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Development and sensory analysis of gluten-free pasta enriched with golden flaxseed flour

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ABSTRACT

Celiac disease (CD) is an autoimmune condition triggered by permanent gluten sensitivity in genetically predisposed individuals. It can occur in any age group, with a significant prevalence worldwide, affecting approximately 2 million people in Brazil, although most remain undiagnosed. Inflammation of intestinal cells due to the presence of gliadin, a protein found in wheat, oats, rye, and barley, leads to deterioration of the mucosa of the small intestine, resulting in symptoms such as diarrhea, bloating, and pain. The complete exclusion of gluten from the diet is essential to prevent complications, however, this poses a significant challenge due to the ubiquity of gluten in many food products.

Keywords: Celiac disease, Genetic predisposition, Gluten.

INTRODUCTION

Celiac disease (CD) is an autoimmune enteropathy caused by a permanent sensitivity to gluten in individuals with a genetic predisposition (GAMA and SILVA; FURLANETTO, 2010). It can be diagnosed in any age group, which shows its high prevalence worldwide (OLIVEIRA, 2013).

In Brazil, CD affects around 2 million people, but most of them are undiagnosed (FENACELBRA, 2021). It is estimated that for every eight people who have the disease, only one has the diagnosis. In Europe, its prevalence ranges between 1:150 and 1:300 inhabitants. Sample studies, carried out in São Paulo, Ribeirão Preto and Brasília, estimate the incidence of the disease at 1:214, 1:273 and 1:681, respectively. This finding places Brazil at the level of the European population, the most affected by the disease (NATIONAL HEALTH COUNCIL, 2013).

CD is characterized by inflammation of the intestinal cells that causes damage to the villi of the mucosa of the small intestine (SCHMIELE et al., 2015), due to gliadin, the causative agent of this pathology, a protein present in wheat, oats, rye and barley, triggering a malabsorption of macronutrients favoring the appearance of classic symptoms, such as diarrhea, distension and abdominal pain

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(OLIVEIRA, 2013). The disease can also lead to the development of anemia, infertility, osteoporosis and intestinal lymphoma (GAMA and SILVA; FURLANETTO, 2010).

The measure to avoid the damage caused by the disease consists of the total exclusion of gluten from the patient's diet (ANDREOLI et al., 2013). However, this becomes a great challenge for individuals affected by CD, since most of the products found in markets and restaurants are added to wheat flour (MARIANI et al., 2015), and its addition is common in instant coffees, chocolate powders, ice cream, chewing gum, canned foods, meat sausages, mustards, yogurts, sauces and soups, and infant foods (ARAÚJO et al., 2010).

Therefore, there is a need to develop non-conventional products so that celiacs have greater food options for consumption, as these generally do not have good acceptability, and it is necessary to perform sensory tests before their exposure in the market (PROLO et al., 2014). In this sense, rice flour is the most widely used option to replace gluten-containing flours because it has a soft white color and is also sold at a lower cost (CAPRILES; ARÊAS, 2010). However, in terms of nutritional value, gluten-free products based on starches and refined flours have the disadvantage of containing low levels of fiber, vitamins and minerals (TOMICKI et al. 2015).

Studies have shown that the consumption of foods with functional properties can significantly improve quality of life (COUTO; WICHMANN, 2015). Flaxseed (Linum usitatissimum) is currently considered the functional food of plant origin with the highest content of polyunsaturated fatty acids represented by the omega 3 and 6 series (CUPERSMID et al., 2012). Its use, mainly in flour form, is recommended in the formulation of gluten-free products (CAPRILES; ARÊAS, 2009).

OBJECTIVE

Considering the importance of developing new gluten-free products enriched with bioactive components of high nutritional value, especially for celiacs, at a lower cost and with good acceptability, this study aimed to develop a gluten-free pasta, based on rice flour and added to golden flaxseed flour, as well as to evaluate its sensory acceptability compared to a standard, gluten-free, commercial and fresh pasta, in order to contribute to a healthy diet and improve the quality of life of these individuals.

