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Improving bread-making processing phases of fibre-rich formulas using chia (*Salvia hispanica*) seed flour

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Abstract

The capacity of chia seed flour to improve the behaviour of wholemeal formulas of wheat bread during the bread-making process was tested. Seven formulas were produced: one employing only wheat flour (control), two formulas substituting 13% and 23% (d.b.) of wheat flour with bran (wholemeal), and these last two bran formulas were combined in turn with chia, in which substituting 5% and 10% (d.b.) of their wheat flour fraction. The fermentation phase improved. Chia led to an increase in the gas retention of dough with 13% of bran, and height was reached with no differences compared to the refined wheat dough. Water retention did not show differences between formulas after the baking phase. The 13% bran/5% chia formula generated breads with 12% fibre content (w.b), but no differences were found in specific volume and similar hardness to the refined wheat ones. Finally, this bran/chia combination, which showed no differences during the bread-making process with the refined wheat formula, was tested for sensory attributes. No significant effect was detected on the sensory attributes compared to the same wholemeal formula without chia flour. Chia modified the properties of wholemeal doughs, which improved the bread making process and produced bread with no deterioration in sensory attributes.

Keywords: bread-making processing, fibre-rich formulas, chia, improvement

1. Introduction

Increased dietary fibre intake is an important indication by Health Authorities because of the displacement of population dietetic habits to high-fat and refined carbohydrate content products, in addition to animal source products (Dhingra, Michael, Rajput, & Patil, 2012). This behaviour leads to higher calorie inputs and poor nutritional contributions (López-Azpiazu et al., 2003). Such dietetic dynamics have been catalogued as one of the main contributors to increase the risk of suffering several health diseases, such as type II diabetes mellitus, hypercholesterolaemia, hypertension, obesity, atherosclerosis, and colon cancer (Dorner & Rieder, 2004; Retelny, Neuendorf, & Roth, 2008). Incremented daily fibre intake have been closely related with reduced coronary diseases as they modify blood lipid profiles, lower blood pressure and reduce glucose concentrations because intestinal absorption slows down (Wu et al., 2014). Thus enriching the fibre content of food products which small amounts of fibre natively is becoming an important process in the food production industry (e.g., refined flours bakery, drinks, beverages, dairy and meat products) because it improves nutritional input and the value of products, and contributes to competitiveness.

Notwithstanding, incorporating fibre content into pre-established product formulas brings about major changes in the production chain and end product properties. These changes should be taken into account when designing strategies to modify processes and formulas in order to obtain high-content fibre products with as few differences as possible compared to the original versions of the same products. Indeed the main affected features are those related with physicochemical properties, such as rheological behaviour, heat conductivity, water retention and activity, consistency, texture parameters, colour, etc. (Bortnowska et al., 2016). Therefore, the study of the impact that incorporating fibre compounds into product formulas has on the processing variables and end product features is a relevant experimentation and development area. Numerous studies have been conducted into bread as a specific product given its importance in total daily food intake. From a technological viewpoint, increasing fibre content impacts properties such as the gas retention capacity of doughs during fermentation, the specific volume of breads, crumb texture properties, mass loss during baking, sensory properties, etc. (Wang, Rosell, & Benedito de Barber, 2002). Most of these problems are related mainly with reduced gluten amounts and difficulties in gluten-network formation in the mixing phase (Pasqualone et al., 2017).

In order to correct these alterations, addition of hydrocolloids of different origins is an extensive research area. The most widely used ones include xanthan gum, guar gum, HPMC, carrageenan, pectin, agarose, etc., which have been employed to improve both dough and bread properties (Mir, Shah, Naik, & Zargar, 2016). Properties such as consistency, elasticity, strength of gas cells, and elasticity of doughs have been improved (Ronda, Perez-Quirce, Lazaridou, & Biliaderis, 2015). In the same way, bread properties such specific volume, mass loss and crumb texture, among others, have also been enhanced (Sciarini, Ribotta, León, & Pérez, 2012). The use of hydrocolloids as an isolated compound is common in the most of them. However, several authors have utilised natural sources, such as seeds, to exploit the nutritional profile of the entire biological system. Some examples are wholemeal oat flour, tamarillo *(Solanum betaceum Cav)*, *Lepidium sativum* seeds, etc. (Gannasin, Adzahan, Mustafa, & Muhammad, 2016; Sahraiyan, Naghipour, Karimi, & Davoodi, 2013). Chia (*Salvia hispanica*) seeds present an interesting chemical profile for the above objectives.

