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Effect of flour chia (*Salvia hispanica* L.) as a partial substitute gum in gluten free breads

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Abstract

This study aimed to evaluate the effect of different proportions of chia flour (*Salvia hispanica* L.) on the physical and nutritional quality of gluten free breads. Three formulations of bread were prepared with different proportions of chia flour (T1- 2.5%, T2- 5% and T3- 7.5%), as well as a standard that included gum. Was performed of chemical analyzes the breads and in the raw material, in addition to volume increase within analysis, cooking losses, specific volume, texture and color in breads The nutritional value increased in the breads made with chia flour. All the textural parameters were affected by the addition of chia flour. The bread with 2.5% chia flour achieved the best rating for sensory acceptance and received a purchase intent rating of 40%. Chia flour used at a ratio of 2.5% to substitute rice and soy flours behaved similarly to gum in relation to the nutritional and physical characteristics of the breads, representing a satisfactory alternative for gluten-free baked goods.

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Introduction

Bread is considered to be a good source of energy and nutrients for humans. It is widely consumed, usually as a snack, and it is appreciated for its appearance, aroma, taste, value and market availability (Borges *et al*., 2011). Bakery products are commonly prepared from wheat flour, which contains proteins that can form a network called gluten. The latter provides properties such as extensibility, elasticity, viscosity and gas retention to dough, and it significantly contributes to the appearance and structure of bread (Capriles and Arêas, 2011). However, some people have a digestive disease characterized by permanent intolerance to these proteins, which is called celiac disease. This disease has no cure, the only treatment is the complete removal of gluten from the diet (Sivaramakrishnan, Senge and Chattopadhyay, 2004).

The preparation of gluten-free products with good technological characteristics is difficult because adjustments to ingredients and the modification of conventional processes are necessary. Gluten-free dough is unable to retain the gas generated during fermentation and baking, resulting in bread with low specific volume and firm and rubbery crumbs, which is rarely well accepted by consumers (Capriles and Arêas, 2011). For these reasons, many studies have been performed with the purpose of developing gluten-free baked products with sensory and nutritional characteristics similar to bread made with wheat flour. Substituting wheat in bread results in changes in flavor, texture and appearance; there is also often a reduction in nutritional properties because most of the time the flour used in making bread is refined, with low levels of micronutrients and dietary fiber (Andrade *et al*., 2011). Chia (*Salvia hispanica* L.) is a plant that contains high levels of polyunsaturated fatty acids, dietary fiber and protein. In the presence of water chia seeds form a mucilaginous, transparent gel composed of soluble fiber. The properties of the gum that is formed mean that it can be used in many products in the food industry (Spada *et al*., 2014). Thus, chia can be potentially used to replace the hydrocolloids that are often required in the preparation of gluten-free breads in order to provide better structure and increased volume for baked products, and also to confer healthy nutritional characteristics to such products. Consequently, this study aimed to prepare gluten-free breads, with chia gum flour as a substitute, and to verify the effect of chia flour (*Salvia hispanica* L.) on the physical and nutritional quality of the developed breads.

Materials and Methods

Raw materials

The ingredients used in the formulation of the loaves were as follows: rice flour, which was provided by the Favarin company (Santa Maria, RS); Pra vida® soy flour; Cia Natural® chia flour; Cisne® refined salt, Fleischmann® freeze-dried yeast;

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Sadia® lite margarine with 38% lipids, União® refined sugar; water, and Genix® HPMC (hidroxypropyl methylcellulose) gum.

Development of the formulations

The basic formulations of the breads were defined from pre-tests developed by Moreira (2007). A standard formulation was prepared without chia flour. In order to verify the action of chia flour as gum, three treatments were formulated, which presented the partial substitution of the mixed flour base (rice and soy flours) by chia flour in proportions of 2.5% (T1), 5.0% (T2) and 7.5% (T3), all of which were without gum. The formulations used in this study are presented as (Table 1).

Processing of the breads

The breads were prepared in a bakery located in the city of Caçapava do Sul, Rio Grande do Sul, Brazil, by the "direct dough" method, which is based on mixing all the ingredients in a single stage (without fermentation). This stage was performed manually (approximately 5 minutes) until a smooth, homogeneous dough was achieved, similar to a cake but firmer and more consistent. The weight of the raw dough placed in each mold was 116 g in order to standardize the results. The dough was then poured into equally sized molds (10 cm x 6 cm x 4.5 cm) and allowed to stand to rise for 50 minutes at room temperature (approximately 25°C). The cooking was performed in a Venâncio industrial oven at an average temperature of 170°C for 25 minutes.