METHODOLOGY

This is a quantitative, cross-sectional study, with sensory analysis, subdivided into three stages: development and adjustment of the formulation of the test mass, sensory analysis of the test mass and the reference mass, with calculation of the Acceptability Index (AI), and statistical data analysis. The formulation and preparation of the test pasta were carried out in the Dietetic Technique Laboratory of a

Higher Education Institution (HEI) during the month of August 2015 and the sensory analyses were carried out in the Sensory Analysis Laboratory of the same HEI during the month of September 2015.

DOUGH PREPARATION

For the development of the test dough, the following ingredients were used: rice flour, potato starch, cassava starch (tapioca starch), ground golden flaxseed flour, xanthan gum, salt, eggs and canola oil, some of which were purchased in a local store in the municipality of Lajeado/RS specialized in natural products and others in a supermarket in the same city.

The Taypé® brand commercial reference dough, traditional fresh, type of noodles, was purchased in a market located in the municipality of Bom Retiro do Sul/RS, whose ingredients included wheat flour enriched with iron and folic acid, eggs, oil and salt.

The formulation of gluten-free pasta was based on a pre-existing project developed by a student of the Nutrition Course of the aforementioned HEI for her Course Conclusion Work (Chart 1).

Table 1 – Composition of the test pasta.

Item	**Quantity (g)**	**Proportion (%)**
Rice flour	390	34,70
Potato starch	160	14,25
Tapioca starch	50	4,45
Golden flaxseed meal	102	9,10
Xanthan Gum	6	0,55
Eggs	250	22,25
Canola oil	45	4,00
Filtered water	120	10,70
TOTAL	**1.123**	**100%**

Initially, the necessary amount of each item was weighed in its exact quantities for the preparation of the pasta. For the weighing of the xanthan gum, an analytical digital scale, with a division of 0.1 g, of the Mars® brand, with a maximum capacity of 1 kg, was used, and for the weighing of the other ingredients, a digital scale, of the Uranus® brand, with a division of 2 g and a maximum capacity of 6 kg, was used.

Then, a mixture of dry products was prepared, made from the mixture of rice flour, potato starch, tapioca starch, golden flaxseed flour and salt, followed by the addition of xanthan gum, previously diluted in water. To this mixture were added the eggs, the oil and the filtered water in a container, which was homogenized until a firm mass was obtained. The dough was kneaded by hand for approximately 10 minutes.

Then, the dough was opened with the help of a non-stick and non-toxic plastic roller, on a flat and rigid surface, so that it acquires a very thin thickness. Subsequently, the dough was cut with the help of a knife, so that it was of medium width, in rectangular shapes, like noodles, with an average dimension of 7 mm in width in order to be similar to the cut of commercial dough.

The formulated dough was cooked right after preparation to prevent it from drying out. Two liters of water at 100ºC were used for cooking. Finally, the dough was drained, to remove the excess water, and packed in an aluminum tray.

During the cooking of the formulated pasta, the cooking of the fresh commercial pasta was also carried out under the same conditions. Both samples were stored at room temperature, around 20ºC, until the moment of sensory analysis. The time between the preparation of the test dough and the cooking of both doughs until the moment of the sensory analysis was 1 hour.

SENSORY ANALYSIS

For the sensory analysis, the white light from the booth was used directed at the samples, which were maintained at room temperature during the test. A total of 50 untrained volunteers participated, including students, professors and employees of the HEI who were willing to participate in the study and who met the inclusion criteria, including individuals who did not have celiac disease and did not have a food allergy to any component of the formulas.

The participants received the evaluation form containing the hedonic scale, printed, for sensory evaluation, structured in nine points ranging from 1 "I disliked it very much" to 9 "I liked it very much", as well as the attributes color, flavor, texture, appearance and global impression.

