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Pumpkin Peel Flour (*Cucurbita máxima* L.) – Characterization and Technological Applicability

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Abstract The objectives of this paper were both the production and the characterization of flour from pumpkin peel as well as the development of breads with partial addition of the flour obtained from pumpkin peel substituting wheat flour. The characterization of the pumpkin peel flour revealed high protein content and good milk solubility index. We developed the following formulations: standard bread, bread with only wheat flour, and breads with 2.5 percent and five percent of pumpkin peel flour. The results demonstrated significant difference ($p < 0.05$) among the formulations regarding protein, ashes, carbohydrates, and caloric value. The texture parameters, in turn, indicated difference regarding cohesiveness and elasticity for the breads produced with 2.5 percent and five percent pumpkin peel flour. Specific volume and diameter also presented significant differences among the formulations. The manufacturing of breads with pumpkin peel flour is a healthy food alternative regarding the reuse of peels to reduces food waste. The formulation with the most satisfactory results among the analyses conducted involved the bread with five percent substitution with pumpkin peel flour.

Keywords: *exploitation,co-products, bakery, proteins*

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1. Introduction

Despite being very important for human nutrition for constituting sources of fibers, calories, fats, carbohydrates, proteins, minerals, and vitamins, vegetables are not very well exploited and are often wasted by the general population, which occurs from cultivation to the final consumption.

Most losses result from the non-exploitation of the edible, non-traditional parts of vegetables, such as leaves, peels, and seeds. Studies on the proximal composition of minerals from fruit peels and seeds in Brazil have reported that many nutrients contained in peels and seeds have higher contents than the pulp. Therefore, flour from vegetable residues have been employed aiming at reducing production costs and providing nutritional enrichment through the manufacturing of breads, cakes, cookies, cereal bars, vitamin supplements, and juices with final products added with improved nutritional and/or sensory quality.

Pumpkins (*Cucurbita máxima* L.) contain a great amount of vitamin A, complex B vitamins, calcium, and phosphorus [1], in addition to carbohydrates and other components of high nutritive and bioactive values. Pumpkin peels do not present significant contents of carbohydrates, lipids, iron, and potassium; however, this part of the vegetable have substantial amounts of proteins and fibers, in addition to ascorbic acid and calcium, which presented relevant concentrations in comparison with the pulp, a commonly consumed part [2]. Therefore, the use of pumpkin peel in flour production may lead to improved nutrients exploitation.

In this context, the objective of this paper was both the production and characterization of pumpkin peel flour as well as the development of breads with partial addition of the flour obtained from pumpkin peel substituting wheat flour.

2. Material and Methods

2.1. Raw Material

The pumpkin (*Cucurbita moschata*) variety known as Cabotiá was provided by the restaurant of the Agronomy School of the Federal University of Goiás, Goiânia-GO. The wheat flour, sugar, butter, fresh biological yeast, and salt were purchased at the local commerce.

2.2. Obtaining Pumpkin Peel Flour

The pumpkins were selected manually by observing external characteristics such as color, physical damages caused by transportation or handling, rot, maturation stage, odor, and size. Subsequently, we washed the pumpkins with running water for dirt removal and immersion in chlorinated water at 50 µL L^{-1} for ten minutes. The pumpkins were peeled, cut in fillets and had the pulp removed with stainless steel knives.

Subsequently, we subjected the peels to drying process in air-circulation kiln during 24 hours, at the temperature of 65°C. The pumpkin peel flour (PPF) was obtained by grinding the dry peels using industrial blender followed by milling in cutting mill. The final product presented yellowish green color in addition to a weak smell peculiar to pumpkin.

2.3. Preparing the Breads with Partial Substitution of Wheat Flour with Pumpkin Peel Flour

We developed the formulations with different concentration of PPF (2.5 percent and five percent) from the standard formulation using only wheat flour. The formulations are presented in Table 1.

Table 1. Formulations of the breads produced with PPF substituting wheat flour

Ingredient	Formulation		
	Standard	2.5% PPF*	5% PPF*
Wheat flour (g)	400	390	380
PPF (g)	0	10	20
Sugar (g)	35	35	35
Butter (g)	50	50	50
Yeast (g)	15	15	15
Water (mL)	250	250	250
Salt (g)	10	10	10

*percentage of pumpkin peel flour regarding 100 percent of the total wheat flour weight of the standard bread formulation.

