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Effect of pre-hydration of chia (*Salvia hispanica* L.), seeds and flour on the quality of wheat flour breads

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ABSTRACT

Chia is an oleaginous seed rich in protein and fibre, and there has been a recovery in their cultivation in recent years. The objective of the present study was to investigate the effect of the addition of chia seeds or flour (with and without pre-hydration) on the technological and sensory quality of the bread. Chia flour significantly increased the water absorption during kneading, and the effect was more pronounced when the flour was pre-hydrated. Chia flour addition also increased the tenacity (mainly in doughs with pre-hydrated flour) and reduced the extensibility of doughs. Adding 10 g/100 g chia seeds produced a decrease in bread volume and an increase in crumb firmness, but this effect was lower when seeds were pre-hydrated. With the addition of chia flour at levels of 10 g/100 g, bread volume remained unchanged in pre-hydrated flour. However, a decrease in the volume of breads made by flour without pre-hydration was also observed. In general, an evaluation of the loaves containing chia by potential consumers, the global score was above 6 out of 9, with no significant differences compared to the control bread. Chia flour without pre-hydration was the only exception where lower values of consumer acceptance were observed.

1. Introduction

Chia (*Salvia hispanica* L) is an annual herbaceous plant belonging to the Lamiaceae family, native to southern Mexico and northern Guatemala. Chia seed, together with corn, beans and amaranth, was one of the most important crops of Pre-Columbian American civilizations (Alvarez-Chavez, Valdivia-Lopez, Aburto-Juarez, & Tecante, 2008).

Because of their low cost and their important place in the diet, bakery products are foods that can be supplemented with components of high nutritional value. Studies on the addition of chia to these types of product had been limited to its possible role as a substitute for fat or eggs in cakes (Borneo, Aguirre, & Leon, 2010). However, in recent years, there has been an increase in the number of studies about chia incorporation in baking products. Thereby, the incorporation of chia flour in pound cakes (Pizarro, Almeida, Sammán, & Chang, 2013) or corn tortillas (Rendón-Villalobos, Ortíz-Sanchez, Solorza-Feria, & Trujillo-Hernández, 2012) was reported. The effect of chia flour incorporation on gluten free doughs and breads has also been studied (Moreira, Chenlo, & Torres, 2013; Steffolani, de la Hera, Perez, & Gómez, 2014). In wheat bread, Bautista-Justo et al. (2007) proposed the inclusion of a blend of soybean, chia, flax and folic acid in order to develop breads with functionalities aimed at women, and Segura-Campos, Salazar-Vega, Chel-Guerrero, and Betancur-Ancona (2013) proposed the use of chia protein hydrolisates to generate breads with functional properties. Farrera-Rebollo et al. (2012) studied the influence of the addition of 6 and 8 g/100 g chia flour, but they only evaluated the porosity of sweet breads. In a recent study, Constantini et al. (2014) observed that the inclusion of 10 g/100 g of chia flour increased the content of soluble fibre, omega-3 fatty acids and the total antioxidant capacity of wheat breads. However, these studies are more focused on the nutritional characteristics of breads and they do not approach other aspects such as the technological quality of breads, or dough characteristics. Iglesias-Puig and Haros (2013) studied the effect on the addition of 5 g/100 g chia seeds and ground chia seeds (whole chia flour, semi-defatted chia flour and low-fat chia flour). Dough mixing behaviour, bread composition and technological parameters (volume, texture, colour and crumb grain) were analysed. The authors also studied the sensory acceptance of breads.

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Chia possesses the property of exuding mucilage that presents similar properties to several hydrocolloids (Capitani, Ixtaina, Nolasco, & Tomás, 2013; Muñoz, Cobos, Diaz, & Aguilera, 2012), whilst hydrating. This mucilage or gum has a molecular weight of $0.8 - 2 \times 10^6$ Da (Lin, Daniel, & Whistler, 1994), a powerful thickening effect and a high water absorption and retention capacity (Vázquez-Ovando, Rosado-Rubio, Chel-Guerrero, & Betancur-Ancona, 2009). Therefore, pre-hydration of chia seeds or flour before incorporation into doughs, could assist in the mucilage release. This will also make interaction of mucilage with the rest of the components easier. This effect has not been studied, but Guarda, Rosell, Benedito, and Galotto (2004) studied the addition of several hydrocolloids on breads, finding an improved effect on bread quality.

We therefore undertook the present study to determine the effect of the addition of different forms of chia (seed or flour), without or with pre-hydration, on the rheological properties of dough, and the technological and sensory quality of breads.