Two samples were offered with standardized portions (approximately 10 g = 1 fillet), one represented by fresh commercial pasta (reference pasta) of the cooked noodles type and the other by prepared pasta (test pasta) cut in a similar way and also cooked, which were served on disposable plastic plates coded with random three-digit numbers. Between the tasting of the samples, drinking water was served to cleanse the palate.

The test pasta was compared to the reference pasta (commercial fresh with gluten) in order to compare the existence of similarity between them through the sensory analysis test. For this reason, non-celiac and untrained tasters were recruited.

To determine the IA of the global impression attribute, the expression IA (%) = A x 100/B was adopted, where A is the average score obtained for the product elaborated and B is the maximum score given to this product, according to Dutcosky (2007), considering the scores of the global impression attribute. A minimum of 70% AI was considered as the threshold to consider that the product was well accepted by consumers.

ETHICAL CRITERIA AND DATA ANALYSIS

The study is an amendment to the project approved by the Research Ethics Committee (COEP) of the IES under protocol No. 742.564/2014. Before performing the sensory analysis test, the volunteers were provided with the Free and Informed Consent Form (ICF) for signature, as a form of consent to participate in the study. Before performing the analysis, the volunteers were also instructed on the correct way to apply the sensory test and the importance of mouthwash between tasting each sample, in addition to receiving explanations about the importance of carrying out the study.

For data analysis, descriptive statistics, mean and standard deviation were calculated for quantitative variables, and absolute and relative frequencies for qualitative variables. The comparison of the color, flavor, texture, appearance and overall impression of the test and reference dough scores was made by means of the test for independent samples and the proportion of participants who reported each category in the evaluation of these items among the masses through the chi-square test. The analyses were performed using the SPSS 20.0 statistical package, and values of $p< 0.05$ were considered significant.

DEVELOPMENT

In the present study, most participants were female (n= 43; 86%), aged between 21 and 30 years (n= 27; 54%), with sixteen (32%) aged less than 21 years and seven (14%) aged over 30 years. Regarding schooling, five (10%) participants had completed high school, 43 (84%) had incomplete higher education, and three (6%) participants had completed higher education.

The attributes of color, flavor, appearance, texture, and overall impression differed significantly between the test mass and the reference mass, as shown in Table 1. It was observed that the mean attributes color (6.58±1.57 and 7.76±1.22; <0.001), flavor (5.92±2.00 and 7.92±0.97; <0.001), texture (6.46±2.12 and 8.12±0.96; <0.001), appearance (6.96±1.60 and 8.02±0.99; <0.001;) and overall impression (6.20±1.92 and 7.88±1.19; <0.001) of the test mass were significantly lower compared to the reference mass. respectively Table 1.

Table 1. Sensory analysis of test and reference masses

	Test Mass	**Reference Mass**	**p**
Colour	6.58±1.57	7.76±1.22	<0.001
Flavor	5.92±2.00	7.92±0.97	<0.001
Texture	6.46±2.12	8.12±0.96	<0.001
Appearance	6.96±1.60	8.02±0.99	<0.001
Global Printing	6.20±1.92	7.88±1.19	<0.001

Data presented as mean and standard deviation. T-test for independent samples. Values of $p<0.05$ considered statistically significant.

Regarding the color attribute of the pasta in the present study, a significantly lower mean acceptance of the test mass was observed in relation to the reference pasta. Kirinus, Copetti and Oliveira (2010), when developing a gluten-free noodle based on soy flour also compared to a reference sample, observed that soy noodles (4.8+1.82) were as well accepted as the reference noodles (4.7±1.17) in terms of color, but with lower means that differed from the present study. Pereira et al. (2013), when making a gluten-free potato bread with 50% chia flour, observed that the appearance was impaired due to the dark color not characteristic of this food.