Primarily, we mixed sugar, egg, and yeast in a recipient subsequently added with flour (wheat flour or with pumpkin peel flour) and left to rest for tem minutes. Later on, we added melted butter, salt, and warm water and transferred the mixture to a floured surface gradually adding wheat until the mass was let go of the hand easily. We followed the mass into the oven, turned off, for 90 minutes, in order to reach fermentation until the volume was doubled. Subsequently, the mass was opened on the table, folded in three parts, and transferred to a greased, floured form. Finally, we baked the mass in oven preheated to 180°C, for 30 minutes. Immediately after leaving the oven, the breads were cooled at room temperature for approximately three hours to have the analyses conducted.

2.4. Physical, Chemical, and Technological Analyses

The analyses of yield, pH, titratable acidity, color, water absorption index, oil absorption index, milk absorption index, water solubility index, and milk solubility index were carried out exclusively for the PPF. Proximal composition, caloric value, and activity of water were established for both the PPF and the breads, while the analyses of texture, specific volume, and diameter were carried out exclusively for the breads. All of the analyses were conducted in triplicate.

The flour yield was established with the pumpkin peel flour (PPF) obtained after drying and grinding of the peel, calculated regarding the initial mass of the peels *in natura*. pH was established using digital potentiometer (Tecnal, TEC 3P-MP) calibrated with buffer solution pH 4.0 and 7.0, followed by pH direct reading with immersion of the electrode in the beaker containing the macerated sample in aqueous solution, according to methodology proposed by the AOAC [3]. Total tritratable acidity was established through titration with sodium hydroxide solution (NaOH) 0.1N using one percent phenolphthalein as indicator, according to the AOAC [3]. The analyses were carried out in triplicate.

The color of the breads and the PPF were established using colorimeter (Hunterlab, ColorQuest II) with calibration obtained through standard plate, with local luminosity of D_{65}, observation angle of 10º, and measure area of 30 mm of diameter. In the breads, the determinations were carried out in three different points in the crust and three in the crumbs, with the results of each part expressed in the average. In the representation of system CIEL*a*b*, values of L*(how light or dark) from 0 (black) to 100 (white); +a* (up to 100) corresponding to red, -a* (up to -80) corresponding to green; +b* (up to +70) corresponding to yellow, and –b* (up to -100) to blue. Color variation (ΔE*) was calculated by Equation 1:

$$\Delta E^* = \sqrt{\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2} \quad (1)$$

where, ΔL*, Δa*, and Δb* represent the difference in the values of L*, a*, and b*, respectively, between the sample and the standard.

The technological analyses of water absorption index, water solubility index, milk absorption index, milk solubility index, and oil absorption index in the PPF were carried out according to the methodology by Anderson et al. [4], with a few modifications.

We established the water absorption index weighting 2.5 g of the sample in centrifuge tube previously weighed, added with 30 mL of water. The tubes remained under mechanical stirring in water bath, at 28°C for 30 minutes and subsequently taken to centrifuge at 3000 rpm during 10 minutes. From the supernatant liquid, an aliquot of 10 mL was pipetted, placed in petri dishes after having been dried and weighted, and kiln-stored at 105°C until constant weight. The reminiscent gel was weighted and the IAA calculated according to Equation 2:

$$\mathrm{IAA} = \frac{\mathrm{PRC}}{\mathrm{PA} - \mathrm{PRE.X3}} \quad (2)$$

where, IAA is the water absorption index (g gel/g of dry matter), PRC is the centrifugation weight residue (g), PA is the dry base sample weight (g), and PRE evaporation residue weight (g) X 3.

The water solubility index (ISA) followed the same stages as in IAA, calculated through the relationship between the evaporation residue weight and the dry sample weight, according to Equation 3:

$$\mathrm{ISA} = \frac{\mathrm{PRE.X3}}{\mathrm{PA}} \mathrm{X100} \quad (3)$$

where, ISA is the water solubility index (%), PA is the dry base sample weight (g), and PRE is the evaporation residue weight (g) X 3.