Chia is an annual herb of the *Labiatae* family, was one of the basic nourishments of Central American civilisations in pre-Columbian times (Ayerza & Coates, 2011), and its consumption provides numerous health benefits given its nutritional profile for essential fatty acids, protein and bio-active peptides, antioxidants, minerals and dietary fibre (Marineli et al., 2014). In line with this, one of the most important aspects of these seeds is fibre content, which includes a polysaccharide gum with high-molecular-weight mucilage. It has been proposed that the structure of the basic mucilage unit is a tetrasaccharide with 4-O-methyl-a-D-glucoronopyranosyl residues, which occurs in branches of b-D-xylopyranosyl in the main chain (Lin, Daniel & Whistler, 1994). This compound has a high water-holding capacity and forms an active hydrocolloid, which has provided interesting results for the above-mentioned objectives (Iglesias-Puig & Haros, 2013; Verdú et al., 2015). Thus the aim of this work was to test the capacity of chia seed flour to improve the bread-making process of fibre-rich dough and end product properties.

2. Material and methods

2.1 Raw materials

The commercial refined wheat flour that we used was obtained from a local producer (Molí del Picó-Harinas Segura S.L. Valencia, Spain). The alveographic parameters were facilitated by the company, which were P = 94±2 (maximum pressure (mm)), L = 128±5 (extensibility (mm)), W = 392±11 (strength (J-4)) and 0.73 of P/L. The fibre source was a commercial wheat bran format (Vegetalia, Barcelona). The black chia seeds flour was obtained from a commercial seed format (BIOCESTA S.L., Valencia Spain) by milling in a stainless steel grinder (Retsch GmbH, ZM 200, Haan, Germany). The proximate compositions of flours are included in Table 1. All the proximate composition analyses were based on ICC (International Association for Cereal Science and Technology) standards 110/1, 156, 136, 105/2 and 104/1 for moisture, dietary fibre, fat, protein and ash, respectively.

Table 1. Proximate composition of flours.

flours	X_p	X_l	X_w	X_a	X_f
pure wheat	0.147±0.06	0.01±0.001	0.14±0.005	0.003±0.001	0.002±0.001
bran	0.151±0.07	0.04±0.002	0.10±0.005	0.035±0.01	0.42±0.026
chia	0.02±0.01	0,30±0,09	0,08±0,003	0,041±0,08	0,31±0,01

X_p: protein content; X_l: fat content; X_w: moisture content; X_a: ash content; X_f: fibre content. Data expressed in g of component/g of flour on a wet basis.

2.2 Bread-making process

Several flour mixtures were prepared with refined wheat flour, which was substituted by using chia flour and wheat bran, as indicated in Table 2, following the formulas of Curti et al., (2013). The control formulation used to prepare dough was based on Verdú et al., (2015) as follows: 56% flour, 2% refined sunflower oil (maximum acidity 0.2º Koipesol Semillas, S.L., Spain), 2% commercial pressed yeast (*Saccharomyces cerevisiae*, Lesafre Ibérica, S.A., Spain), 4% white sugar (≥ 99.8% of saccharose, Azucarera Ebro, S.L., Spain), 1.5% salt (refined marine salt ≥ 97% NaCl, Salinera Española. S.A., Spain) and water 34.5% (w/w). Due to the differences in moisture content between wheat bran and chia, the amount of added water varied for each formulation so that the ratio between total moisture (provided by wheat flour, wheat bran, chia and added water) and dry matter (provided by wheat flour, wheat bran and chia) equalled the control formula (pure wheat bread: 0.89 g water/g dry matter). Bread dough was made according to a closed process, with no modifications between mixes in order to observe the effect on a possible continuous industrial process and consumers. The process was carried out by mixing all the ingredients in a food mixer (Thermomix® TM31, Vorwerk, Germany). Then 450 g of dough were placed in the metal mould (8x8x30cm) for fermentation. Dough height was approximately 1±0.1 cm. Ten breads of each formula were produced and analysed.

The fermentation phase was carried out in a chamber with controlled humidity and temperature (KBF720 Binder Tuttlingen, Germany) for 60 minutes; 37°C and 90% of relative humidity (RH) were the used conditions. The growth kinetics of doughs were monitored by a laser distance measurer device (BOSCHGLM 50, 1.5 mm of accuracy, laser diode 635 nm), installed and calibrated inside the chamber. Height was taken in from the middle of dough every 5 minutes by taking the metal mould dimensions (width and length of the base) as a reference. Dough behaviour during fermentation was modelled using the adapted Gompertz prediction model. The Gompertz function is a non-linear sigmoid growth function - developed by Gompertz (1825) to calculate the mortality rate of microorganisms. The equation is as follows:

$$H = \alpha \cdot \exp((-\exp\,(\frac{V}{\alpha} \cdot (Lt - t) + 1\,)) \qquad (1)$$

where H is calculated as height, t is time, α is the observed height during the process, V is the maximum growth rate, and Lt represents the latency time before dough development begins. Model parameters were determined by a non-linear regression procedure and were obtained by minimising the sum of the squares from the prediction errors.

