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# Evaluation of replacing wheat flour with chia flour (*Salvia hispanica* L.) in pasta

# Avaliação da substituição da farinha de trigo por farinha de chia (*Salvia hispanica L.*) em massas alimentícias

Matheus Rodrigues Oliveira[1]; Mariana Ercolani Novack[2]; Carina Pires Santos[3]; Ernesto Kubota[4]; Claudia Severo da Rosa[5*]

## Abstract

In recent years, chia (*Salvia hispanica* L.) has become increasingly more prevalent in the Brazilian diet and has triggered the interests of many researchers due to its functional properties and associated health benefits. The objective of this study was to develop pasta with different percentages of chia flour in lieu of wheat flour, and to evaluate the impact of chia on the nutritional, technological, and sensory properties of pasta. Pastas were prepared by replacing 7.5% (T1), 15% (T2), and 30% (T3) of wheat flour with chia flour relative to the control formulation (C). The quality of the pastas were evaluated through cooking tests (increase in weight and volume, cooking time, and loss of solids in the cooking water), chemical composition (moisture, fat, fiber, protein, ash, and carbohydrates), and color, using a Minolta colorimeter and sensory analysis by means of acceptance testing. Pasta made with chia flour had higher nutritional value and superior technological characteristics than did the control. Sensory analysis results showed that pasta with 7.5% chia flour had higher rates of acceptability in terms of the flavor, while the control pasta prevailed in terms of color and texture.

**Key words**: *Salvia hispanica* L., cooking test, pasta, chia flour

## Resumo

Nos últimos anos a chia (*Salvia hispanica L.*) vêm se tornando cada vez mais presente na dieta dos brasileiros e despertando o interesse de muitos pesquisadores, pelas suas propriedades funcionais e seus respectivos benefícios à saúde. O objetivo desse trabalho foi desenvolver massas alimentícias com diferentes percentuais de farinha de chia em substituição a farinha de trigo e avaliar o impacto da chia nas características nutricionais, tecnológicas e sensoriais. As massas foram desenvolvidas pela substituição de 7,5% (T1), 15% (T2) e 30% (T3) da farinha de trigo por farinha de chia em relação à formulação controle (C). Avaliou-se a qualidade das massas por meio de testes de cozimento (aumento de peso e de volume, tempo de cozimento e perda de sólidos na água de cozimento), composição química (umidade, lipídios, fibras, proteína, cinzas e carboidratos) cor, pelo colorímetro Minolta e análise sensorial através de teste de aceitação. As massas formuladas com farinha de chia apresentaram maior valor nutricional e características tecnológicas superiores a controle. Os resultados da análise sensorial demonstraram que a massa com 7,5% de farinha de chia obteve maior aceitabilidade no sabor e a massa controle na cor e textura.

**Palavras-chave**: *Salvia hispanica L.*, teste de cozimento, massas alimentícias, farinha de chia

[1] Tecnólogo em Alimentos, Universidade Federal de Santa Maria, UFSM, Santa Maria, RS. Brasil. E-mail: matheus_ro@hotmail.com

[2] Discente do Programa de Pós-graduação em Ciência e Tecnologia de Alimentos, UFSM, Santa Maria, RS, Brasil. E-mail: mariananovack@gmail.com

[3] Tecnóloga em Alimentos, Santa Maria, RS, Brasil. E-mail: carina88ps@gmail.com

[4] Prof. Titular, Deptº de Tecnologia e Ciência dos Alimentos, UFSM, Santa Maria, RS, Brasil. E-mail: Tecnólogo em Alimentos, Universidade Federal de Santa Maria, UFSM, Santa Maria, RS, Brasil. E-mail: ernehk2008@yahoo.com.br

[5] Profª Adjunta, Deptº de Tecnologia e Ciência dos Alimentos, UFSM, Santa Maria, RS, Brasil. E-mail: claudiasr37@yahoo.com.br

[*] Author for correspondence

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## Introduction

Pasta has a high rate of acceptability because it is a readily available, versatile, and inexpensive food. The simplicity of the pasta production, in addition to its ease of handling and storage stability, facilitated its popularity and wide consumption around the world (CHILLO et al., 2008). In terms of market, Brazil is among the five biggest producers of pasta in the world, and is the second largest consumer. Therefore, pasta is already part of the standard Brazilian staple basket (ABIMA, 2013). According to data from the ABIMA (2013), the average consumption of pasta per capita is 6.1 kg/inhabitant/year. Nevertheless, pasta is considered insufficient with regards to its nutritional value since it contains high levels of carbohydrates and lacks proteins in terms of both quantity and quality. However, merely suggesting a reduction in the consumption of pasta or other carbohydrate-rich foods to the public is not a sufficient strategy to significantly raise awareness and cause an impact. An alternative may be to improve the nutritional value of pasta without compromising the associated sensory characteristics (NICOLETTI et al., 2007).

