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FOOD TECHNOLOGY

Physicochemical and sensory characterization of gluten-free fresh pasta with addition of passion fruit peel flour

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ABSTRACT: *The aim of this study was to develop a gluten-free fresh pasta formulation with addition of yellow passion fruit peel flour (PPF). A control formulation containing a mixture of rice flour and corn flour and formulations with 10 and 20% of PPF addition were produced. Sensory analysis, physicochemical characterization and technological properties were assessed. The PPF addition to gluten-free pasta increased cooking time, soluble solids loss and water absorption; it also modified the color of the formulations. The control formulation and the formulation containing 10% PPF had the best sensory parameters, leading to an acceptability index over 70%. The 10% PPF addition increased fiber (3.25%) and ashes (2.15%) content and also lowered percentage of carbohydrates (41.19%) and energy value (223.26 kcal/80g); content of proteins and lipids were similar between the formulations. Principal component analysis showed that the control formulation stands out due to its sensory properties while the formulation containing 10% PPF improved nutritional properties. Therefore, the increase in nutritional value of gluten-free fresh pasta due to the PPF addition can be considered an alternative to meet market demands for healthier food choices.*
Key words: *maize flour, rice flour, byproduct, Passiflora edulis.*

Características físico-químicas e sensoriais de massa alimentícia fresca sem glúten com adição de farinha de casca de maracujá

RESUMO: *O objetivo deste estudo foi desenvolver massa alimentícia fresca sem glúten com adição de farinha de casca de maracujá amarelo (FCM). Uma formulação controle composta de uma mistura de farinha de arroz e farinha de milho, e formulações com adição de 10 e 20% de FCM foram produzidas. As amostras foram analisadas quanto às características sensoriais, físico-químicas e tecnológicas. A adição de FCM às formulações aumentou o tempo de cozimento, a perda de sólidos solúveis e a absorção de água, bem como, modificou os parâmetros de cor. As formulações que apresentaram melhores resultados, quanto aos atributos sensoriais, foram o controle e a que continha 10% de adição de FCM, que apresentaram índice de aceitabilidade acima de 70%. A adição de 10% de FCM aumentou o teor de fibras (3,25%) e cinzas (2,15%) e reduziu a porcentagem de carboidratos (41,19%) e o valor energético (223,26 kcal/80g), enquanto o teor de proteínas e lipídios foi semelhante entre formulações. A análise de componentes principais demonstrou que a amostra controle se destacou por suas propriedades sensoriais, enquanto a adição de 10% de FCM promoveu as propriedades nutricionais. Portanto, o aumento do valor nutricional da massa fresca sem glúten produzida com adição de FCM pode ser considerada uma alternativa para atender uma demanda crescente do mercado que busca escolhas alimentares mais saudáveis.*
Palavras-chave: *farinha de milho, farinha de arroz, subproduto, Passiflora edulis.*

INTRODUCTION

Passion fruit belongs to *Passifloraceae* family, and the *Passiflora* genus contains approximately 500 species. This fruit is of great economic importance for Brazil, which is responsible for approximately 60% of its worldwide production. Yellow passion fruit (*Passiflora edulis f. flavicarpa*) has attractive flavor and aroma; its consumption happens *in natura* and its derivatives are consumed as concentrated juice (MANIWARA et al., 2014; CORRÊA et al., 2016). Processing of this fruit at industrial scale leaves a considerable amount of fruit peels as by-products (PINHEIRO et al., 2008). The passion fruit peel amounts to 60% (in mass) of the whole fruit and it is composed of flavedo

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and albedo. The flavedo contains large amounts of bioactive compounds, such as the flavonoid luteolin and fibers, which have the ability to reduce LDL and increase HDL levels, useful for improving treatment of diseases such as diabetes and promoting reduction of body weight. The albedo contains a high content of niacin, iron, calcium, and pectin, which has wide use in the food industry as a gelling agent, stabilizer and thickener (OLIVEIRA et al., 2016a; LÓPEZ-VARGAS et al., 2013).