2. Materials and methods

2.1. Materials

Wheat flour (11.25 g/100 g protein, 14.54 g/100 g moisture) used in all the experiments was provided by Harinera Castellana (Medina del Campo, Valladolid, Spain). Chia seed (3.78 g/100 g moisture, 23.90 g/100 g protein, 32.86 g/100 g lipid) was supplied by Trades (Barcelona, Spain). Characterization of wheat flour and chia seed was provided by suppliers. Chia flour was obtained milling chia seed for 10 s using a super junior "s" grinder (Moulinex, Selongey, France). Dry yeast, Saf-Instant (Lesaffre, Lille, France) and salt from local market were used.

The lipid content of the chia seeds was determined using AACC method 30-25, and the moisture and protein content of the chia seed and wheat flour using methods 44-15 and 46-11, respectively (AACC, 2010).

2.2. Methods

2.2.1. Dough properties

Water-absorption (amount of water required to achieve a consistency of 500 FU) and the mixing behaviour were studied using doughLAB equipment (Newport Scientific Pty. Limited, Warriewood, Australia). Alveograph measurements were performed using the MA 82 Alveograph (Chopin, Tripette et Renaud, Villeneuve La Garenne, France) following the standard AACC Approved Method 54-30 (AACC, 2010). The DoughLab and alveograph tests were performed in duplicate. These tests could only be performed in doughs made with chia flour. In doughs made with chia seeds, whole seeds when used were found to interfere with the measurements and thus lead to erroneous results. The samples studied were wheat flour (control), wheat flour with chia flour (5 g, 10 g and 15 g of chia flour/100 g wheat flour) and wheat flour with previously hydrated chia flour (5 g, 10 g and 15 g of hydrated chia flour/100 g wheat flour). The hydration process consisted of mixing 1 part of flour/seed with 3 parts of tap water and allowing it to rest for 30 min at 20 °C. In the case of doughs with hydrated chia flour, the remainder of the water to reach 60 g/100 g was incorporated during the test. Additionally, rheofermentometer studies (Chopin, Villeneuve-la-Garenne, France) were used to analyse dough development according to fermentation time and gas production and release from the dough using the method described by Czuchajowska and Pomeranz (1993). Each test was performed in duplicate. The doughs were elaborated according the same procedure and formulation used in bread making. For the breadmaking, doses of 10 g/100 g were selected as better nutritional characteristics of bread have been identified with this formula (Constantini et al., 2014). Preliminary tests on the technological quality of breads have been conducted using rheofermentometer. Then, the samples analysed with the rheofermentometer were the control dough and dough with 10 g of chia seed or flour/100 g of wheat flour with and without previous hydration.

2.2.2. Bread making

The ingredients used (g/100 g flour) were water (60 g/100 g), instant dry yeast (1 g/100 g), salt (1.8 g/100 g) and ascorbic acid (0.01 g/100 g). Water temperature was calculated to reach a dough temperature of 23 °C. Chia flour and seed were added at 10 g/100 g wheat flour.

After mixing all the ingredients for 13 min using a double-arm kneader AB-20 (Salva, Lezo, Spain), bread dough was divided into 350 g portions, hand-rounded, mechanically moulded, placed in a baking pan (232 × 108 × 43.5 mm) and proofed for 90 min at 30 °C and 75% RH. The breads were baked in an electric oven for 20 min at 230 °C. After baking, the loaves were left to cool for 60 min, after which they were removed from the pans. They were then introduced into polyethylene bags and stored at 20 °C until analysis. All the elaborations were performed twice.

2.2.3. Evaluation of bread quality

Bread volume was determined using a laser sensor, with the BVM-L 370 volume analyser (TexVol Instruments, Viken, Sweden). Weight loss was measured as the difference between the weight of the dough moulded and the weight of the bread after baking. Measurements were performed in triplicate.

Crumb texture was determined by a TA-XT2 texture analyser (Stable Microsystems, Surrey, UK) supplied with the "Texture Expert" Software. A 25-mm diameter cylindrical aluminium probe was used in a "Texture Profile Analysis" (TPA) double compression test designed to penetrate to a depth of 50% at a test speed of 2 mm/s and with a 30 s delay between first and second compressions. Texture measurements were performed on 30 mm thick slices at 18 h after baking. Analyses were performed on two slices from three breads for each type of elaboration.