The baking process was carried out at the end of fermentation. Dough samples were baked individually. Metal moulds were placed in the middle of the oven (530x450x340, grill power 1,200W, internal volume 32L, Rotisserie, DeLonghi, Italy) plate, which was preheated to 180ºC. Baking time was 35 minutes. Having finished this operation, breads were cooled for 1 h under room conditions (25ºC/70% R.H). All the samples were weighed to determine mass loss during the process based on Equation 2:

$$\Delta M_B = \frac{m_f - m_0}{m_0} \cdot 100 \qquad (2)$$

where ΔM_b is the mass increment in %, m_f is mass post-baking and m_o is the initial mass before baking.

2.3 Analytical determinations

2.3.1. Specific volume

Specific bread volumes were measured by the millet seed displacement method. Then the specific volume (*Sv*) was calculated as the ratio between volume (mL) and bread weight (g). The increment in the specific volume compared to the control *(*ΔSv) was also calculated as a %.

2.3.2. Texture profile analysis

The texture profile analysis (*TPA*) was performed following the method used by Miñarro et al. (2012), where two 12.5-mm-thick cross-sectional slices were obtained from the centre of each bread. The texture profile analysis was carried out in a TA-TX2 texture analyzer (Stable Micro Systems, Surrey, UK). A 25-kg load cell and a 35-mm diameter probe were used. The assay speed was set at 1.7 mm/s to compress the bread crumb centre at 50% of its previous height. The time between compressions was 5 s.

The studied parameters were hardness (*D*), springiness (*S*), cohesiveness (*C*), gumminess (*G*), chewiness (*Ch*) and resilience (*R*). Ten bread samples of each formula were performed and analysed.

2.3.3. Moisture and fibre content

The moisture (X_w) and fibre (X_f) contents of the breads were determined based on ICC (International Association for Cereal Science and Technology) Standards 136 and 156, respectively.

2.3.4. Consumer test

In order to test the acceptance of the wholemeal breads obtained with the improved dough formulas, a consumer test was carried out. The study was done on the breads with 13% bran, which would represent any wholemeal bread found on the market, and with the 13% bran and 5% chia combination, which was the closest to the refined wheat bread from a technological viewpoint. The process was undertaken by 50 non-expert and untrained assessors, who are regular consumers of wholemeal breads. Tests were based on the semi-structured scales (AENOR, 2006) by which the attributes appearance, crumb colour, odour, aftertaste, touch texture, mouth texture and global acceptance were assessed. These attributes were selected as the most descriptive for both industry and consumers of such products. A questionnaire was used, based on 10-cm lines where three reference points were represented (0 = unpleasant, 5 = acceptable, and 10 = pleasant) for each attribute. Each assessor evaluated two samples served at room temperature and coded them with a 3-digit random number. Samples were prepared as crumb squares with constant dimensions (side of 3 cm), separated from bread slices to avoid the effect of volume differences between the resultant breads.

2.4 Statistical analysis

The experimental results from fermentation kinetics, baking phase, breads features and consumer test were studied by one-way ANOVA. In those cases where the effect was significant (P-value < 0.05), the average was compared by Fisher's least significant difference (LSD).

Table 2. Formulas and results of the bread-making process and analytical determinations of breads.