For the milk absorption index (IAL) and the milk solubility index (ISL), we weighted 2.5g of sample, suspended and maintained in whole milk at 4°C, for 30 minutes. The suspensions were centrifuged at 3000 rpm, for ten minutes. Subsequently, an aliquot of 10 mL of supernatant was placed in a petri dish of known weight and air-circulation kiln-dried at 60°C until constant weight to establish the evaporation residue and the centrifugation precipitate was weighted. We conducted a control (in triplicate) to obtain the amount of soluble solids in milk and subtract them in the calculations of evaporation residues to establish ISL, according to Equation 4:

$$\text{IAL} = \frac{\text{PRE}}{\text{PA} - (\text{PRE} - \text{PRC})\text{X3}} \quad (4)$$

where, IAL is the milk absorption index (g gel/g of dry matter), PRE is the evaporation weight residue (g), PA is the dry base sample weight (g), and PRC is the evaporation residue weight of the control (g).

To establish the percentage of ISL, we used Equation 5:

$$\text{ISL} = \frac{(\text{PRE} - \text{PRC})\text{X3}}{\text{PA}}\text{X100} \quad (5)$$

where, ISL is the milk solubility index (%), PRE is the evaporation residue index (g), PRC is the evaporation residue index of control (g), and PA is the dry base sample weight (g).

In order to establish the oil absorption index in the aliquot of 2.5 g of sample, we suspended it in 30 mL of soy oil, at 28°C, in a centrifuge tube of 50 mL, previously weighted, with intermittent stirring, for 30 minutes. Later, the suspension was centrifuged in centrifuge 3000 rpm, during ten minutes. The supernatant liquid of the sample was discarded leaving the tube slightly inverted for a minute. The oil absorption index was obtained through the relationship between the centrifugation residue index and the dry base sample weight, according to Equation 6:

$$\text{IAO} = \frac{\text{PRC}}{\text{PA}} \quad (6)$$

where, IAO is the oil absorption index (g gel/g of matter dry), PRC is the centrifugation residue weight (g), and PA is the dry base sample weight (g).

The proximal composition was established through the analyses of moisture, according to technique described by the Association of Official Analytical Chemists [3]; total nitrogen, according to the method of micro-Kjeldahl [3]; total lipids, by Soxhlet [3]; and fixed mineral residue [3]. The content of carbohydrates was calculated by employing the difference method subtracting a hundred from the values of moisture, ashes, proteins, and lipids. The energy value was estimated through the coefficients of ATWATER (carbohydrates = 4.0 kcal g^{-1}; lipids = 9.0 kcal g^{-1}; proteins = 4.0 kcal g^{-1}) [5].

The activity of water in the breads and in the PPF were established in triplicate, with grinded sample, which was placed in the capsule of the Aqualab equipment gauge (Aqualab CX–2). In order for the reading to be carried out, the equipment was calibrated with a pattern of 0.5 for activity of water and temperature of 25°C.

The texture profile of the breads was carried out using a texturometer model TA-XT2i (StableMicro Systems, Surrey, United Kingdom), equipped with probe P36 cylindrical, with 36 mm of diameter, according to method by AACC 74-09 with adaptations [6]. We measured the parameters of texture one hour after subjection to oven. The tests were conducted in TPA mode (Texture Profile Analysis) in three samples prepared with the removal of the edges of the breads in three runs, under the following conditions: 2.0 mm/s for pretest velocity; 5.0 mm/s for test and post-test velocity; distance of 20 mm; auto-trigger for 20 g; deformation of 50 percent (1mm), and the time between the two compressions equal to five seconds.

The method used consists of double compression of the sample generating force-time and force-distance graphs from which the values required to calculate the texture parameters are obtained. These parameters were calculated through the curve as follows: hardness: force peak measured during the first compression cycle (N); cohesiveness: relationship between the areas of the second and the first compressions of the initial point until the peak (dimensionless); elasticity: distance from the initial point of the second compression until the peak (m); masticability: hardness product, cohesiveness, and elasticity (J).

The specific volume of the breads was established using the method of millet seed displacement calculated through the relationship between the volume of the baked bread (cm^3) and its weight (g) with an analytical balance. The specific volume determination was carried out in three repetitions with results expressed in cm^3/g [7]. We measured the diameter of the breads by cutting them in slices that were subsequently measured using caliper gauge in centimeters, with three repetitions [8].