2.2.4. Consumer testing

Hedonic sensory evaluation of breads was conducted with 66 bread-usual-consumer volunteers, 38 women and 28 men, from 18 to 55 years of age, from different socioeconomic backgrounds; the volunteers were drawn from the staff and students of the Agricultural Engineering College of Palencia in Spain. Consumer test were carried out in the Sensory Science Laboratory of the Agricultural Engineering College at the University of Valladolid in Palencia, Spain, in individual booths.

Breads were evaluated on the basis of acceptance of their appearance, flavour, taste, flavour persistency, texture, and overall acceptability on a nine-point hedonic scale. The scale of values ranged from a high score of 9, "like extremely", to a low score of 1, "dislike extremely". Samples were analysed one day after baking. They were presented as half-pieces for appearance and 2 cm slices for flavour, taste, flavour persistency, texture, and overall acceptability. The slices were served in random order on white plastic dishes coded with random, four-digit numbers. Control bread and breads with 10 g of chia seed, pre-hydrated chia seed, chia flour or pre-hydrated chia flour/100 g wheat flour were analysed. All breads were analysed in the same session. Water was available for rinsing.

2.2.5. Statistical analysis

Differences between the parameters for the doughs and the breads were studied by analysis of variance (one-way ANOVA).

Table 1
Effect of chia flour addition on rheological properties of doughs.

	P value (mm H_2O)	L value (mm H_2O)	W (J × 10^4)	WA (g/100 g)	DT (min:s)	Stability (min:s)
Control	42.0a	132.0d	154.5d	50.8a	4:02bc	7:04d
Chia (5 g/100 g)	48.5b	79.5c	109.5bc	51.6ab	4:37d	6:32c
Chia (10 g/100 g)	63.5c	49.0b	103.0ab	51.6ab	4:44d	5:54ab
Chia (15 g/100 g)	77.0d	33.5a	97.5a	52.2bc	4:20cd	6:18c
Hydrated Chia (5 g/100 g)	47.0b	78.0c	108.5bc	53.9cd	3:52a	5:28a
Hydrated Chia (10 g/100 g)	64.0c	54.0b	113.5c	54.2d	3:25a	5:28a
Hydrated Chia (15 g/100 g)	77.5d	35.0a	102.0ab	57.5e	3:52a	6:10bc

Values with different letters in the same parameter are significantly different ($p < 0.05$).
P, maximum pressure; L, extensibility; W, deformation energy; WA, water absorption; DT, departure time.

Fisher's least significant difference (LSD) was used to describe means with 95% confidence intervals. The statistical analysis was performed with the Statgraphics Plus V5.1 software (Statpoint Technologies, Inc., Warrenton, USA). Correlations were obtained using the same program.

3. Results and discussion

3.1. Effect of flour and seeds of chia on dough properties

Table 1 presents the alveographic and DoughLab parameters of samples with chia flour (with and without pre-hydration). Mainstreaming in the formulation of chia flour caused a decrease in extensibility (L) and an increase in the tenacity (P) of the dough, and there were no differences according to previous hydration. The consequent increase in the P/L ratio can be attributed partly to the mucilage present in the chia, as already observed by Guarda et al. (2004) and Gomez, Ronda, Blanco, Caballero, and Apesteguia (2003) studying the individual incorporation of hydrocolloids or fibres into breads. However, in that study, the incorporation of hydrocolloids produced an increase in alveograph strength, contrary to the findings after the incorporation of chia flour in the present study. After the incorporation chia flour, the increase in the P/L ratio and the reduction in the alveograph strength may be due, at least in part, to the reduction in the gluten concentration caused by the presence of fats (Agyare, Addo, Xiong, & Akoh, 2005) and non-gluten-forming proteins (Maforimbo, Skurray, Uthayakumaran, & Wrigley, 2006; Ribotta, Arnulphi, Leon, & Añon, 2005), which interfere with gluten formation.