Celiac disease is an immune-mediated enteropathy which develops in genetically susceptible individuals, and it is caused due to the ingestion of gluten proteins reported in cereals, such as wheat, barley, rye and certain oats varieties. This disease leads to immune-based damage caused on the small intestine and can also aggravate other diseases, such as osteoporosis, and due to its prevalence, is considered a concern for public health agencies (SANGUINETTI et al., 2016; SOLER et al., 2016). Treatment of this disease requires exclusion of gluten from the diet, which ensures proper physiological development of the organism, maintaining the homeostasis of bone mineral density and fertility and reducing the risk of nutritional deficiencies (MORENO et al., 2016). In order to meet market demand for better gluten-free products, development of gluten-free foods and beverages has acquired great importance in recent years (SHARMA et al., 2015).

Brazil has the third largest consumer market of pasta in the world; in 2015 its consumption was of around 1.24 million tons (ABIMAPI, 2016). Pasta is the resulting product of mechanical kneading (with no post-fermentation) of wheat flour and/or durum wheat products and/or other cereals, legumes, roots and tuber products (BRASIL, 2005). Gluten-free cereal flours can be used in food processing as a substitute for wheat flour. Maize flour is a low-cost raw material which contains approximately 10% of proteins and natural pigments, such as cryptoxanthin and zeaxanthin, which are vitamin A precursors and also act as natural dyes conferring pigmentation to foods products (NUSS & TANUMIHARDJO, 2010). The use of rice flour derived from broken grains which would be discarded due to not meeting quality standards adds value to rice production chains by preventing waste generation. The addition of rice flour to a food formulation is interesting due to the low sodium levels and good digestibility (ASMEDA et al., 2016; PHONGTHAI, et al., 2017).

New technologies aimed to improve the use of gluten-free flours and agro industrial by-products have been studied. When used in the development of a food product, these ingredients can improve nutritional parameters of such product due to their high contents of fiber, vitamins and minerals; however, they should not adversely affect sensory and technological properties of the formulated product (LIAO & HUNG, 2015). The aim of this research was to develop and characterize formulations of gluten-free fresh pasta containing passion fruit peel flour.

MATERIALS AND METHODS

Passion fruit peel flour (PPF), rice flour and corn flour were obtained from the local market in the city of Umuarama/PR/Brazil. All reagents used were of analytical grade. Three formulations of fresh pasta were developed, as shown in table 1. The control formulation was produced with maize and rice flours only, and other two formulations were produced by adding PPF to final concentrations of 10% and 20% replacing maize and rice flours. These percentages of PPF were defined in preliminary tests. The pasta formulations were processed manually and molded to fettuccine format using a pasta extruder (GPANIZ MF5, Brazil).

Technological properties (cooking time, water adsorption, soluble solids loss and volume increase) of the pasta formulations produced were evaluated according to methods 66-50.01 of AACC (1999). Cooking time was determined by cooking 10g of sample pasta in 140mL of boiling distilled water; the cooked product was pressed every 30 seconds against two glass slides, until gelatinization of starch granules (disappearance of intact starch granules). Results were expressed in minutes.

Table 1 - Formulations of gluten-free fresh pasta.

Ingredients	Control	10% PPF	20% PPF
Rice flour (g)	70	65	60
Maize flour (g)	30	25	20
Yellow passion fruit peel flour (g)	0	10	20
Water (mL)	50	50	50
Salt (g)	1	1	1
Oil (mL)	6	6	6
Xanthan gum (g)	1	1	1
Egg (g)	50	50	50

Note: Control - without passion fruit peel flour; PPF - passion fruit peel flour.

Water absorption was determined according to FOGAGNOLI & SERAVALLI (2014), by assessing the pasta weight increase during cooking. Samples (100g) were weighed before and after cooking, and a ratio between these values generated the final results. After cooking, the remaining water used was placed under 105°C until constant weight would be reached in order to determine the soluble solids loss. The volume increase was determined by assessing the water volume displaced by 10g of pasta both before and after cooking. Results were expressed as percentages (AACC, 1999).

Color parameters of pasta formulations were assessed using a digital colorimeter (KONICA MINOLTA Chroma Meter, CR-400, Japan); the parameters luminosity (L^*), chromaticity – intensity of red/green (a^*) and intensity of yellow/blue (b^*), according to the CIE (International Commission on Illumination) model (MCGUIRE, 1992), were assessed.