Formulas				*Fermentation*			*Baking*	*Breads*									
doughs	***% bran***	***% Chia***	***Total substituted wheat (%)***	***H***	***V***	***Lt***	***ΔMb***	***X_w***	***X_f***	***Sv***	***ΔSv***	***D***	***C***	***S***	***G***	***R***	***Ch***
pure wheat	0	0	0	8.2±0.8b	3.84±0.89ab	1.33±0.1c	22±2.4a	0.38±0.01a	0.02±0.01a	3.02±0.12c	-	1.01±0.01c	0.89±0.02c	3.49±0.88a	3.54±0.89a	0.29±0.01ab	3.93±1.06a
wholemeal	13	0	13	6.3±0,9ab	3.23±0.7ab	0.84±0.1b	19.7±1.7a	0.39±0.02a	0.09±0.01b	2.25±0.14b	-25,3	0.98±0.02b	0.86±0b	5.18±0.42a	5.09±0.37b	0.29±0ab	5.99±0.49b
		5	18	8.4±0,9b	5.43±0.89b	1.21±0.2c	19.6±2.1a	0.39±0.01a	0.11±0.01bc	3.01±0.09c	-0,2	0.97±0.03ab	0.87±0.01bc	4.97±1.05a	4.87±1.17ab	0.3±0b	5.7±1.27b
		10	23	7.9±0,7b	4.15±0.73b	1.17±0.1c	19.2±1.5a	0.39±0.03a	0.13±0.01c	2.97±0.08c	-1,7	0.98±0.02b	0.84±0.01b	6.57±1.99b	6.41±1.74b	0.3±0b	7.8±0.99b
	23	0	23	4.2±0,8a	1.87±0.8a	0.4±0.1a	19.3±2a	0.39±0.01a	0.15±0.01cd	1.89±0.13b	-37,2	0.93±0.03a	0.81±0.01a	13.42±1.76c	12.5±1.43d	0.28±0a	16.44±1.12d
		5	28	4.4±0,8a	2.35±0.71a	0.73±0.2b	20.6±1.4a	0.38±0.02a	0.17±0.01d	2.15±0.08b	-28,7	0.96±0.02ab	0.82±0.01ab	9.82±1.68c	9.44±1.76c	0.3±0b	11.88±1.61c
		10	33	5.8±0,9ab	2.51±0.81a	0.61±0.1b	20.2±1.4a	0.38±0.01a	0.18±0.01d	1.58±0.1a	-47,6	0.95±0.03ab	0.81±0.02a	9.82±1.56c	9.42±1.79c	0.29±0ab	12.06±1.42c

Percentages of flours are indicated on a dry basis. *H*: height of doughs at 60 min (cm); *V*: maximum growth rate (cm/min); *Lt*: latency time (min); ΔM_b: mass loss during baking (%); X_w: moisture content (g water/g of bread); X_f: fibre content (g fibre/g of bread); *Sv*: specific volume (mL/g); Δ*Sv*: incremented specific volume compared to pure wheat (%);*D*: hardness (N); *C*: cohesiveness (-); *S*: springiness (mm); *G*: gumminess (N); *R*: resilience (-); *Ch*: chewiness (N.mm). Values in the same column followed by different letters significantly differ ($p < 0.05$)

3. Results and discussion

3.1 Bread-making process

3.1.1 Fermentation

Table 2 contains the results of the bread-making parameters for each formula. Fermentation phase results and the kinetics of the dough height (H) evolution is represented in the Figure 1. Figure 1-A shows the fermentation kinetics for the refined wheat and the wholemeal basic dough formulas with 13% and 23% of added bran. Curves presented notable differences, principally in height (*H*) at 60 minutes, which reduced following the rise in bran content. This behaviour has been typically described by other authors (Curti et al., 2013). The maximum growth rate (*V*) for all formulas with 13% bran was equal (between 3.23±0.7 and 5.43±0.89 cm/min), but lowered for 23% (between 1.87±0.8 and 2.51±0.81 cm/min), although both 13% and 23% presented a shorter latent time (*Lt*) compared to pure wheat. In short, the impact of adding bran was a disruption of the gas retention capacity of doughs, which is one of the main setbacks in the bread-making process given its implications in the other phases, and then in the properties of end breads.

These behaviours are linked to a reduction in the amount of gluten due to wheat flour being substituted, which usually means considerable spoilage to dough's technological properties. As a percentage of the dry matter wheat was substituted for insoluble fibre, which had a larger particle size compared to the refined wheat flour, it led to a disruption in the gluten network formation, and also lessened gas retention during the mixing process (Bock & Damodaran, 2013)

The next step was to determine the behaviour of doughs by incorporating 5% chia and 10% chia into each formula, as mentioned before. Figure 1(1-B and 1-C) shows the results. Figure 1-B represents the fermentation kinetics for *H* of the refined wheat dough, the dough with 13% bran and 13% bran with 5% chia and 10% chia. The results show how presence of chia in the formula increased the gas retention capacity of dough. *H* was higher in 5% than 10% of chia, which allowed gas to be maintained until values that had not differences from the refined wheat dough. A slight increase in the gas retention capacity was observed for the doughs with 23% bran (Figure 1-C) when combined with 10% chia, while no effect was noted with 5% chia.