At all the levels of chia incorporation, there was an increase in the absorption of water, with the exception of doughs made by 5 g/100 g and 10 g/100 g of chia flour without hydration, in which significant differences from control were not observed. This is in concordance with the observations of Iglesias-Puig and Haros (2013). This increase could be mainly due to the mucilaginous properties of chia. A greater increase in water absorption by the dough was observed with pre-hydrated flours due to greater release of mucilage prior to kneading. The high water-absorption capacity of chia fibre has been reported previously by Vázquez-Ovando et al. (2009), and our results on dough behaviour during kneading coincide with the observations by Guarda et al. (2004) using other hydrocolloids and with those of Gomez et al. (2003) using different fibres. However, the incorporation of non-gluten-forming proteins can also help to increase water absorption (Ribotta et al., 2005). The effect of chia on the development time was different depending on pre-treatment. The addition of chia flour caused an increase in development time which could be due mainly to the lower rate of hydration of the components due to increased competition for water between chia fibre and gluten proteins. Conversely, when the chia was hydrated prior to incorporation into the formulation, development time decreased relative to the control probably because the absorption of water by the mucilage had already occurred and there was no direct competition with the gluten for water, thus facilitating a more rapid development. Despite this, Guarda et al. (2004) also observed an increase in the kneading time after the incorporation of small amounts of certain hydrocolloids, but a reduction in kneading time with the incorporation of larger quantities; this coincides with our observations, as the amount of mucilage released is greater in the case of pre-hydrated flour. Dough stability decreased after the addition of chia flour with or without pre-hydration. Apart from the gluten dilution effect when chia was incorporated, both the fibre and the non-gluten-forming proteins of the chia interfered with the interactions between the wheat glutenins, making the gluten network was less stable and weaker and thus unable to maintain consistency for the same amount of time as the control dough. A reduction in dough tolerance was also detected by Gomez, Oliete, Caballero, Ronda, and Blanco (2008) in their study of the incorporation of nut flour, and by Doxastakis, Zafiriadis, Irakli, Marlani, and Tananaki (2002), who studied the incorporation of full-fat lupin, soya and triticale flour blends, which, like chia, have a high fat and protein content.

3.2. Effect of chia flour and seeds during fermentation

Fig. 1 shows the dough development, and Fig. 2 the gas production and gas retention during the fermentation of the control sample and those with 10 g/100 g of chia (seed or flour). The formulation with pre-hydrated chia flour presented a similar behaviour to the control during fermentation, reaching maximum growth heights between 100 and 103 min of fermentation, respectively, although the control presented a better tolerance to long fermentations. Slower dough growth with respect to the control was observed after the incorporation of chia flour without pre-hydration and of hydrated chia seeds, with lower maximum heights, reached at longer times of fermentation. Finally, the incorporation of chia seeds without pre-hydrate produced least dough growth and the curve showed a strange behaviour as there were two peaks. In the gas retention curves, all samples with chia (seed or flour) presented rupture of the gluten network and escape of the gas produced during fermentation at an earlier point than the control sample, which is consistent with the lower strength of these doughs on alveograph analysis. As already stated, this may be due to the interaction of chia flour particles and its components with the gluten structure, in addition to dilution of the gluten, resulting in the formation of a dough with less continuity and greater porosity, allowing the CO_2 to escape. Roccia, Ribotta, Perez, and León (2009) observed a similar effect after incorporating soya (non-gluten-forming proteins) into wheat dough. In the case of the addition of pre-hydrated flour or seeds, there was an increased gas production in the early stages of the fermentation, which partly explains the differences in the development of these dough

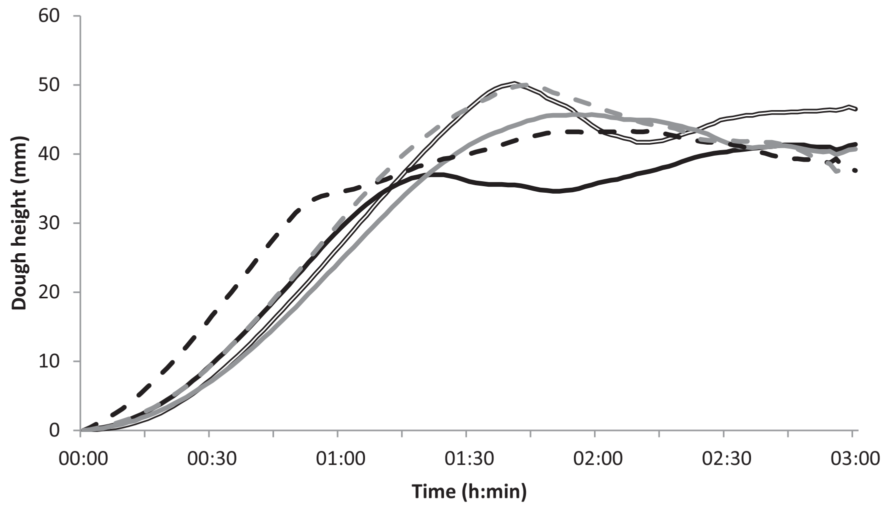

Fig. 1. Dough development curves from the rheofermentometer analysis of breads. Control bread (continuous double black line), 10 g chia seeds/100 g flour (continuous black line), 10 g chia flour/100 g flour (continuous grey line), 10 g pre-hydrated chia seeds/100 g flour (dashed black line), 10 g pre-hydrated chia flour/100 g flour (dashed grey line).

compared with the dough without pre-hydration. This effect may be due to the activation of hydrolytic enzymes in the pre-hydrated chia and the consequent production of fermentable sugars; however, this finding requires further analysis in future studies because there are no previous studies on this subject.