In order to reduce the visual impact of the color attribute of the dough test of the present study in relation to the reference pasta, golden flaxseed flour was used instead of brown to leave the dough with a clear and homogeneous color, more similar to the traditional one. This fact can be confirmed due to the same hedonic values (grade 8.0 = I liked it a lot) presented in the relative frequency in the color attribute for both samples. The study by Russo et al. (2012) evaluated five types of savory pizza doughs, one of which was a standard formulation and the others containing different proportions of flaxseed flour, in which a significant difference in the color attribute was also observed between the formulated doughs and the reference dough as there was an increase in the increment of flaxseed flour, and the relative frequency assigned scores of 7 and 8 by the tasters, corroborating the current study.

Regarding the taste of the pasta in the present study, a significantly lower mean acceptance of the test pasta was observed in relation to the reference pasta, corroborating the study by Prolo et al. (2014), when comparing a gluten-free lasagna pasta based on rice flour, potato starch, tapioca starch and corn starch (5.86±1.84) with a reference sample (7.36±1.25), however, both averages were lower than in the present study. In the study by Kirinus, Copetti and Oliveira (2010), the samples of gluten-free soy-based noodles (4.1+1.71) and quinoa (2.6±1.19) were also not as well accepted as the reference sample (5.2±1.20) in relation to taste.

In the present study, a hedonic value of 7.0 (I liked it regularly) was assigned to the flavor attribute for the test dough and a score of 8.0 (I liked it a lot) for the reference pasta, corroborating the study by Prolo et al. (2014). On the other hand, in the study by Giovanella, Schlabitz and Souza (2013), where they developed four types of gluten-free biscuits made from quinoa flour and potato starch in different concentrations, a higher relative frequency of 9 (I liked it very much) was observed for sample B, which was prepared with the second highest proportion of non-conventional flours (31% quinoa flour and 21% potato starch).

In the texture attribute of the pasta in the present study, a significantly lower mean acceptance of the test mass was observed in relation to the reference pasta, corroborating the study by Kirinus, Copetti and Oliveira (2010), with all the means lower than those of the present study. On the other hand, the study by Prolo et al. (2014), when making a gluten-free lasagna pasta (6.20+1.96), did not observe a significant

difference in this attribute when compared to a reference pasta (6.90+1.68), also presenting both means lower than those of the present study.

In the present study, the same hedonic value (8.0 = I liked it a lot) was assigned to the texture attribute for both the test dough and the reference dough, demonstrating that the texture was not impaired in relation to the scores obtained, differing from the study by Pereira et al. (2013), who, when making a gluten-free potato bread plus 50% chia flour, He noted that the texture was impaired, as it could be "lighter", according to comments from tasters on the evaluation sheets. In order to improve the texture of the gluten-free pasta in the present study, golden flaxseed flour was added, due to its fiber retaining water during the cooking process, which contributes to a soft dough (KIRINUS, COPETTI AND OLIVEIRA, 2010). This fact can be confirmed, probably, because the relative frequency was the same in the texture attribute for both samples.

In order for products made without gluten to have a texture similar to the gluten-containing product, it is enough to add components such as starch or protein-rich flours, especially those of vegetable origin, as they are capable of forming a gluten-like network during the process and cooking (KIRINUS, COPETTI AND OLIVEIRA, 2010). Among them, rice flour is the raw material that best replaces wheat flour, due to the favoring of starch polymerization, which leaves its structure with a function similar to a gluten-containing dough that, after cooking, prevents adhesion (FERNANDES et al., 2013). In addition, rice flour, when cooked, favors the starch gelatinization process, which improves the adhesion of the dough. Sweet tapioca starch also contributes to improving the elasticity and texture of the formulated dough (FARIAS, 2009).

Regarding the appearance attribute of the pasta in the present study, a significantly lower mean acceptance of the test mass was observed in relation to the reference pasta. The study by Prolo et al. (2014), when making a gluten-free lasagna pasta (6.74±1.68) did not observe a significant difference in this attribute when compared to a reference pasta (6.18±1.78), with both averages lower than those of the present study.