2.5. Statistical Analysis

The results of the chemical, physical analyses of the breads were subjected to statistical analysis using Analysis of Variance (ANOVA) and Tukey Test to compare the averages with significance level of five percent through PAST software. The results of the chemical, physical, and technological analyses of pumpkin peel flour were analyzed through the mean values and standard deviation.

3. Results and Discussion

3.1. Physical, Chemical, and Technological Analyses of Pumpkin Peel Flour

In average, a pumpkin of three kilos provided 491 g of humid peels. After the drying process in air-circulation kiln, we obtained 153 g of dry peels, which resulted in 125 g of pumpkin peel flour. Thus, the average yield of the humid peels until obtaining the PPF was 25.46 percent.

The mean values of the physical, chemical, and technological analyses of the PPF are demonstrated in Table 2.

The PPF presented a moisture content below the maximum moisture limit (15 g.100 g^{-1}) proposed in Resolution RDC n 263 [9]. According to El-Dash and Germani [10], flours with moisture above 15 g.100 g^{-1} tend to form lumps hampering the production of mass using continuous process, in which both the flour and the water should flow uniformly to maintain the proportion of these ingredients in the mass mixture while manufacturing the bread.

Table 2. Physical, chemical, and technological composition of pumpkin peel flour

Analyses	PPF*
Moisture (g.100 g^{-1})	7.58 ± 0.32 (4.22)
Ash (g.100 g^{-1})	5.56 ± 0.02 (0.36)
Proteins (g.100 g^{-1})	17.99 ± 0.08 (0.44)
Lipids (g.100 g^{-1})	7.02 ± 0.11 (1.57)
Carbohydrates (g.100 g^{-1})	61.85 ± 0.05 (0.08)
Caloric value (Kcal)	382.54 ± 0.35 (0.09)
pH	6.62 ± 0.08 (1.21)
Titratable acidity (g.100 g^{-1})	24.2 ± 0.2 (0.83)
Water activity	0.389 ± 0.03 (7.71)
L*	66.95 ± 3.91 (5.84)
a*	1.39 ± 0.22 (15.82)
b*	23.09 ± 2.75 (11.91)
Water absorption index (g gel.g dry matter^{-1})	1.72 ± 0.06 (3.49)
Oil absorption index (g gel.g dry matter^{-1})	2.25 ± 0.02 (0.89)
Milk absorption index (g gel.g dry matter^{-1})	1.41 ± 0.03 (2.13)
Milk solubility index (g.100 g^{-1})	22.50 ± 0.01 (0.04)
Water solubility index (g.100 g^{-1})	18.28 ± 0.02 (0.11)

* Values expressed as mean ± standard deviation (coefficient of variation (%))

The PPF presented an ash content (5.56 g.100 g^{-1}) lower than the value found by Achu et al. [11], who obtained values of 3.47 g.100 g^{-1} and 4.75 g.100 g^{-1} for ashes, in five species of *Cucurbitaceae* seeds. Regarding the contents of lipid and protein, wheat flour generally presents values of 1.4 g.100 g^{-1} and 9.8 g.100 g^{-1}, respectively [12], which means that the PPF has a content of lipid and protein higher than the values indicated for the wheat flour. In this case, it is worth to highlight the importance of the pumpkin peel flour to contribute to the increase in the protein content of foods. Regarding the content of carbohydrates, the PPF presented 61.85 g.100 g^{-1} – a significant result in comparison to the values found only in traces by Santangelo [13] when studying pumpkin seed flour in panettone value. The caloric value found in the PPF was approximately 382.54 kcal due to the considerable value found for carbohydrates.

By comparing the pumpkin peel flour and the wheat flour, we may state that the PPF presented lower contents of moisture and carbohydrates than wheat flour, corresponding to 13 g.100 $g^{-1}$and 75.1 g.100 g^{-1}, respectively [12].

The pH of the pumpkin peel flour was very close to the dry legumes and peels. Couto et al. [14] found a mean pH value of 6.0 for pequi peel flour used when manufacturing traditional breads. From the food conservation point of view, pH is a very important parameter for being able to select microbial presence, perform chemical interactions, and establish strict industrials treatments. In addition to influence on conservation, acidity is also a fundamental component for food taste.