Presence of chia allowed the gas retention capacity to be recovered in doughs, principally for the doughs with 13% bran, which completely recovered. However, 23% bran seemed an excessive substitution level to recover this capacity despite chia being present. The *H* correction was principally attributable to the mucilage of the chia seed dry matter, which is a polysaccharide gum with high-molecular-weight. It forms an active hydrocolloid that is involved in gas retention improvement in the fermentation phase of the bread-making process. This effect was in line with the results reported in several previous studies (Iglesias-Puig & Haros, 2013; Verdú et al., 2015). This hydrocolloid improved the volume rate of doughs given the establishment of the hydrophilic complexes formed between their ionic groups and proteins, such as gluten, which favours gas impermeable network formation. This fact was evidenced when no differences in the fermentation kinetics were observed in the doughs with 23% of wheat cumulative substitution, based on 13% bran plus 10% chia. While the 23% substitution was based exclusively on bran, major spoilage was detected. Thus in line with the impact on the fermentation phase, 5% and 10% chia were able to improve the properties of wholemeal doughs with 13% of bran, and to obtain fermentation parameters that showed no significant differences compared to the refined wheat formula.

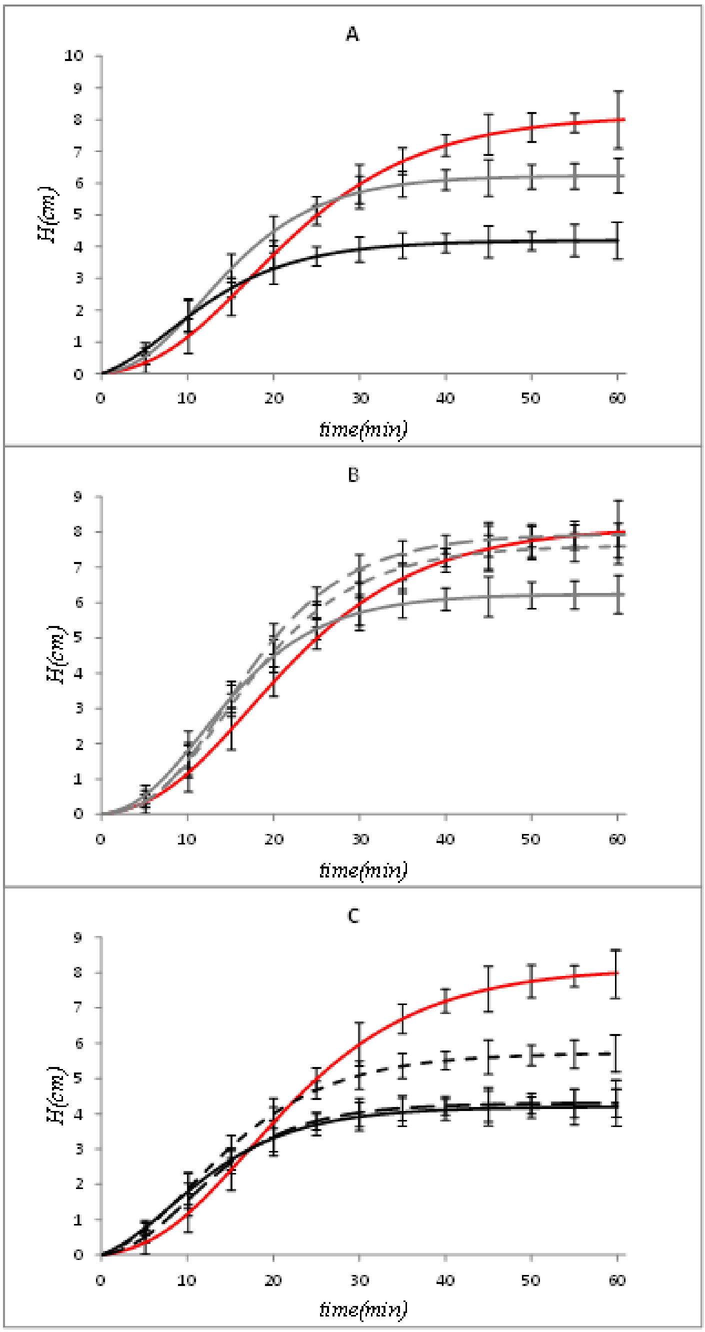

Figure 1. Fermentation curves that resulted from the Gompertz curve-fitting procedure. A: formulas without chia; B: wheat and 13% bran/chia formulas; C: wheat and 23% bran/chia formulas. — Refined wheat flour; — 13% bran; — 23% bran; — — 13% bran/5% chia; — — 23% bran/5% chia; --- 13% bran/10% chia; --- 23% bran/10% chia. *H*: height of the central dough zone at each time in *cm.* Bars indicates standard deviation.