3.3. Effect of the incorporation of chia seeds and flour on bread quality

Table 2 presents the quality parameters of the bread after the addition of chia to the formulation. As a general trend, chia incorporation reduced the specific volume of the loaves. Specific volumes were greater after the addition chia flour that after the addition of seeds, which coincides with the observations of Iglesias-Puig and Haros (2013) with percentages of a 5%. Moreover, the specific volume of the breads was better when the added products were pre-hydrated, and we did not find differences between the control and bread made with pre-hydrated chia flour. These findings coincide with the results in the rheofermentographic analysis because the underlying reason for the loss of volume is rupture of the gluten network during fermentation and loss of part of the gas formed during this period. In fact, the Pearson's correlation between specific volume and maximum growth of dough height during fermentation after the incorporation of 10 g/100 g of chia flour or seeds with or without pre-hydration was $r = 0.95$ ($p \leq 0.0001$). Many papers have reported a negative effect on bread volume after the incorporation of flax seed flour (which has a similar composition to chia) into the formulation of bakery products; this is mainly due to dilution of the gluten by this flour and/or interference with the protein network by its components (Conforti & Davis, 2006; Mentes, Bakkalbassi, & Ercan, 2008). The positive effect of incorporating chia flour instead of seed on bread quality could be due to the beneficial effect of the chia lipids, which remain available to interact in the dough, favouring expansion of the loaves (Pareyt, Finnie, Putseys, & Delcour, 2011). For its part, the beneficial effect of pre-hydration can be attributed to the action of the mucilage released in this process, as already described by Guarda et al. (2004) when investigating the addition of other hydrocolloids. With regard to weight loss during the baking process, this showed a significant correlation of 99% with bread volume, with $r = 0.61$; this would appear logical due to the larger volume and hence larger surface area for the evaporation of water.

In the case of the addition of chia flour the firmness could be thought to diminish, as other authors have observed this effect with the addition of fibres (Gomez et al., 2003) and lipids (Pareyt et al. 2011), by influencing the retrogradation of wheat starch. For its part the addition of pre-hydrated flour or seeds could also reduce firmness due to the effect of the mucilage, as was observed by Guarda et al. (2004). However differences in the firmness of the breads are primarily due to changes in specific volume, as a negative correlation has been observed ($r = -0.96$; $p < 0.001$) between the specific volume of the bread and the firmness of the crumb. The incorporation of chia, in all its forms and percentages, decreased springiness of the bread crumbs. Scanlon and Zghal (2001) described bread as a soft solid formed by two phases, a fluid one which corresponds to the air and a solid that corresponds to the gas-cell wall material. The solid phase is fully interconnected and the nature of the connectivity determines the mechanical properties of the bread. Consequently, a weaker gluten network leads to the development of a less interconnected bread crumb, evidenced as a lower springiness. Therefore the decline in springiness produced by the addition of chia was mainly due to the negative effect of the chia on the gluten network.

3.4. Consumer's acceptance analysis of breads made with flour and seeds of chia

Consumer acceptance test results are shown in Table 3. No significant differences were found between control breads and those with added chia seed for any of the parameters studied. Physical properties including texture, colour, taste and flavour are clearly different, but their assessment by consumers did not present significant differences. On the other hand, breads made with chia flour were awarded lower scores than control bread for texture, persistence of flavour and appearance. As for taste, smell and overall evaluation, no significant differences were observed between control and pre-hydrated flour breads, but the addition of chia flour without pre-hydration led to a poorer assessment. The better assessment of breads with pre-hydrated flour could have been due to the higher moisture level and hence less sensation of dryness. In the case of the incorporation of seed, this effect could also have been achieved by release of the oil contained in the seeds on chewing. The lower score for visual appearance of breads with chia flour may have been due to the greyish colour of crumb, which is