Sensory analysis of the pasta formulations were carried out by applying an acceptance test to a group of untrained testers (n=101) composed of individuals of both sexes and ages ranging from 16 to 60 years. A structured nine-point hedonic scale was used (9 = like extremely; 8 = like very much; 7 = like moderately; 6 = like slightly; 5 = neither like nor dislike; 4 = dislike slightly; 3 = dislike moderately; 2 = dislike very much; 1 = dislike extremely) and the attributes overall appearance, taste, flavor, texture and color were evaluated. The sensory analysis procedure was approved by the Ethics Committee - COPEP-UEM/ CAAE: 54973116.1.0000.0104. Portions of 200g of pasta were cooked in 2.8L of water and 1g of salt at the time point defined previously by the cooking test. Cooked samples (20g) were provided to the testers in encoded disposable cups at random. The acceptability index (AI) of the formulations was calculated according to Equation 1, where A is the average grade obtained for the tested sample and B is the maximum grade given to the same sample (DUTCOSKY, 2013).

$$IA\ (\%) = \frac{Ax100}{B} \qquad \text{Eq. (1)}$$

The pasta formulations which obtained the best results from the sensory analysis underwent further analyses. Moisture, ashes, protein, lipid and fiber content according to the AOAC (1995) (total carbohydrates estimated by difference) were evaluated. The energy value was calculated using the conversion factors established by the resolution RDC n° 360 of December 23, 2003 (BRASIL, 2003a) and it was expressed in kcal/80g of pasta as recommended by resolution RDC Nº 359 of December 23, 2003 (BRASIL, 2003b), and compared with control pasta.

All assays were carried out in triplicates. In order to analyze the results, Student t-tests and one way analysis of variance (ANOVA) followed by Tukey post-hoc tests were carried out for assessment of two or three or more groups, respectively. Statistical differences were considered significant assuming $p<0.05$. All analyses were carried out with the aid of Statistica® 8.0 software. The same software was also used to carry out Principal Component Analysis (PCA).

RESULTS AND DISCUSSION

Regarding results for technological properties (Table 2), cooking times of the pastas containing 10% PPF and 20% PPF were similar ($p>0.05$), but they differed from the time determined for control sample, which can be attributed to the increase in fiber content of the formulations containing PPF (GATTA et al., 2017). The values reported in the present research were similar to the results observed by GATTA et al. (2017) (9min for spaghetti produced with semolina and 20% of wheat bran), but lower than those reported by FERREIRA et al. (2016) (11 – 15min for gluten-free pasta developed with a mixture of sorghum–rice–corn flour and potato starch). Thus, the type of flours used for pasta production can influence its cooking time.

Pastas prepared with PPF absorbed more water in comparison to control sample not containing PPF. Such effect might be due to the high fiber content of the PPF (30.11%) added to the pasta formulation, as fiber components possess plenty of polar groups which can retain water (DHARMARAJ et al., 2016). LORUSSO et al. (2017) reported a value of 128.6% of water absorption for pasta prepared with semolina flour, which was lower than the values reported in the present study, evidencing that the use of gluten-free flours can also contribute to water absorption.

FOGAGNOLI & SERAVALLI (2014) state that higher amounts of gluten-free flour used for preparation of pasta can affect the volume increase during cooking, which also depends on cooking time, pasta format and content and quality of gluten proteins. In the present research, addition of PPF to the pasta formulations here tested did not influence this parameter.

The soluble solids loss was higher in formulations containing PPF than in the control formulation; values for loss of soluble solids up to 6% are considered adequate for pastas to be classified as of high quality, according to HUMMEL (1966). AJILA et al. (2010) stated that loss of soluble solids is an important parameter for evaluation of overall

Table 2 - Technological properties of gluten-free fresh pasta formulations.

Formulation	Cooking time (min)	Water absorption (%)	Volume increase (%)	Soluble solids loss (%)
Control	9:53^{b} ± 5.66	200.18^{c} ± 0.98	1.05^{a} ± 0.07	0.05^{b} ± 0.00
10% PPF	10:05^{a} ± 7.07	236.92^{b} ± 3.41	1.03^{a} ± 0.04	0.11^{a} ± 0.01
20% PPF	10:36^{a} ± 1.41	265.15^{a} ± 0.40	1.03^{a} ± 0.04	0.10^{a} ± 0.02

Note: Control - without passion fruit peel flour; 10% PPF - formulation with 10% of passion fruit peel flour; 20% PPF – formulation with 20% of passion fruit peel flour. The averages of the columns followed by the same letter do not differ from each other, by the Tukey test at 5% probability.

quality of pasta. During the cooking process, some of the starch and other soluble components dissolve in water causing it to become cloudy and thick as result.