3.1.2 Baking

After completing the fermentation phase, the baking process of the fermented doughs was carried out and assessed. This phase was studied according to the mass loss (ΔMb) of doughs during the baking time, which was assumed as water losses from thermal treatment. The other calculated parameter was grams of water retained per gram of dry matter without fat (*gW/gDM*). Table 2 shows the mass loss results. The refined wheat dough represented the maximum mass loss with 22%, and the formulas with 13% and 23% bran indicated a reduction up to 19.7% and 19.3%, respectively. In this case, addition of chia did not present any differences when bran formulas were compared. When the fraction of dry matter without fat was considered (gW/gDM), presence of chia increased in some cases (Figure 2) up to around 0.69 gW/gDM (maximum) and to about 0.12 of fibre content (X_f). It corresponded to the 13% bran/5% chia formula. This formula presented an X_f of 11%, which is 5 times more than the refined wheat sample. Instead the doughs with 23% bran displayed a reversed tendency. In this case a larger amount of fibre led to reduced water retention, which could be attributed to the differences in dough dimensions observed in the fermentation phase which had an effect in the baking phase. A lower gas fraction per unit of dough volume led to both better heat transfers to the matrix and water escaping (Wagner, Quellec, Trystram, & Lucas, 2008). So although fibre increases water retention, the effect of dough volume had a stronger impact on this parameter.