Chia (*Salvia hispanica* L.) is native to the Americas, with its range extending from western and central Mexico to northern Guatemala. The chia seed contains between 0.25 g to 0.38 g oil$^{-1}$g, and the main constituents are triglycerides, including polyunsaturated fatty acids (linoleic and linolenic acid). In addition, the chia seed contains higher protein content (from 0.19 g to 0.23 g $^{-1}$g) than do traditional cereals such as wheat, corn, oats, and barley (COATES; AYERZA, 1996; IXTAINA et al., 2011). Its high fiber content (around 42%) can also improve satiety, reduce energy consumption, and promote weight loss. (COATES; AYERZA, 1996). Chia seeds are also used as food supplements in the manufacture of cereal bars, breakfast cereals, and biscuits in the USA, Latin America, and Australia (IXTAINA et al., 2011). Since it is rich in fiber, chia plays an important physiological role; it can swell upon water absorption due to the presence of carbohydrates with free polar groups that make hydrophilic bonds, and thus retaining water. These bonds lead to the formation of a gel that increases stool volume, causing peristalsis in the intestines to facilitate the transit of the fecal bolus, and reducing the likelihood of intestinal diseases (VÁZQUEZ-OVANDO et al., 2009).

The objective of this study was to develop pastas with different percentages of chia flour to substitute wheat flour, and to evaluate the impact of chia on the nutritional, technological, and sensory properties of pasta.

## Materials and Methods

*Determination of the chemical composition*

Moisture was removed by drying in an oven at 105 °C to ensure that the weight is consistent throughout the experiment. Ash levels were determined by incineration in muffle at 550 °C. Protein levels were determined by the Kjeldahl method. Total lipids levels were obtained by extracting the ethereal fraction in a Soxhlet apparatus. Carbohydrate levels were determined by calculating the difference (AOAC, 1998). Total, insoluble, and soluble dietary fiber fractions were determined by the enzymatic-gravimetric method (method 985.28) according to AOAC (1998).

*Raw material*

Chia was purchased from a market in Santa Maria, Rio Grande do Sul, Brazil. The grains were ground in an analytical mill (Quimis, model Q 298A21, Brazil). The flour was then standardized to a particle size of 60 mesh (0.25 mm). Other ingredients were purchased in a local market.

*Processing of the pasta*

Wheat flour classified as special wheat flour was purchased from a local market. Preparations were made in accordance with pre-tested formulations, following the techniques of preparation described by Barbosa (2002). Standard pasta: 400 mL of water mixed with 1,000 g of special wheat flour for 15 min until the dough was homogeneous. The dough was then opened and cut on a manual pasta machine (Anodilar, Caxias do Sul, Brazil).

The dough was cut into cylindrical shapes of 5, 4, and 3 mm thick (final thickness of the pasta; repeated for 4 times) and cut into noodles 26 cm in length and 0.5 cm in width. Next, the pastas were dried at 90 °C for 6 h before being analyzed for quality according to protocols by Chillo et al. (2008), and the remainder was dried in an oven with an air circulation at 55 °C for further analysis. Pasta with 7.5% chia flour contained 925 g of wheat flour and 75 g of chia flour (75 g). Pasta with 15% chia flour contained 850 g of wheat flour and 150 g of chia flour (150 g). Pasta with 30% chia flour contained 700 g of wheat flour (700 g) and 300 g of chia flour. The pastas were evaluated visually after being cut and dried.

*Cooking tests*

The cooking time was determined by following the methodology described by (NABESHIMA; EL-DASH, 2004). A sample of 10 g was placed in 300 mL of boiling water, while the time was tracked. At random intervals, a portion was removed from the sample and compressed between two glass plates in order to observe the disappearance of the white core, which indicates the end of the cooking time.

Water absorption was determined by measuring the increase in weight during cooking. Pasta weighing 10 g was placed in 300 mL of boiling water and cooked for an optimal time. Increase in volume was measured by the volume of distilled water displaced by 10 g of pasta before and after cooking in a 250 mL graduated cylinder. The loss of soluble solids was verified by calculating the percentage of solids present in the cooking water (NABESHIMA; EL-DASH, 2004).