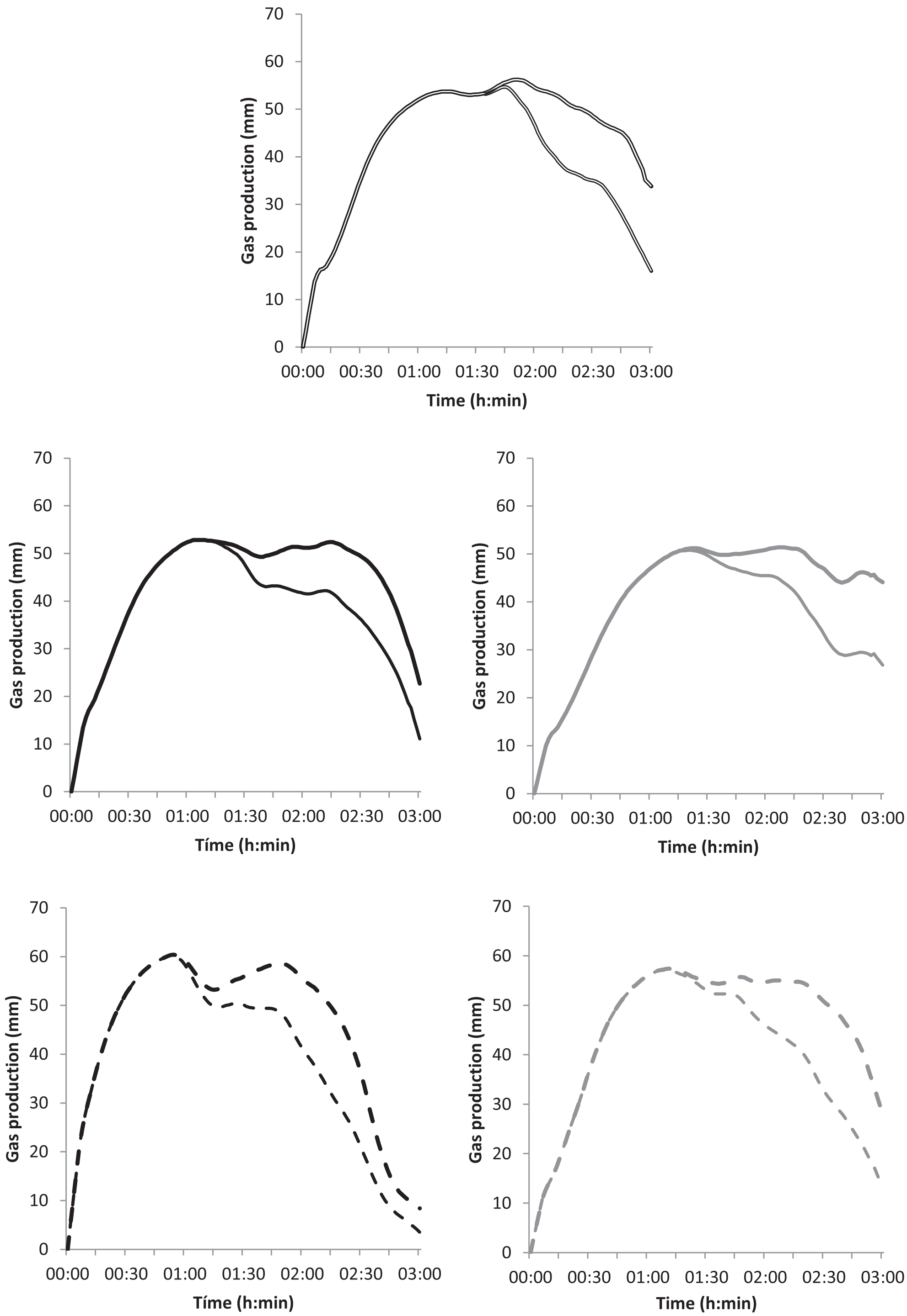

Fig. 2. Gas production (thick line) and gas retention (fine line) curves from the rheofermentometer analysis of breads. Control bread (continuous double black line), 10 g chia seeds/100 g flour (continuous black line), 10 g chia flour/100 g flour (continuous grey line), 10 g pre-hydrated chia seeds/100 g flour (dashed black line), 10 g pre-hydrated chia flour/100 g flour (dashed grey line).

not usual in bakery products. In contrast, breads with seeds have a more similar appearance to other products with bran or other seeds and the crumb appearance was more similar to that of the control bread, but with small specks or spots that corresponded to the seeds. It was also found that the lower volume of bread with chia seed, and the greater hardness of the slices, did not significantly influence the assessment of the product.