It should be noted here that the appearance attribute of a product differs from the color attribute, because the appearance involves a qualitative aspect with broader characteristics, such as visual texture (smooth/coarse, glossy/matte, wrinkled); size and shape (dimensions and geometry); interactions between pieces or particles (agglomerated/loose, etc.), as well as the color itself (hue, luminosity, uniformity, purity) (DUTCOSKY, 2009).

Table 2 shows the relative frequencies of participants who reported disliking very much (1) to liking very much (9) when asked about the color, taste, texture and appearance of the test dough and the reference dough. Although a higher proportion of participants liked the reference dough more than the test

dough, in all the items evaluated, less than 25% of the participants reported not having liked the test dough to some degree in terms of color (p=0.002), taste (p<0.001), appearance (p=0.036) and texture (p=0.003).

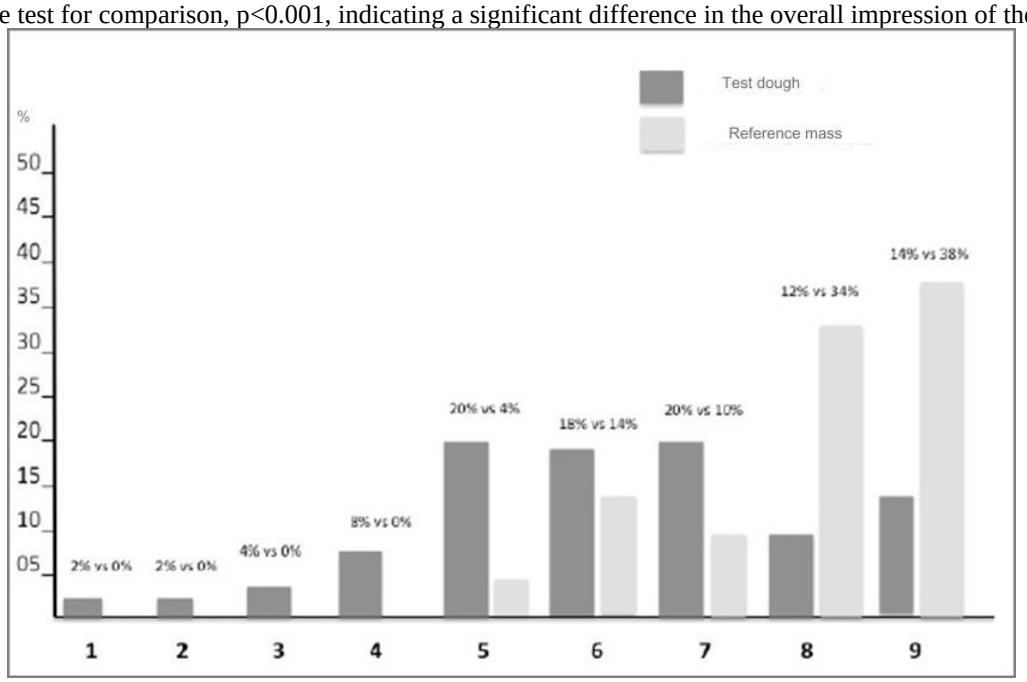
Table 2. Evaluation of the test mass compared to the reference mass by the participants

Attribute	**Test Mass**	**Reference Mass**	**p**
Colour			
1	0%	0%	
2	0%	0%	
3	0%	2%	
4	12%	0%	
5	16%	4%	**0,002**
6	22%	10%	
7	10%	4%	
8	32%	58%	
9	8%	22%	
Taste			
1	2%	0%	
2	4%	0%	
3	6%	0%	
4	18%	0%	
5	8%	2%	**<0,001**
6	12%	6%	
7	24%	20%	
8	22%	42%	
9	4%	30%	
Texture			
1	4%	0%	
2	2%	0%	
3	4%	0%	
4	12%	0%	
5	4%	2%	**0,003**
6	12%	6%	
7	22%	10%	
8	28%	42%	
9	12%	40%	
Appearance			
1	0%	0%	
2	2%	0%	
3	2%	0%	
4	4%	0%	
5	8%	2%	**0,036**
6	16%	8%	
7	24%	12%	
8	30%	42%	
9	14%	36%	

Data presented in relative frequency. Qu-square test. Values of p<0.05 considered statistically significant. 1. I disliked it very much; 2. I disliked it a lot; 3. Disliked regularly; 4. Slightly disliked; 5. Indifferent; 6. I liked it slightly; 7. I liked it regularly; 8. I liked it a lot; 9. I really liked it.