*Sensory analysis*

To evaluate the acceptability of the pasta, a 7-point hedonic scale was used for acceptance testing, in which the upper and lower extremes respectively correspond to 7 (liked very much) and 1 (disliked very much). To evaluate the color, flavor, appearance, and texture attributes, the pasta was placed in boiling water with 6.5 g of salt and 10 mL of oil, and was served to tasters soon after cooking. The sensory panel was composed of 50 untrained tasters recruited randomly. The pastas were numbered with 3 random figures and 20 g of heated pasta, along with a glass of water to rinse the taste buds, were served on disposable plates monadically according to previously describes methods (DUTCOSKY, 2006).

*Determination of color*

Color was determined using the CIELAB system in a CR-300 device (Minolta, Japan) by reading the parameters $L^*$ (which represents the percentage of brightness, where black is 0% and white is 100%), $a^*$ (where $+a^*$ is red), and $b^*$ (where $+b^*$ is yellow). The readings were taken at room temperature on the surface of the pastas, with five repetitions for each evaluated sample.

*Statistical analysis*

Statistical analysis of the data obtained in all experiments were performed by the analysis of variance (ANOVA) and Tukey's test with a 5% significance level by using SPSS version 17.0.

## Results and Discussions

All pastas evaluated in both the dry and raw states demonstrated uniformity in terms of length (26 cm), thickness (3 mm), and width (0.5 cm); they also exhibited smooth and uniform coloration. According to Dexter et al. (1981), such quality characteristics are essential in the commercial aspect of the product.

Chemical composition of chia seeds is shown in table 1. It can be seen that the seeds are rich in protein, fat, and fiber (23.27%, 28.35%, and 37.44%, respectively). Similar results were found by Sargi et al. (2013) upon analyzing the composition of chia seeds, 45.30% for total carbohydrates, which is almost entirely composed of fibers. Vázquez-Ovando et al. (2009) determined the total, insoluble, and soluble fiber contents of chia seeds with values of 56.46%, 53.45%, and 3.01% respectively; ACNFP, (2003) found 33.95% for total fiber, 30.43% for insoluble fiber, and 3.01% for soluble fiber. This result was similar to that found in this study. Chia seeds are also rich in proteins (23.17%) when compared to other grains such as rice, corn, barley, wheat, and amaranth. However, chia has not been marketed as a source of protein, mainly because the profile of amino acids is limiting for schoolchildren. Nevertheless, it can be mixed with other grains to improve the protein balance in formulations for adults (AYERZA; COATES, 2011). Similar results were found by Sargi et al. (2013) upon analyzing the composition of chia seeds, showing a protein content of 21.52%. A study conducted by Muñoz et al. (2012) and Sargi et al. (2013) on chia, perilla (*Perilla frutescens*), and flax (*Linumusitatis simum*) seeds showed that these seeds are also rich in protein and all present values above 20%. On the other hand, the fat content of the chia seed is high (28.35%). According to Peiretti (2011), the fat composition of chia seeds is an excellent source of alpha-linolenic acid (LNA, 18:3, n-3) ranging from 396.56 $mg.g^{-1}$ to 544.85 $mg.g^{-1}$, representing 46.72% to 62.44% of the total fatty acids present in the chia seed. Similarly, the ash content (5.45%) is high compared to other commonly consumed cereals like wheat, sorghum, and rice. Furthermore, the minerals in greater abundance in the chia seed include phosphorus, calcium, magnesium, and iron (CAPITANI et al., 2012).

The chemical composition of dried pastas prepared with different percentages of chia is shown in table 1. There were significant differences ($p < 0.05$) for all the evaluated fractions. The moisture content increased compared to the control, showing values ranging from 8.98% to 10.39%. This increase in moisture content can be attributed to the fiber and mucilage contained in the chia flour that retains water. These results are within the established guideline for dried pasta (13%) according to ANVISA (2000). The ash content exhibited a proportional increase with the substitution of wheat flour by chia flour. These results are consistent with the study by Gimenez et al. (2012), who developed pastas with the wheat flour replaced by different proportions of fava bean flour, which is also rich in minerals. The ash content is directly related to the degree of extraction for the flour and the yield during milling, and also interferes with the particle size and makes the flour darker. It also has a direct impact on the protein content of the flour, since both are in higher concentrations in the aleurone layer of the wheat grain (SCHMIELE et al., 2011).

