analysis). WCF: Whole Chickpea Flour. *Limit of quantification: 1.0 x 10¹ CFU g⁻¹.

Figure 2: Texture profile (force x time) of sandwich bread (Control) and made with partial substitution of wheat flour by 30% of whole chickpea flour (WCF 30%).

Table 4. Texture profile analysis of sandwich bread control (C) compared with 30% whole chickpea flour samples (30% WCF).

Parameter	Sample*	Day 1	Day 15
Firmness (N)	C	993 ± 28 ^b	1916 ± 157 ^a
	30% WCF	925 ± 188 ^b	1633 ± 231 ^a
Springiness	C	0.79 ± 0.02 ^a	0.75 ± 0.07 ^a
	30% WCF	0.80 ± 0.04 ^a	0.84 ± 0.15 ^a
Cohesiveness	C	0.53 ± 0.02 ^a	0.30 ± 0.07 ^b
	30% WCF	0.56 ± 0.02 ^a	0.31 ± 0.05 ^b
Chewiness	C	422 ± 47 ^a	429 ± 4 ^a
	30% WCF	439 ± 65 ^a	412 ± 59 ^a
Specific volume (mL/g)	C	3.77 ± 0.04 ^a	3.36 ± 0.01 ^b
	30% WCF	3.71 ± 0.04 ^a	3.31 ± 0.02 ^b

Means followed by different letters in the same line indicate significant differences ($p < 0.05$) between samples.

DISCUSSION

The production of whole chickpea flour using hydration of the grains followed by drying in the oven showed to be appropriate heat treatment for the preparation of sandwich bread. Alajaji and El-Adawy⁸ showed that other methods for cooking chickpea grains can also be used, such as microwave cooking, which can reduce cooking time and also increase in-vitro protein digestibility of grains.

Regarding the higher fat content of the developed formulation (30% WCF) compared to the control, it should be emphasized that chickpea grains have a higher total lipid content than refined wheat flour⁷, which justifies this result. According to Hidalgo et al²³, legumes have a disreent lipid content but chickpea grain has the highest value, up to 7%, while fiber content can vary widely, from 1 to 38%.

The higher content of dietary fiber and protein is also interesting from a nutritional point of view, as the quality of bread was improved, which can be better explored by the food industries. Similar results were reported by Man et al²⁴ in a study with partial replacement of wheat flour by different concentrations of chickpea flour (from 0 to 30%) in bread production. The authors concluded that such substitution also increased the values of protein and fiber content, however decreased the volume of bread due to the dilution of gluten content.

Regarding the technological characteristics of the product developed in the present study, it was possible to obtain bread added with WCF without affecting the texture and volume characteristics. As demonstrated by Du et al²⁵, chickpea flour has adequate characteristics for bread production, such as good water and oil absorption and low capacity of retrogradation.

About the texture proprieties, it was observed that firmness increased over the storage time. The high hardness value obtained on the 15th day demonstrates that the products should be consumed as close as possible to the production date when the texture is soft and well accepted by the consumers. As explained by Eliasson²⁶ the starch can undergo a phenomenon called retrogradation, where the amylose and amylopectin molecules are re-associated in a more orderly state, forming crystalline areas with consequent expulsion of water molecules (syneresis) and hardening of the bread structure.

Other authors who studied the addition of chickpea flour in bread formulations reported that the partial replacement of wheat flour by chickpea flour promotes rheological changes in the dough. Mohammed et al¹³ evaluated such substitution at 10, 20 and 30% and concluded that the higher the concentration of chickpea flour, the higher the water absorption and time of dough development, while the extensibility and resistance to deformation decrease since such flour has no gluten. Shrivastava and Chakraborty¹² also used chickpea flour in bread making; however, a flour fermentation process was applied for 83 h using different blends of wheat flour and chickpea flour, resulting in a loaf bread nutritionally better when compared to the loaf bread made only with wheat.

CONCLUSION

The substitution of 30% of refined wheat flour by whole chickpea flour is an interesting option for producing a more nutritious sandwich bread, with higher values of protein and dietary fiber, and was well accepted in the sensory evaluation. The addition of WCF did not cause negative effects on the texture and volume characteristics of the bread. The sandwich bread produced with WCF should be consumed as close as possible to the manufacturing date when the texture is soft and well accepted by consumers. The developed formulation can be used by the food industry and also in domestic preparations, contributing to the diversification and nutritional enrichment of sandwich bread.

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