Figure 1 shows the relative frequency of the evaluation of the test mass and the reference mass in terms of global impression, with a higher positive evaluation for the reference mass compared to the test mass ($p<0.001$).

Figure 1. Relative frequency of participants for the evaluation of the overall impression of the test mass with the reference mass. Chi-square test for comparison, $p<0.001$, indicating a significant difference in the overall impression of the masses.



Caption: 1. I disliked it very much; 2. I disliked it a lot; 3. Disliked regularly; 4. Slightly disliked; 5. Indifferent; 6. I liked it slightly; 7. I liked it regularly; 8. I liked it a lot; 9. I really liked it.

The relative frequency, in the present study, was assigned the same score (8.0 = I liked it very much) for the appearance attribute for both the test dough and the reference dough, lower than the score assigned in the study by Giovanella, Schlabitz and Souza (2013), in which the relative frequency was assigned a score of 9 (I liked it very much) to gluten-free biscuits made with the second highest proportion of non-conventional flours (31% quinoa flour and 21% quinoa flour). potato starch).

Regarding the acceptability index (AI) of the global impression attribute, the test mass of the present study was equal to 69.1%, while the IA of the reference mass was equal to 88%. Both masses presented acceptable indices in comparison with the reference value of 70%, although it was higher for the reference mass. In this sense, the overall impression of the pasta in the current study showed a positive evaluation of the reference pasta compared to the test pasta, corroborating with the studies of Mariani et al. (2015) when comparing samples of a standard biscuit (wheat) in relation to those containing rice bran and rice and soybean flours and with the Prolo et al. (2014) study when comparing a lasagna pasta made with refined wheat flour to a Gluten-free sample, made with rice flour, potato flour and tapioca starch.

The AI of both samples was acceptable, although it was higher for the reference dough, similar to the study by Giovanella, Schlabitz and Souza (2013), which obtained a GI higher than 71% in four gluten-

free biscuit formulations and to the study by Pereira et al. (2013), in which all samples demonstrated satisfactory AI results from the comparison of the formulation of three samples of gluten-free potato breads with different concentrations of chia flour as a substitute for cream of rice and potato starch.

As limitations of the present study, it should be noted that the participants were offered only pasta without sauce or other condiments, because these, when added to the consumption of commercial pasta, can "mask" the attributes of the product, which provides greater acceptability. It is also worth mentioning that the tests were carried out with non-celiac individuals, who did not have the habit of consuming gluten-free foods, and this may explain the lower acceptance of the test mass in relation to the reference one. Another factor that may have influenced the acceptance of the samples is the fact that both were offered at room temperature, when the population's habit of consuming pasta is at a higher temperature, and the test pasta, at room temperature, presented a "whole flavor" and "highlighted", as reported by the participants, due to the addition of flaxseed flour.

FINAL THOUGHTS

The study proved that it is possible to formulate a gluten-free pasta, based on rice flour and added golden flaxseed flour, however, when compared to a standard, gluten-free, commercial and fresh pasta, it presented a lower acceptance in relation to the attributes color, flavor, texture, appearance and overall impression.

Although the results showed that there was a significant difference between the masses in all attributes, the test mass was reasonably accepted by the participants, proven by the calculation of the AI, making it viable for consumption. However, it is suggested that further studies should be carried out in order to improve the formulation of gluten-free pasta enriched with golden flaxseed flour.

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