**Table 1.** Chemical composition of chia flour, control pasta, and dry pasta prepared with different percentages of chia flour.

| Fractions % | Chia flour | Control | T1 | T2 | T3 |
|---|---|---|---|---|---|
| Moisture | $3.27^c \pm 0.75$ | $8.98^b \pm 0.06$ | $10.39^a \pm 0.01$ | $9.13^b \pm 0.06$ | $9.10^b \pm 0.15$ |
| Ash | $5.45^a \pm 0.44$ | $0.44^d \pm 0.02$ | $0.69^c \pm 0.01$ | $1.02^b \pm 0.01$ | $1.53^b \pm 0.01$ |
| Protein | $23.17^a \pm 0.34$ | $11.62^e \pm 0.03$ | $12.37^c \pm 0.16$ | $13.28^d \pm 0.04$ | $14.44^b \pm 0.23$ |
| Ethereal E. | $28.35^a \pm 0.65$ | $0.07^d \pm 0.01$ | $0.30^e \pm 0.01$ | $0.89^c \pm 0.01$ | $1.59^b \pm 0.02$ |
| Total fiber | $37.44^a \pm 0.59$ | $2.90^e \pm 0.08$ | $11.68^d \pm 0.09$ | $17.59^c \pm 0.08$ | $26.62^b \pm 0.03$ |
| Insoluble fiber | $33.24^a \pm 0.41$ | $7.01^e \pm 0.05$ | $10.36^d \pm 0.12$ | $14.6^c \pm 0.01$ | $22.69^b \pm 0.01$ |
| Soluble fiber | $4.20^a \pm 0.29$ | $1.24^d \pm 0.01$ | $1.32^d \pm 0.03$ | $2.99^c \pm 0.02$ | $3.92^b \pm 0.04$ |
| Carbohydrates | $1.97^e \pm 0.43$ | $75.99^a \pm 0.02$ | $64.67^b \pm 0.19$ | $58.09^c \pm 0.01$ | $46.85^d \pm 0.23$ |

Identical letters in the same column do not differ statistically at the 5% level by the Tukey's test. Control: pasta with 100% wheat flour, T1: pasta with 7.5% chia flour in place of wheat flour, T2: pasta with 15% chia flour in place of wheat flour, T3: pasta with 30% chia flour in place of wheat flour.

The protein content of the pastas differed statistically in all treatments ($P < 0.05$); it increased with increasing substitution of wheat flour by chia flour. Coorey et al. (2012) observed the same behavior when studying the effects of chia flour on the nutritional quality of chips, indicating higher values of protein ranging from 5.10% to 7.14% with 2.5% and 8% of chia flour in the chips, respectively. Similar results were found by Chillo et al. (2008) on fresh pasta made from amaranth flour (12.2%), and pasta with amaranth flour and chickpea flour (13.86%). Replacing 30% of wheat flour by chia flour resulted in a significant increase of protein content (14.44%). This result is significant because pasta is considered a low nutritional value product. All protein contents ranged from 8% to 15% as established by the Standards of Identity and Quality of Pastas (ANVISA, 2000). There was a significant increase in the total, insoluble, and soluble fiber contents as the proportion of chia flour in the pasta was increased. According to Ordinance No. 27 of 1/13/1998 (ANVISA, 1998), foods considered as source of fiber have at least 3 g of fiber/100 g of sample and foods with high fiber content have 6 g of fiber/100 g of sample. Therefore, dried pasta with chia flour can be classified as foods with a high fiber content. According to the American Diabetes Association, 25 to 30 g of fiber is the recommended daily intake for the best physiological and nutritional outcomes (CAPITANI et al., 2012). In addition, there was an increase in fat content in the pastas that is proportional to the added chia flour.

Table 2 shows the results of the technological properties and colors of the pastas. Water absorption, volume increase, and loss of soluble solids demonstrated significant differences ($p < 0.05$) across treatments. The level of substitution affected water absorption, with substituting 30% of wheat flour by chia flour showing the highest level of water absorption (322%). This behavior is due to the high fiber content of chia flour. The fibers, when mixed with water, form three-dimensional networks. Chia flour contains mucilaginous compounds that form a water-retaining gel upon contact with water (MUÑOZ et al., 2012). Capitani et al. (2012) stated that even though the soluble fiber (SF) content is low, the mucilage fulfills the functional property of water retention. They also reported that high proportions of hemicellulose and lignin are responsible for greater absorption. Capitani et al. (2012), while characterizing the physicochemical and functional properties of chia seeds, obtained results for water absorption capacity in the range of 6.13 g to 10.46 g, higher than those found by Khattab and Arntfield (2009) in the analysis of canola, soybeans, and flaxseed (3.90 and 3.28 g, respectively), and superior to linseed flour (6 g, 0.3 g). Meanwhile, pasta with 30% chia flour differed significantly from the others with a greater increase in volume (291%). This phenomenon is closely linked to the water absorption capacity of the chia flour. Muñoz et al. (2012) performed an analysis on the microstructure of chia seeds and reported 2.7 g of water being absorbed by 100 mg of mucilage, which corresponds to 27 times its weight.