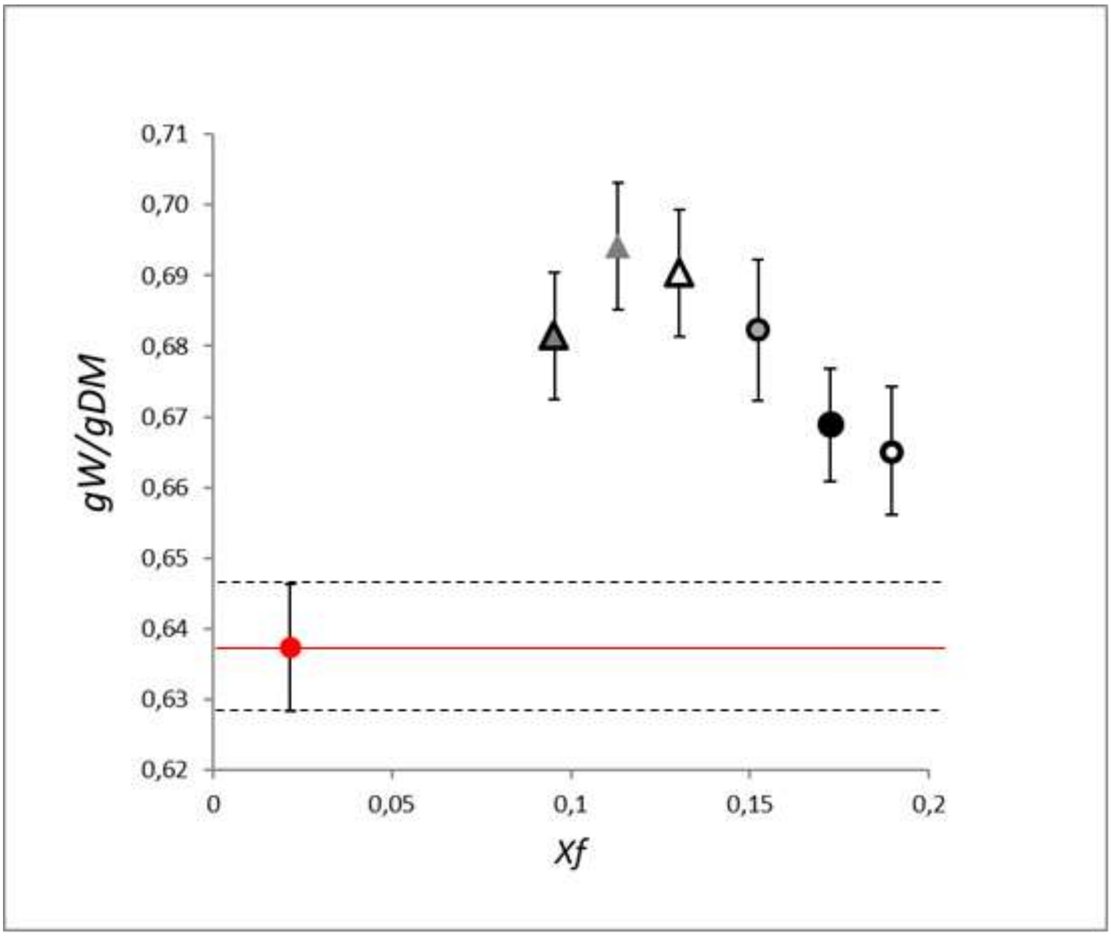

Figure 2. Fibre content of bread (X_f) vs. ratio between grams of water retained per gram of bread dry matter without fat (*gW/gDM*). ●— Refined wheat flour; ▲ 13% bran; ▲ 13% bran/5% chia; △ 13% bran/10% chia; ● 23% bran; ● 23% bran/ 5% chia; ○ 23% bran/10% chia. Dotted lines mark the standard deviation of the refined wheat flour data and bars denote the standard deviation for the other formulas.

3.2 Analytical determinations

3.2.1 Specific volume

When the process ended, the specific volume (*Sv*) of cooled breads was evaluated. Results are reported in the Table 3. In the first place, it is noteworthy that specific volume was affected by the substitution level. However, when chia was added at both 5% and 10%, no differences were observed for the bread with 13% bran. These results were according to the differences in H of doughs at 60 min of fermentation, although the dough system expands during the baking process and water loss with phase changes in the flour components is produced, the differences between formulas were mainly maintained. Owing to the reduced gas retention capacity in the fermentation phase, the specific volume of breads was strongly affected by the incorporation of bran. Figure 3 shows the specific volume of breads in the relationship with fibre content (X_f) and hardness (D). This plot shows how the increased gas retention capacity with addition of chia was maintained for 13% bran, and produced breads with an equal specific volume compared to the refined wheat bread. All the other samples presented an inverse relationship between both variables. Therefore, chia provided gas retention capacity to bran formulas, generating breads which contained around 6-fold higher total fibre content than pure wheat breads but maintained the same specific volume values.

3.2.2 Texture profile analysis

These differences in the specific volume of breads had a strong impact on other fundamental features for this bread to be accepted: texture properties. Modifications in the retained gas fraction had a direct impact on crumb structure, and then on its resistance at deformation forces (Wang, Austin, & Bell, 2011). Moreover, substituting part of wheat could produce textural differences at the same specific volume because of differences in cell wall stability, thickness, etc., depending on the compounds present and their interactions (Demirkesen et al., 2014). The results of the texture parameters are shown in Table 3.

Parameters like hardness, gumminess and chewiness showed increase with the refined wheat substitution percentage, which presented significance in the cases of 23% bran and its combinations with chia compared to pure wheat formula, however springiness and cohesiveness presented significant reduction (Table 3). These results were expected for high-fibre content composite breads, and match other works (Almeida, Chang, & Steel, 2013; Gómez, Buchner, Tadini, Añón, & Puppo, 2013), in which inclusion of fibres caused crumb hardening.

Figure 3 shows the relationship between hardness (*D*), specific volume (*Sv*) and the fibre content. As it is possible to observe hardness (*D*) increased with fibre content and decreased with specific volume (*Sv*). Dependence among these properties was evidenced, along with their possible influence on product palatability. However, the 13% bran and 5% chia combination presented no differences with the refined wheat bread for hardness, with only a slight increase for 10% chia for the same amount of bran. Incorporation of chia led to improvements when the 13% substitution levels were used, and chia was added by between 5 and 10%, which generated breads with no differences in terms of specific volume and hardness to the refined wheat breads.

So from a technological point of view, inclusion of chia was capable of providing properties to both doughs and breads that made them strikingly similar to the refined wheat breads with some combinations, and with the advantages that this entails in the production chain.