Chemical composition of the breads and raw materials

The products and raw materials, were subjected to the following analyses: moisture (No. 934.01); ash (No. 923.03); proteins, through the determination of total nitrogen by the Kjeldahl method (No. 46-13); lipids, by extraction with petroleum ether (No. 945.08); and dietary fiber, by the enzymatic-gravimetric method (Nos. 985.29 and 991.42), according to methods described in the AOAC (2005). The non-fiber carbohydrate content was obtained by the difference of the other fractions. The total energy value of the breads was derived by multiplying the amount in grams of carbohydrates, proteins and lipids by the respective kcal/g (Atwater factors) (Mahan and Scott-Stump 2002).

Cooking losses

To determine the amount of loss that occurred during cooking the breads the raw dough was weighed on an analytical balance and then the baked breads were also weighed after cooling for one hour. The method to determine cooking losses followed Equation 1 (Philippi 2003).

Table 1. Formulations used in the preparation of gluten-free bread.

Ingredients	Standard (%)	T1 (%)	T2 (%)	T3 (%)
Rice flour*	33.83	32.98	32.13	31.28
Soy flour*	8.44	8.24	8.03	7.82
Chia flour*	0.00	1.05	2.11	3.17
Refined salt	0.85	0.85	0.85	0.85
Refined sugar	1.27	1.27	1.27	1.27
Freeze-dried yeast	1.69	1.69	1.69	1.69
Gum (HPMC)	0.64	0.00	0.00	0.00
Lipids (lite margarine)	2.54	2.54	2.54	2.54
Water	50.74	50.74	50.74	50.74

Source: Moreira *et al.*, 2004 with modifications.*Levels of rice flour and soy a flour substituted by chia flour: Treatment 1 (1.05% flour chia equals in substitute 2.5% the flour mix); Treatment 2 (2.11% flour chia equals in substitute 5.0% the flour mix); Treatment 3 (3.17% flour chia equals in substitute 7.5% the flour mix).

$$\text{Cooking losses (g)} = \text{weight of raw dough (g)} - \text{final weight (g)} \qquad (1)$$

Rise of dough

To measure this property, the same sized molds were used to bake all the formulations. After having been removed from the molds, the loaves were cut into 1.5 cm wide slices; the height of the slices was measured with a ruler and expressed in cm, following the methodology proposed by Garda *et al.* (2012).

Specific volume

The specific volume of the loaves was determined by displacement method of millet seeds (occupied mass) and measured its volume in graduated cylinder. The specific volume (mL.g^{-1}) calculated in accordance with Equation 2 (Pizzinatto *et al.*, 1993; El-Dash *et al.*, 2006).

$$\text{SV (mL/g)} = \frac{\text{volume (mL)}}{\text{weight (g)}} \qquad (2)$$

Where:

SV = specific volume

Table 2. Chemical composition the raw materials.

Flours	Moisture (%)	Ash (%)	Protein (%)	Lipids (%)	Total dietary fiber (%)	Carbohydrates (%)
Rice	9.08±0,33	0.43±0,02	10.77±0,67	1.03±0,02	2.49±0,22	76.20
Soy	5.13±0,89	4.51±0,14	36.35±0,75	22.61±0,38	21.91±1,10	9.49
Chia	6.49±0,11	5.07±0,04	21.22±0,20	19.62±1,36	45.80±0,77	1.80

Texture

The texture of the bread crumbs was determined by using a TAX-T2i texture analyzer in which a 36 mm cylindrical probe compressed the sample to 40% of its original size, at a speed of 1.7 mm.s^{-1}. This provided the parameters of hardness (g), cohesiveness and chewiness (g). For the analysis, two slices, which together measured 2.5 cm in thickness, were used.

Color of crust and bread crumbs

The color analyses of the crust and bread crumbs were conducted using a colorimeter (Minolta Chroma Meter CR-300). The experiment followed the $L^* a^* b^*$ color space system or CIE-L^* a^* b^*, defined by the CIE (International Commission on Illumination) in 1976. This evaluates values for L^* (lightness); a^*, which indicates a hue that moves from green (-) to red (+); and b^*, which indicates a hue that goes from blue (-) to yellow (+) (Minolta 1994).

Statistical analysis

The analyses were performed in three repetitions, which were conducted in triplicate. The results were expressed as mean ± standard deviation and subjected to analysis of variance (ANOVA). The averages were compared by Tukey's test, with a significance level of 95% ($p < 0.05$). The results were analyzed using Statistica version 7.0 software.