**Table 2.** Averages of the technological properties and color of control pasta and pasta with different percentages of chia flour.

| Treatment | Cooking time (min) | Water absorption (%) | Volume increase (%) | Loss of solids (%) | $L^*$ | $a^*$ | $b^*$ |
|---|---|---|---|---|---|---|---|
| Cont. | $14.0^b \pm 0.11$ | $231^c \pm 0.01$ | $229^c \pm 0.01$ | $13.20^a \pm 0.16$ | $82.10^a \pm 0.56$ | $1.85^b \pm 0.14$ | $15.38^a \pm 0.40$ |
| T1 | $15.6^a \pm 0.30$ | $240^c \pm 0.02$ | $234^b \pm 0.01$ | $7.85^c \pm 0.05$ | $73.29^b \pm 0.87$ | $1.91^b \pm 0.08$ | $13.12^b \pm 0.18$ |
| T2 | $15.5^a \pm 0.22$ | $281^b \pm 0.03$ | $278^b \pm 0.08$ | $8.47^c \pm 0.03$ | $66.13^c \pm 0.54$ | $2.20^{ab} \pm 0.08$ | $12.79^b \pm 0.16$ |
| T3 | $16.0^a \pm 0.31$ | $322^a \pm 0.02$ | $291^a \pm 0.02$ | $8.91^b \pm 0.02$ | $60.20^d \pm 0.56$ | $2.37^a \pm 0.47$ | $13.04^b \pm 0.07$ |

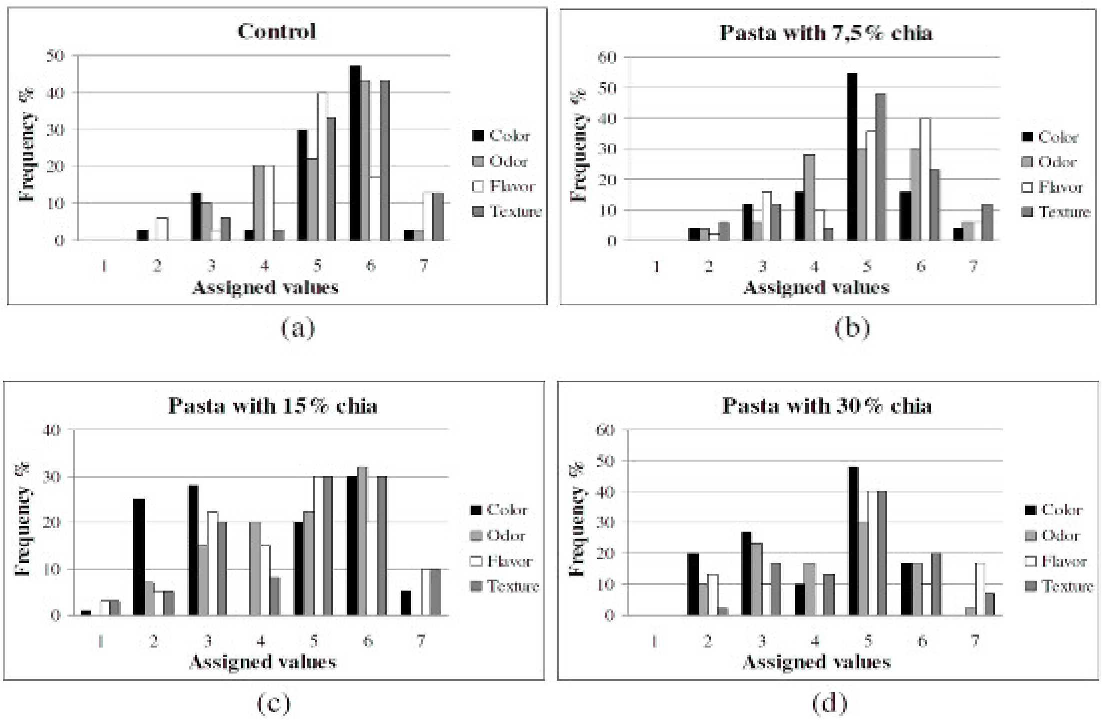
Identical letters in the same column do not differ statistically at the 5% level by the Tukey's test. Control: pasta with 100% wheat flour, T1: pasta with 7.5% chia flour in place of wheat flour, T2: pasta with 15% chia flour in place of wheat flour, T3: pasta with 30% chia flour in place of wheat flour.