4. Conclusions

It is possible to incorporate chia in bread making processes at levels of 10 g/100 g, without reducing product acceptability by consumers. However, it is preferable to add pre-hydrated seed or flour in order to optimize acceptability, specific volume and texture compared with flour or seeds without pre-hydration. Thereby, it is

Table 2
Effect of 10 g/100 g chia addition on bread quality parameters.

	Specific volume (cm^3/g)	Weight loss (g/100 g)	Hardness (N)	Springiness
Control	3.40c	9.24b	8.23ab	0.95c
Chia flour	3.14b	9.07b	9.94bc	0.85a
Chia seed	2.83a	7.21a	11.00c	0.88b
Hydrated Chia flour	3.51c	8.73b	7.95a	0.88b
Hydrated Chia seed	3.04b	8.18ab	11.05c	0.91b

Values with different letters in the same parameter are significantly different ($p < 0.05$).

Table 3
Effect of 10 g/100 g chia addition on consumer's acceptance.

	Visual appearance	Odour	Texture	Flavour	Flavour persistence	Overall acceptability
Control	7.30b	6.71b	6.80c	6.44b	6.30c	6.74b
Chia Flour	5.97a	5.68a	5.86a	5.47a	5.36a	5.67a
Hydrated Chia Flour	6.17a	6.35b	6.30ab	6.02b	5.80ab	6.29b
Chia Seed	6.98b	6.55b	6.35bc	6.44b	6.08bc	6.47b
Hydrated Chia Seed	6.98b	6.68b	6.58bc	6.45b	6.20bc	6.65b

Values with different letters in the same parameter are significantly different ($p < 0.05$).

reasonable to suggest that chia pre-hydration could be incorporated in the use of flour with greater alveograph strength, additives or enzymes. This could also be applied to complete replacement, although this will require further study. Furthermore, the influence of the way in which chia is incorporated should be explored in future studies on the nutritional advantages.

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References

AACC. (2010). *Approved methods of the AACC*. St. Paul, Minnesota: American Association of Cereal Chemists.

Agyare, K. K., Addo, K., Xiong, Y. L., & Akoh, C. C. (2005). Effect of structured lipid on alveograph characteristics, baking and textural qualities of soft wheat flour. *Journal of Cereal Science, 42*, 309–316.

Alvarez-Chavez, L. M., Valdivia-Lopez, M. D., Aburto-Juarez, M. D., & Tecante, A. (2008). Chemical characterization of the lipid fraction of Mexican chia seed (*Salvia hispanica* L.). *International Journal of Food Properties, 11*, 687–697.

Bautista-Justo, M., Castro-Alfaro, A. D., Camarena-Aguilar, E., Wrobel, K., Wrobel, K., Alanis-Guzman, G., et al. (2007). Integral bread development with soybean, chia, linseed, and folic acid as a functional food for woman. *Archivos Latinoamercianos de Nutrición, 57*, 78–84.

Borneo, R., Aguirre, A., & Leon, A. E. (2010). Chia (*Salvia hispanica* L.) gel can be used as egg or oil replacer in cake formulations. *Journal of the American Dietetic Association, 110*, 946–949.

Capitani, M. I., Ixtaina, V. Y., Nolasco, S. M., & Tomás, M. C. (2013). Microstructure, chemical composition and mucilage exudation of chia (*Salvia hispanica* L.) nutlets from Argentina. *Journal of the Science of Food and Agriculture, 93*, 3856–3862.

Conforti, F. D., & Davis, S. F. (2006). The effect of soya flour and flaxseed as a partial replacement for bread flour in yeast bread. *International Journal of Food Science and Technology, 41*, 95–101.

Costantini, L., Lukšic, L., Molinari, R., Kreft, I., Bonafaccia, G., Manzi, L., et al. (2014). Development of gluten-free bread using tartary buckwheat and chia flour rich in flavonoids and omega-3 fatty acids as ingredients. *Food Chemistry, 165*, 232–240.

Czuchajowska, Z., & Pomeranz, Y. (1993). Gas formation and gas retention. I. The system and methodology. *Cereal Foods World, 38*, 499–503.

Doxastakis, G., Zafiriadis, I., Irakli, M., Marlani, H., & Tananaki, C. (2002). Lupin, soya and triticale addition to wheat flour doughs and their effect on rheological properties. *Food Chemistry, 77*, 219–227.