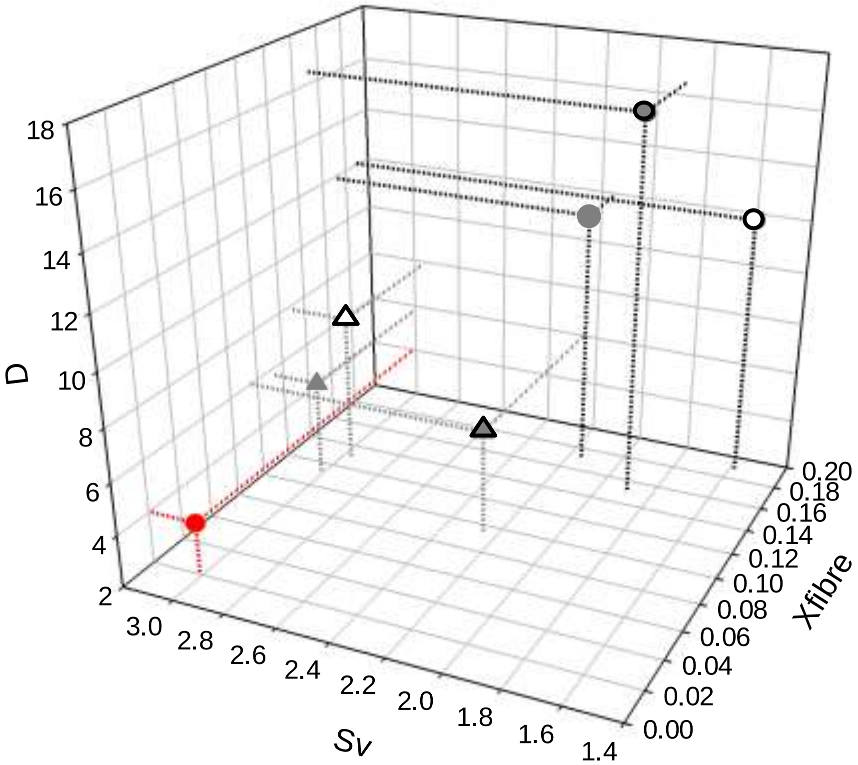

Figure 3. Relationship among specific volume: *Sv* (cm^3/g), hardness: *D* (N) and fibre content: X_f (g fibre/g bread). ●— Refined wheat flour; ▲ 13% bran; ▲ 13% bran/5% chia; △ 13% bran/10% chia; ● 23% bran; ● 23% bran/ 5% chia; ○ 23% bran/ 10% chia.

3.2.3 Consumer test

Following the results, the study was done on the breads with 13% bran and with the 13% bran and 5% chia combination, which was the closest to the refined wheat bread from a technological viewpoint. The aim was to know if both formulas could offer similar acceptance, even if they had a higher total fibre content with the 13% bran/5% chia bread. That was crucial because addition of chia normally results in changes in mouth and touch textures, and in colour and odour, which could imply it being rejected, even by consumers of wholemeal products (Aravind, Sissons, Egan, & Fellows, 2012; Eriksson, Koch, Tortoe, Akonor, & Oduro-Yeboah, 2014).

Table 4 shows the results of the consumer test carried out on the above-mentioned formulas. The scores of both formulas did not go below 5 points on the used scale based on a 10-point system. Both the bran and bran/chia formulas presented similar sensory responses, and no significant differences were found. Although it was non-significant, the formula with chia obtained slightly lower scores than the other one. The fact that whole chia seeds were used explains these results because all their original aromatic substances and pigmentation remained. The use of isolated chia mucilage could be a possibility to reduce these effects and maintain the same technological advantages, although the remaining nutritional load would drastically drop. Global acceptance of the bran/chia bread could be assumed as similar to bread that contains only bran. This means that it is possible to produce acceptable wholemeal bread under refined wheat bread process conditions using chia seed flour to improve formulas, and to enhance the product's nutritional profile.

Table 3. Consumer test results

Formula	*Visual appearance*	*Crumb colour*	*Odour*	*Aftertaste*	*Touch texture*	*Mouth texture*	*Global acceptance*
13% bran	8.3±1.7a	8.4±2.2a	8.1±2a	3.7±2.6a	7.2±1.7a	7.4±2.3a	7.3±2.2a
13% bran+5% chia	7.9±2.4a	7.3±2.2a	6.6±2.2a	3.9±2.7a	6.9±2a	7.1±2a	6.9±2.2a

Values indicate average, standard deviation and statistical results with values followed by different letters are significantly different at $p < 0.05$ in columns.

4. Conclusions

Addition of chia seed flour to wholemeal bread formulas brings about changes in both dough and bread which could improve processes in each production chain phase, as long as the amount of fibre content does not exceed 13% bran and 5% chia in this case. In the fermentation phase, chia offers good gas retention capacity, and the wholemeal dough develops exactly the same as refined wheat dough. Improvements were also observed in the baking phase, where no differences in mass loss were noted due to the increased water retention capacity per gram of dry defatted matter. The texture properties of wholemeal breads were similar, equalled the refined wheat breads in some cases, and even contained a higher total fibre content (11.3%). Finally, presence of chia did not significantly affect the end product's sensory acceptation.

In conclusion, whole chia seed flour has properties that can be used to improve processing wholemeal breads since it counterbalances the main problems produced by fibre throughout the bread-making process.

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