In addition, the control pasta exhibited greater loss of soluble solids, which differed statistically from the others ($P < 0.05$). In contrast, pastas containing chia flour, T1 and T2, showed smaller loss of soluble solids. Hummel (1966) classified pastas according to the loss of solids: up to 6% is characteristic of pastas made from wheat of very good quality, up to 8% of average quality, and values equal to or greater than 10% are low-quality pastas. The added chia flour improved the quality of the pastas by reducing the loss of solids. This result can be attributed to the composition of the chia grain, which rich in protein and this causes the retention of amylose during cooking (CHILLO et al., 2008). Zhao et al. (2005), upon adding flours of legumes (beans and chickpeas) to pastas, observed an increase in the loss of solids during cooking, contrary to the results found with the addition of chia flour.

The $L^*$ parameter (Table 2) varied significantly ($p < 0.05$) across treatments. There was a reduction of brightness in the pastas as the proportion of chia flour was increased; the lowest value was noted for the pasta with 30% chia flour. Vázquez-Ovando et al. (2009), when determining the color of chia seeds, observed the incidence of 89% of seeds with black color, a fact that proves the behavior found in the color analysis. Pastas with lighter colors typically have better acceptance than do whole grain pastas, mainly because consumers are accustomed to consuming pasta with wheat semolina. According to Chang and Flores (2004), greater intensity of the yellow color is a highly desirable feature in pasta products because this is one of the most influential visual appeals in the acceptance of pastas. Regarding the $a^*$ values, treatment T3 showed higher values differing statistically from the others; the biggest change in this parameter was caused by the chia flour, reducing the natural yellowish appearance ($b^*$) of wheat flour pasta. These data corroborate the study by Bordin and Roque-Specht (2012) on pastas with added soy fiber. The control pasta differed statistically from others featuring greater intensity of the yellow color ($b^*$ value), favoring acceptability, which was expected because the added chia flour made the pasta darker.

The results of the sensory analysis are shown in Figure 1. It can be seen that the pasta with better acceptance by the tasters was the one containing 7.5% of chia flour (Figure 1b), and the pasta with the worst acceptance was the one with 30% chia flour (Figure 1d). The scores assigned to the colors of the pastas are between concepts 2, equivalent to "Disliked," and 6, equivalent to "Liked Very Much." The control pasta showed better color and texture. The pasta with 30% chia flour triggered the lowest acceptance with regards to color. This fact can be explained by the very dark color of the pasta, to which consumers are not accustomed. Among the pastas with chia flour, the preferred color was the pasta with 7.5% chia flour, which was the most accepted with respect to the flavor attribute, followed by the pasta with 15% chia flour. There is some preference nowadays for differentiated pastas with added fiber, as was the case in this study, where the tasters preferred the pasta with chia flour regarding flavor compared to the control. Similar results were also reported by Bordin and Roque-Specht (2012), while developing pastas with 4%, 6%, and 8% concentrations of soybean fiber, of which the pasta with 6% fiber was preferred in terms of flavor.

**Figure 1.** Frequency distribution histograms of the scores for: a) control pasta (100% wheat flour), b) pasta with 7.5% chia flour in place of wheat flour, c) pasta with 15% chia flour in place of wheat flour, d) pasta with 30% chia flour in place of wheat flour.




## Conclusion

Results demonstrated that chia flour, being rich in fiber, protein, minerals, and fats, has the potential to be used in pasta to increase its nutritional value.

The substitution of wheat flour by different percentages of chia flour provided an increase in the nutritional and technological properties of pasta.

Pastas with chia flour content showed darker colors than the control. Sensory analysis revealed that pasta with 7.5% chia flour was preferred in terms of flavor and the control pasta selected for the color and texture.

## Ethical aspects

The study on humans was approved by the Research Ethics Committee (REC – CONEP) at the Federal University of Santa Maria – UFSM – according to CNS Resolution 196/96 under no. CAAE 25228213.9.0000.5346.

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