Color is one of the parameters that best define product quality and consumer acceptance. As expected, addition of PPF changed the color of the formulations as shown in figure 1. The color parameters assessed (Table 3) showed that the control formulation had the highest luminosity (L^*), which is due to no addition of PPF. The PPF addition to the pasta decreased luminosity values and modified the a^* and b^* chromaticity values. MICELI et al. (2015) also noted a color modification in fresh pasta produced with addition of borage leaves. According to these authors, colored pasta has achieved market success in recent years and is well accepted by consumers.

Results of the sensory analysis of the pasta formulations (Figure 2) showed that for attributes overall appearance, taste and color, the control formulation had the highest acceptance among testers, followed by the pastas developed with 10% and 20% PPF addition. The values for flavor and

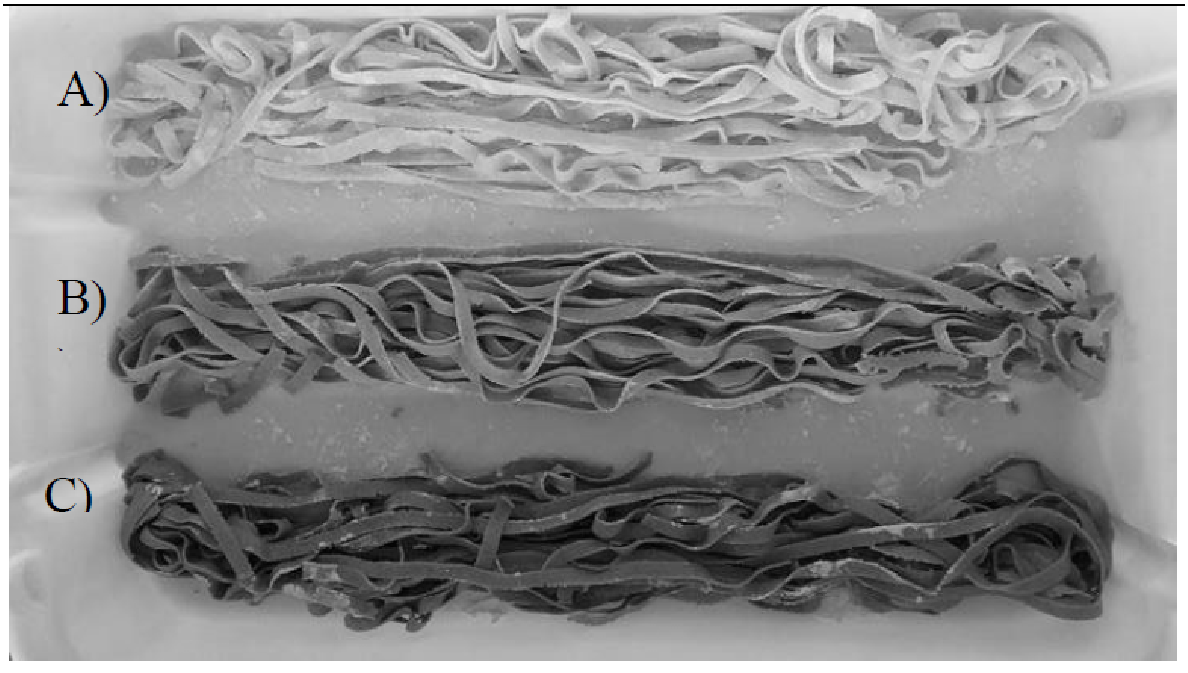

Figure 1 - Gluten-free fresh pasta with passion fruit peel addition (PPF). (A). control, (B). 10% PPF addition and (C). 20% PPF addition.

Table 3 - Color parameters (L, a*, b*) of the gluten-free fresh pasta formulations.