Results and Discussion

The chia flour (Table 2) stands the dietary fiber content (53.80%) and ash (5.07%), soy flour next. The rice flour was found to nutritionally inferior others. The high total dietary fiber content found in chia flour is similar to results described by Vásquez-Ovando *et al.* (2009) evaluated the dry chia flour and defatted found 29.56% for crude fiber and 56.46% for total dietary fiber. The high ash content found in chia flour indicates the presence of significant amount of minerals, according Migliavacca *et al.* (2014) chia seed may be considered mineral sources such as calcium, phosphorus, potassium, zinc, magnesium and copper. Larger amounts of proteins and lipids found in soy flour (36.35 and 22.61% respectively). The chia flour showed protein content and lipid (19.62 and 21.22%, respectively) similar to soy flour and rice flour higher. According to Migliavacca *et al.* (2014) lipid content in chia seed can reach 33%, while the protein values ranging from 15 to 25%, these variations are due to various factors such as cultivation area of plant, climate change, nutrient availability .

Chemical composition and energy values of the breads

The moisture (Table 3) content was higher for the breads with 5.0% and 7.5% chia flour and there was no difference between them. According to Muñoz *et al.* (2012), chia seeds contain a lot of mucilage, which is responsible for water retention and which contributes increased volume when placed in water. This mucilage enables chia to absorb up to 12 times its weight in water. When compared with linseed flour, chia has the ability to absorb 5 times more water. The aforementioned authors also mention that chia's high capacity for water retention and gel formation is due to the amount of soluble fiber that it contains. Pereira *et al.* (2013) evaluated gluten-free potato bread enriched with chia, and for formulations with 25 and 50% of chia flour they found moisture contents of 50.45% and 50.27% respectively, results similar to those found in the present study.

The content of ash, proteins and lipids were higher for the treatments with 2.5, 5.0 and 7.5% of chia flour; there were no differences between them, except for the protein content of Treatment 1, which differed from the others. The lipid contents of Treatments 1 and 2 were numerically higher and only Treatment 3 was different from the standard. Literature and Table 2 reports confirm that chia can be considered as a good source of protein and it contains higher protein levels than some traditional crops such as corn, rice and oats (Weber *et al.*, 1991; Ayerza and Coates, 2005). The increase in lipid content in this study can also be regarded as a positive factor since chia is rich in poly-unsaturated fatty acids. Studies by Ayerza and Coates (2004) and Segura-Campos *et al.* (2012) showed that the fatty acid in the highest amount (about 60%) in the lipid composition of chia seed is α-linolenic acid (Omega 3), which makes the results of the present study even more promising

Table 3. Chemical composition and energy value of gluten-free breads

	Standard (%)	T1 (%)	T2 (%)	T3 (%)
Moisture	48.42±0.03^{b}	48.48±1.24^{b}	52.19±0.02^{a}	52.01±0.04^{a}
Ash	2.06±0.01^{b}	2.45 ±0.06^{a}	2.38±0.10^{a}	2.44 ±0.04^{a}
Protein	12.12±0.17^{c}	13.23±0.29^{b}	14.42±0.34^{a}	14.44±0.36^{a}
Lipids	3.33±0.08^{b}	3.56±0.01^{a,b}	3.54±0.19^{a,b}	3.66±0.05^{a}
Total dietary fiber	6.83±1.21^{b}	6.12±0.93^{b}	9.01±0.66^{a}	8.45±0.30^{a}
Insoluble fiber	5.59±1.28^{a,b}	4.90±0.60^{b}	7.36±0.91^{a}	7.05±0.60^{a}
Soluble fiber	1.24±0.18^{a}	1.22±0.33^{a}	1.65±0.42^{a}	1.40±0.56^{a}
Available carbohydrates[1]	27.25	26.17	18.45	19.00
Energetic value* (Kcal/100g)	187.45	189.64	163.34	166.67

Analyses performed in three repetitions and values presented on a wet basis. Different letters on the lines differ statistically at a level of 5% probability by Tukey's test ($p < 0.05$). ** standard: with gum; T1: 2.5% chia flour; T2: 5.0% chia flour; T3: 7.5% chia flour.

Table 4. Specific volume, cooking losses and rise in dough obtained for the gluten-free breads

Treatment*	Specific volume (mL/g)	Cooking losses (g)	Rise in dough (cm)
Standard	2.61±0.22^{a}	17.23±0.39^{a}	4.12±0.16^{a}
T1	2.32±0.05^{a,b}	17.69±0.29^{a}	3.57±0.05^{b,c}
T2	2.13±0.20^{b}	14.60±0.29^{b}	3.83±0.10^{a,b}
T3	1.95±0.12^{b}	14.43±0.57^{b}	3.37±0.12^{c}

Analysis carried out in three repetitions. Different letters in columns differ statistically at the level of 5% probability by Tukey's test. * Standard: with HPMC; T1: 2.5% chia flour; T2: 5.0% chia flour; T3: 7.5% chia flour.

because this fatty acid is not synthesized and should form part of the diet.