Farrera-Rebollo, R. R., Salgado-Cruz, M. D., Chanona-Perez, J., Gutierrez-Lopez, G. F., Alamilla-Beltran, L., & Calderon-Dominguez, G. (2012). Evaluation of image analysis tools for characterization of sweet bread crumb structure. *Food and Bioprocess Technology, 5*, 474–484.

Gomez, M., Oliete, B., Caballero, P. A., Ronda, F., & Blanco, C. A. (2008). Effect of nut paste enrichment on wheat dough rheology and bread volume. *Food Science and Technology International, 14*, 57–65.

Gomez, M., Ronda, F., Blanco, C. A., Caballero, P. A., & Apesteguia, A. (2003). Effect of dietary fibre on dough rheology and bread quality. *European Food Research and Technology, 216*, 51–56.

Guarda, A., Rosell, C. M., Benedito, C., & Galotto, M. J. (2004). Different hydrocolloids as bread improvers and antistaling agents. *Food Hydrocolloids, 18*, 241–247.

Iglesias-Puig, E., & Haros, M. (2013). Evaluation of performance of dough and bread incorporating chia (*Salvia hispanica* L.). *European Food Research and Technology, 237*, 1–10.

Lin, K. Y., Daniel, J. R., & Whistler, R. L. (1994). Structure of chia seed polysaccharide exudate. *Carbohydrate Polymers, 23*, 13–18.

Maforimbo, E., Skurray, G., Uthayakumaran, S., & Wrigley, C. W. (2006). Improved functional properties for soywheat doughs due to modification of the size distribution of polymeric proteins. *Journal of Cereal Science, 43*, 223–229.

Mentes, O., Bakkalbassi, E., & Ercan, R. (2008). Effect of the Use of ground flaxseed on quality and chemical composition of bread. *Food Science and Technology International, 14*, 299–306.

Moreira, R., Chenlo, F., & Torres, M. D. (2013). Effect of chia (*Salvia hispanica* L.) and hydrocolloids on the rheology of gluten-free doughs based on chestnut flour. *LWT – Food Science and Technology, 50*, 160–166.

Muñoz, L. A., Cobos, A., Diaz, O., & Aguilera, J. M. (2012). Chia seeds: microstructure, mucilage extraction and hydration. *Journal of Food Engeneering, 108*, 216–224.

Pareyt, B., Finnie, S. M., Putseys, J. A., & Delcour, J. A. (2011). Review: lipids in bread making: sources, interactions, and impact on bread quality. *Journal of Cereal Science, 54*, 266–279.

Pizarro, P. L., Almeida, E. L., Sammán, N. C., & Chang, Y. K. (2013). Evaluation of whole chia (*Salvia Hispanica* L.) flour and hydrogenated vegetable fat in pound cake. *LWT – Food Science and Technology, 54*, 73–79.

Rendón-Villalobos, R., Ortíz-Sanchez, A., Solorza-Feria, J., & Trujillo-Hernández, C. A. (2012). Formulation, physicochemical, nutritional and sensorial evaluation of corn tortillas supplemented with chia seed (*Salvia hispanica* L.). *Czech Journal of Food Science, 30*, 118–125.

Ribotta, P. D., Arnulphi, S. A., Leon, A. E., & Añon, M. C. (2005). Effect of soybean addition on the rheological properties and breadmaking quality of wheat flour. *Journal of the Science of Food and Agriculture, 85*, 1889–1896.

Roccia, P., Ribotta, P. D., Perez, G. T., & León, A. E. (2009). Influence of soy protein on rheological properties and water retention capacity of wheat gluten. *LWT – Food Science and Technology, 42*, 358–362.

Scanlon, M. G., & Zghal, M. C. (2001). Bread properties and crumb structure. *Food Research International, 34*, 841–864.

Segura-Campos, M. R., Salazar-Vega, I. M., Chel-Guerrero, L. A., & Betancur-Ancona, D. A. (2013). Biological potential of chia (*Salvia hispanica* L.) protein hydrolysates and their incorporation into functional foods. *LWT – Food Science and Technology, 50*, 723–731.

Steffolani, E., de la Hera, E., Perez, G., & Gómez, M. (2014). Effect of chia addition on the quality of gluten-free bread. *Journal of Food Quality, 37*, 307–319.

Vázquez-Ovando, A., Rosado-Rubio, G., Chel-Guerrero, L., & Betancur-Ancona, D. (2009). Physicochemical properties of a fibrous fraction from chia (*Salvia hispanica* L.). *LWT – Food Science and Technology, 42*, 168–173.