Formulation	L	a*	b*
Control	79.47[a]± 0.37	-0.24[c]± 0.06	22.66[b]± 0.84
10% PPF	63.38[b]± 2.64	3.28[b]± 0.19	25.57[a]± 2.39
20% PPF	58.45[c]± 1.10	4.05[a]± 0.07	20.08[c]± 1.16

Note: Control - without passion fruit peel flour; 10% PPF - formulation with 10% of passion fruit peel flour; 20% PPF - formulation with 20% of passion fruit peel flour. The averages of the columns followed by the same letter do not differ from each other, by the Tukey test at 5% probability.

texture did not differ between the control formulation and the formulations containing 10% PPF ($p>0.05$), but these values were higher in comparison to the values for pasta with 20% PPF addition ($p<0.05$). COSTA et al. (2015) developed pasta formulations with wheat flour and passion fruit peel flour, and the control formulation also had greater acceptance among testers, followed by formulations with lower amounts (25%) of passion fruit peel flour, results similar to those reported in the present study.

The acceptability index for overall appearance was 80.97, 70.74 and 54.13% for the control formulation and for the formulations containing 10% PPF and 20% PPF, respectively. An acceptability index of at least 70% is required for a product to have its sensory properties considered as

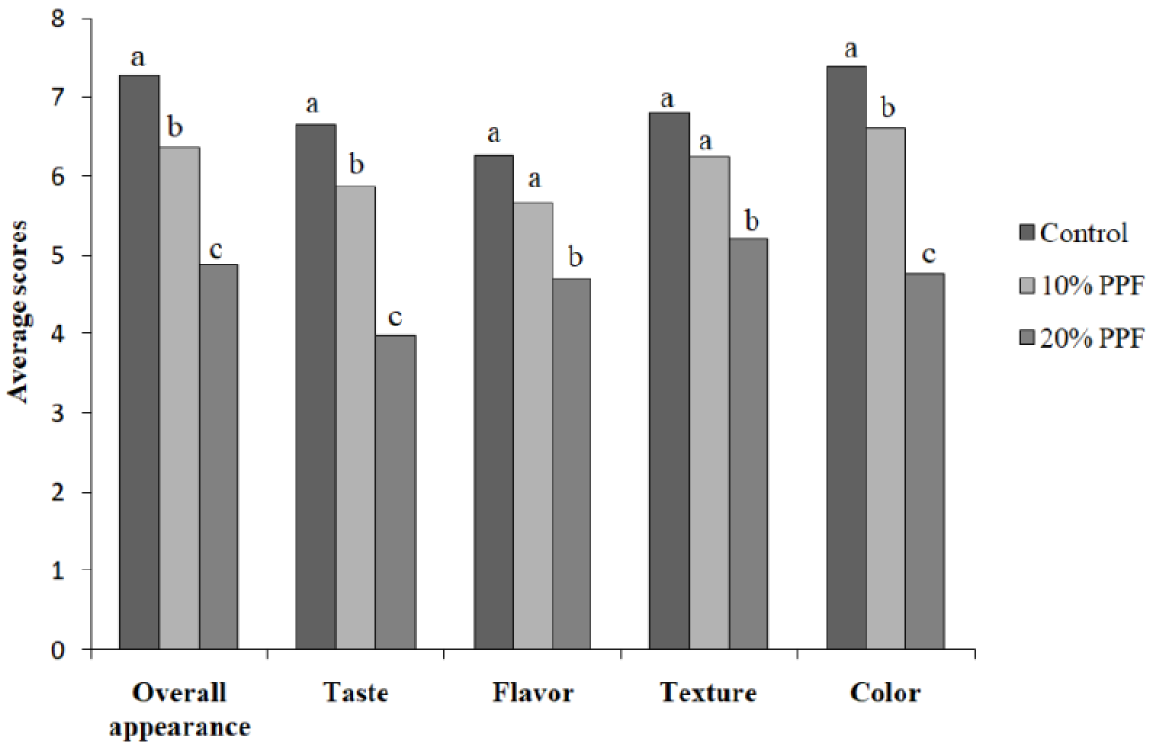

Figure 2 - Average scores obtained by the sensory evaluation of gluten-free fresh pasta formulations. Note: Control - without passion fruit peel flour; 10% PPF - formulation with 10% of passion fruit peel flour; 20% PPF - formulation with 20% of passion fruit peel flour.

accepted (TEIXEIRA et al., 1987). BOUASLA et al. (2017) also evaluated the properties of gluten-free precooked rice pasta enriched with different amounts (10%, 20% and 30%) of legume flours (yellow pea, chickpea and lentil), and all formulations had acceptable scores for appearance, stickiness, color, flavor and taste. YING (2016) verified the acceptance of pasta developed with addition of purple passion fruit wheat flour and reported an overall acceptance among testers of 64.68%.