The breads with 5.0% and 7.5% of chia flour differed from the others in relation to the total dietary fiber content. The results obtained in the present study were higher than those found by Vasconcelos *et al.* (2006), who evaluated the addition of soy flour at levels of 5%, 10% and 15% and oat bran (6% for all formulations) as dietary fiber in bread. The values found by the aforementioned authors ranged between 5.70 and 5.96%. According to the Brasil (2012), in order for a food to be considered a source of fiber it should contain at least 2.5 g per serving, and to be included in the class of foods with high fiber content the minimum content required is 5 g per portion of food. Bearing in mind that in the case of bread the stipulated portion is 50 g, and based on these parameters, it is possible to state that all the breads produced in the present study can be considered as sources of dietary fiber.

The insoluble fiber content of the breads with 5.0% and 7.5% chia flour did not differ statistically from the value obtained for the standard. It should be considered that although the standard did not include chia flour, it did include gum, which can significantly influence these values because HPMC is a cellulose-derived polymer which has the ability to form gel in aqueous medium due to presence of fibers (Dikeman and Fahey 2006; Fahs 2010).

Specific volume, rise in dough and cooking losses

The results for specific volume (Table 4) found for the breads with chia flour showed significant difference between Standard and T3, demonstrating that the increase in the proportion of chia flour in the breads influence this parameter. However, these values were lower than for the standard formulation,

Table 5. Lightness values (L^*) and chromaticity coordinates (a^* and b^*) for the crust and crumbs of gluten-free breads.

Color of crust				Color of crumbs		
**	L*	a*	b*	L*	a*	b*
Standard	67.0±2.31[a]	8.11±1.55[b]	37.4±0.63[a]	80.41±1.76[a]	0.80±0.05[d]	27.16±0.46[a]
T1	53.7±1.37[b]	12.91±0.66[a,c]	33.6±0.40[b]	69.27±1.53[b]	1.97±0.09[c]	21.33±0.21[b]
T2	50.5±2.14[b]	13.56±0.78[a]	31.8±0.79[c]	64.30±0.26[c]	2.59±0.08[b]	20.02±0.33[c]
T3	49.3±2.08[b]	10.23±1.59[b,c]	27.1±0.24[d]	59.71±0.77[d]	3.05±0.09[a]	18.23±0.28[d]

Analysis carried out in three repetitions. Different letters in columns differ statistically at a level of 5% probability by Tukey's test ($p < 0.05$) ** Standard: With HPMC; T1: 2.5% chia flour; T2: 5.0% chia flour; T3: 7.5% chia flour.

which was significantly higher, except for the bread with 2.5% chia flour.

The gluten-free breads had difficulties in expanding the dough because they did not contain the gluten network that guarantees expansion through the entrapment of gas formed by fermentation. The addition of flour that was rich in fiber also reduced volume further by increasing the resistance of the dough in relation to the gas cells (Gill *et al*., 2002; Moreira 2007). According to Katina *et al*. (2006), the addition of fiber in baked goods can cause problems regarding technological quality because it reduces the volume and elasticity of the crumbs.

The results for the specific volume of the breads with 5.0 and 7.5% chia flour (2.13 and 1.95 mL/g respectively) did not achieve the same volume as the bread made with gum (2.61 mL/g) but they were similar to the results found by Clerici and El-Dash (2006), who studied gluten-free breads made with extruded rice flour (1.71 to 2.35 mL/g).

The breads showed the same behavior in relation to the rise in dough. The treatments containing chia flour had lower results. The highest value was obtained for the treatment with gum (4.12 cm) and the lowest was for the treatment with 7.5% chia flour (3.37 cm). Authors have suggested that the use of gum in the preparation of gluten-free breads can increase its size. This occurs due to the water absorption capacity of the gum, and this interaction also provides force for the bread dough to expand in the early stages of cooking, consequently reducing the loss of gas and increasing the growth of the bread (Haque and Morris, 1993).

The treatments with 5.0 and 7.5% chia flour had lower values for cooking losses, differing significantly from the results obtained for the standard bread and the bread with 2.5% chia flour, these showed less ability to retain water during processing. Similar results were found by Garda *et al.* (2012), who prepared gluten-free breads with rice flour, tapioca starch and corn starch. When these flours were replaced with a mixture of 3% chia seed and linseed, the authors found higher cooking losses for the standard formulation compared to the formulations made with the replacement flours. They suggested that this result was due to the action of the mucilage from the seeds in the dough, which provided greater water retention and lower cooking losses, similar to what occurred in the present study.