Sensory acceptance analysis also provided data regarding purchasing intention; 48.44, 35.94 and 15.62% of the testers would purchase the control formulation and the formulations containing 10% PPF and 20% PPF, respectively, indicating that the less PPF added to the formulation, the better acceptability of the gluten-free pasta becomes.

The formulation developed with 10% PPF addition had better technological and sensory properties than the pasta formulation containing 20% PPF. Thus, the proximal compositions of the control formulation and the formulation containing 10% PPF were assessed; results are shown in table 4. Regarding moisture content, resolution RDC n° 93 of October 31, 2000 (BRASIL, 2000) establish that the maximum value for wet or fresh pasta should be 35%; therefore, the results for this parameter obtained in the present study indicated the formulations assessed are in accordance with Brazilian legislation. In the present study, there was a significant difference in the moisture contents between the control and the formulation containing 10% PPF. According to OLIVEIRA et al. (2016b) the presence of fibers in yellow passion fruit flour contributed to water retention, increasing the moisture content of food products.

Protein content of the formulations did not differ among them ($p>0.05$), and the values were similar to those reported by OVANDO-MARTINÉZ et al. (2009) in their study on spaghetti with addition of 45% green banana flour. AJILA et al. (2010); however, reported obtaining a lower protein content (3.6%) in pasta formulations enriched with mango by-products in comparison to the values obtained in the present research. Lipid contents of the control and the 10% PPF formulation were similar, but the values were higher than the ones reported by FERREIRA et al. (2016) in pasta produced with different types of flours. Ashes content was higher in the formulation enriched with PPF in comparison to the control pasta. Minerals have important roles in human physiology as constituents of body tissues, regulators of metabolism of various enzymes and keeping acid-base balance. The deficiency of one or more mineral components can lead to major organic disorders, such as osteoporosis and anemia (SOETAN, et al. 2010). Addition of 10% PPF to pasta formulation increased fiber content in comparison to the control. According to resolution RDC 54 of November 12, 2012 (BRASIL, 2012), for a food product to be considered a source of fiber it must have 2.5g of fibers per portion of food. As the formulation containing 10% PPF had 2.6g of fiber per portion, it can be considered a source of fiber. Presence of fibers contributed to satiety after food consumption and it can help to lower the glycemic index (COSTA et al., 2015; OLIVEIRA et al., 2016b).

The energy value of the control formulation was 249.86kcal/80g, higher than the value obtained for the formulation containing 10% PPF (223.26kcal/80g), which is due to replacement of cereal flours by passion fruit peel flour.

Analysis of the results was carried out using the principal component analysis (PCA), shown in figure 3, which demonstrates the projection of the assessed parameters (Figure 3A) and the formulations (Figure 3B) on factorial planes (PC1xPC2). The two principal components (PC) were responsible for 98.64% of the total variance. REKAS & LUKASIAK (2015), in pasta developed

Table 4 - Proximal composition of the gluten-free fresh pasta formulations.

Formula-tion	Moisture (%)	Protein (%)	Lipids (%)	Ashes (%)	Fiber (%)	TC (%)
Control	31.31^{b}±0.75	8.77^{a}±0.88	8.68^{a}±0.60	0.87^{b}±0.18	1.18^{b}±0.56	49.19^{a}±1.92
10% PPF	34.32^{a}±0.38	7.40^{a}±0.20	8.69^{a}±0.02	2.15^{a}±0.16	3.25^{a}±0.16	41.19^{b}±0.38

Note: Control - without passion fruit peel flour; 10% PPF - formulation with 10% of passion fruit peel flour; 20% of PPF - formulation with 20% of passion fruit peel flour; TC – total carbohydrates. The averages of the columns followed by the same letter do not differ from each other, by the test-T at 5% probability.

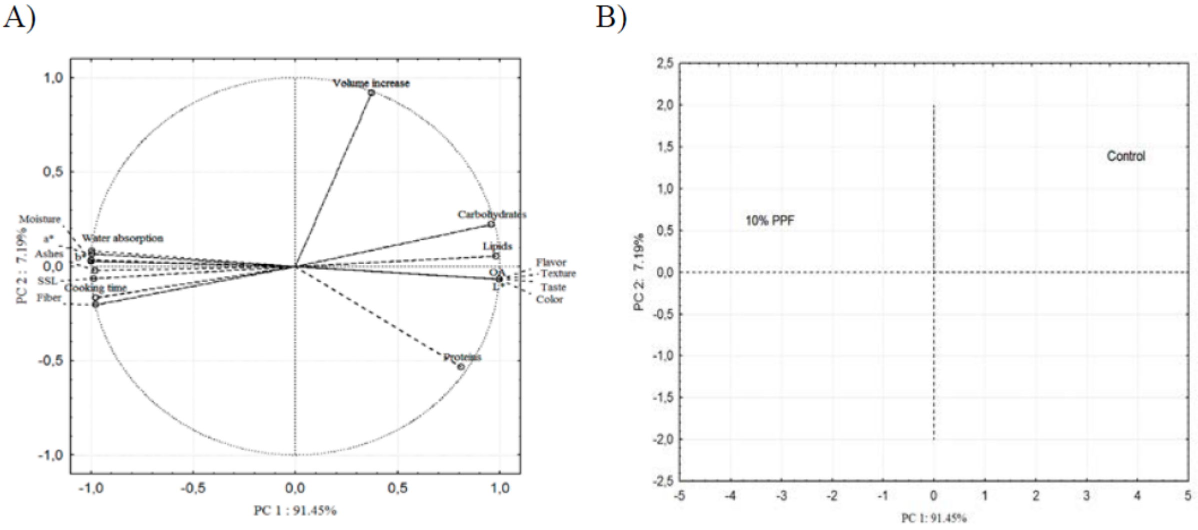

Figure 3 – Principal component analysis of the pasta formulations with better sensory results. (A). projections of the analyses and (B). projections of the formulations. Note: Control - without passion fruit peel flour; 10% PPF - formulation with 10% of passion fruit peel flour; SSL - soluble solids loss, OA - overall appearance.

with addition of maltodextrin, reported PC1 and PC2 were responsible for 49.07% and 17.07% of the variation observed, respectively. According to HAIR et al. (1998) values of PC variation ranging between 50 and 69% are acceptable, while values above 70% indicated that appropriate explanation of the variance should be among the first three components.

When the vectors are close to each other they indicated a positive correlation between the attributes; when they are at an orthogonal position it means there is possibly no linear correlation, and when they are at an 180° angle it indicated a negative correlation (MONTANUCI et al., 2010). In the present study, all attributes evaluated in the sensory analysis (aroma, flavor, color, texture, and overall appearance), as well, as luminosity and contents of lipids and carbohydrates had positive correlations (Figure 3A). Such values were higher for the control formulation, as can be seen in figure 3B, due to its localization at right side of the graph. Conversely, the formulation containing 10% PPF was at the left side (Figure 3B); such also occurs to technological properties, chromaticity (a* and b*), moisture, fibers, and ashes contents (Figure 3A), and thus the values for these parameters were higher for the formulations with 10% PPF addition. Protein content and the volume increase had lower correlation with the different formulations, which can be due the similar values reported for these variables. Thus, the PCA demonstrated the correlation between the results obtained and their association with the formulations evaluated.

CONCLUSION

Regarding technological properties, the addition of PPF to gluten-free pasta increased cooking time, soluble solids loss and water absorption and modified color parameters in comparison to a control formulation with no PPF added. The control formulation and the formulation containing 10% had adequate acceptability indexes at values above 70%. The 10% PPF addition to pasta increased fiber (3.25%) and ashes (2.15%) contents and lowered carbohydrates percentage (41.19%) as well as energy value (223.26kcal/80g). Principal component analysis demonstrated the correlation between the evaluated attributes, and it allowed for discrimination of the formulations according to its characteristics. Therefore, passion fruit peel flour can be used as an alternative ingredient in order to increase the nutritional value of gluten-free pasta, the amount of 10% being recommended due to it leading to a more easily accepted formulation among testers.

DECLARATION OF CONFLICTING INTERESTS

The authors declare no conflict of interest.

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AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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