Color of crust and bread crumbs

Table 5 shows the values for the color of the crust and bread crumbs of the gluten-free breads made with chia and without gum. For both the color of the crust and the crumbs, the Treatments 1, 2 and 3 were darker than the standard, which was shown by lower luminance values and a greater tendency to red (higher a^* values) and blue (lower b^* values), indicating that the dark pigmentation of the chia flour significantly influenced the color of the breads. Similarly, Koca and Anil (2007) and Borges *et al*. (2011) found breads that were darker than the standard when preparing breads with linseed flour.

Texture of the breads

All the texture parameters (Figure 1) were affected by the partial substitution of soy and rice flours with chia flour and the removal of gum. The affected parameters were hardness (the force necessary to perform the deformation or breakage

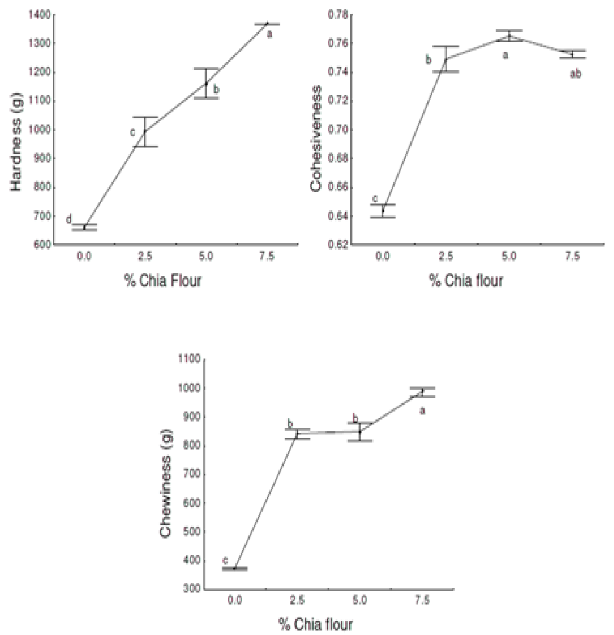

Figure 1. Textural parameters of gluten-free breads with chia flour and without gum. Averages followed by the same letter were not significantly different from each other. 0% *Standard formulation with gum; T1: 2.5% chia flour; T2: 5.0% chia flour; T3: 7.5% chia flour.

of the sample); chewiness (the energy needed to transform solid material into a state ready for swallowing); and cohesiveness (the forces involved in the internal bonding of the sample) and they were all higher when the flour was substituted with chia. There was a significant increase in hardness in line with the increased percentages of chia flour. Regarding cohesiveness, the formulation with 7.5% substitution showed no difference from the other treatments with chia flour. The values for chewiness for the treatments with 2.5 and 5.0% chia showed no significant difference between each other. The increase in these parameters in the presence of chia flour can probably be associated with a reduction in the volume of the breads and decreased free water content in the dough, which probably resulted in a decrease in smoothness when compared to the standard treatment (Borges *et al*., 2011).

A study by Borges *et al*. (2011) showed similar results in the evaluation of the addition of whole linseed flour to salt rolls, which resulted in an increase in firmness in the bread with 10 to 15% added linseed flour. Esteller and Lannes (2008) also reported that the addition of rye flour generated an increase in the hardness of bread, which indicates that the addition of fiber contributed to decreasing the softness of the studied breads. The result for hardness in the bread with 2.5% chia flour were similar to the results found by Silva *et al.* (2010) in relation to bread made with wheat flour. This is a positive factor because gluten-free bread usually has lower textural characteristics when compared to traditional bread.

Conclusion

The partial substitution of the mixture of rice flour and soy flour for chia flour resulted in an significant increase in the nutritional value of the bread com 7,5% de farinha de chia. The bread with 2.5% chia flour showed results for specific volume and cooking losses that were similar to the standard, In terms of the rise in dough, the standard received the highest value, followed by the bread with 5.0% chia flour. The breads with chia flour were darker in color compared to the standard. All the texture parameters (hardness, chewiness and cohesiveness) were higher in the breads with chia flour. According to these results chia flour at a concentration of 2.5% substituting rice flour and soy flour, behaved similarly to gum in terms of the physical and nutritional characteristics of the breads. Consequently, bread prepared with chia flour represents a new variation of functional foods. It provides a healthy and alternative food, which is a gluten-free product suitable for celiacs and also for the general population.

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