Amorim et al. [15] established values of pH (6.22) and titratable acidity (23.5) of pumpkin seeds flour (*Cucurbita máxima* L.) and obtained results close to the values found in this study. As well as Santangelo [13], who also found values similar to this study (6.16 for pH and 23.21for titratable acidity) for pumpkin seed flour.

The value for the activity of water found in the pumpkin peel flour (0.389) was higher than that reported by Freire [16] for passion fruit peel flour (0.337) and lower than the powder pumpkin leaf (0.500) according to Piekarski [17]. The value found in this study is below the limit to allow the development of microorganisms, which would be 0.60 according to Chisté et al. [18].

Regarding the color parameters, we observed that the PPF presented a luminosity (L*) value closer to the value corresponding to white, a* value closer to green, and b* value closer to yellow. The color variation (ΔE*) of the pumpkin peel flour was 35.2 in relation to the white plate pattern, which was close to the result found by Fernandes et al. (2008), who assessed the color of potato peel flour with variation of 36.18 in relation to the white plate. The values observed for the instrumental parameters of color for the PPF, presented in Table 2 were also close to the values found by Fernandes et al. [19] for whole wheat flour with 68.69 for L* and only 3.97 for a*, higher than those found in this study. Couto [20] assessed pequi peel flour and found 28.86 for b*, which is relatively higher than the value found for the PPF (23.09).

By analyzing the IAA, we observed the formation of a gel able to absorb water through hygroscopic properties present in the flour. A study conducted by Fiorda et al. [21] on cassava bagasse flour found values of 1.66 g of gel.g of dry matter $^{-1}$ for the IAA for cassava flour – close to the value indicated in this study (1.72 g of gel.g of dry matter^{-1}) and higher values of IAA for cassava bagasse flour (6.73 g of gel.g of dry matter^{-1}). The IAA found by Ferreira [22] for the flour of broken rice grains *in natura* was higher than the value found in this study (2.26 g of gel.g of dry matter^{-1}).

The IAL found for the PPF was low (1.41 g of gel.g of dry matter $^{-1}$), indicating little affinity with milk against the values found in the study developed by Ferreira [22] using the flour of broken rice grains (11.68 g of gel.g of dry matter $^{-1}$). The result found for the ISL in this study (22.5 g.100 g^{-1}) was higher than that reported by Ferreira [22] for the flour of broken rice grains (11.68 g.100 g^{-1}).

The IAL presented the same tendency as the IAA, with low values, suggesting that it is not indicated to be employed to develop food products which do not require heating or instant foods. In this study, the ISL was higher than the ISA, indicating that the PPF may be incorporated in desserts milk-based products for consumption.

The IAO for the pumpkin peel flour was 2.25 g of gel.g of dry matter^{-1} indicating little affinity with oil. A study conducted by Fiorda et al. [21] pointed out that the cassava flour had higher IAO than the PPF, with 12.41 g. of gel g of dry matter $^{-1}$, while the cassava bagasse flour (0.59 g of gel.g of dry matter^{-1}) presented lower values.

3.2. Physical and Chemical Analyses of the Breads Formulated with Wheat Flour and with Pumpkin Peel Flour Substituting Wheat Flour

Table 3 demonstrates the mean contents of the physical and chemical analyses of the bread produced with wheat flour and with pumpkin peel flour substituting wheat flour:

Table 3. Physical and chemical analyses of standard bread and bread incorporated with PPF.

Analyses	Formulation		
	Standard	2.5% PPF*	5% PPF*
Moisture (g.100 g^{-1})	$37.52^a \pm 0.23$	$37.38^a \pm 0.57$	$37.36^a \pm 0.12$
Ash (g.100 g^{-1})	$1.24^b \pm 0.01$	$1.49^a \pm 0.02$	$1.50^a \pm 0.02$
Proteins (g.100 g^{-1})	$7.53^b \pm 0.2$	$7.87^b \pm 0.26$	$8.61^a \pm 0.22$
Lipids (g.100 g^{-1})	$2.84^a \pm 0.09$	$2.73^a \pm 0.09$	$2.68^a \pm 0.06$
Carbohydrates (g.100 g^{-1})	$49.87^b \pm 0.3$	$49.53^b \pm 0.32$	$48.85^a \pm 0.33$
Caloric value (Kcal)	$255.16^b \pm 0.39$	$254.87^b \pm 0.35$	$253.96^a \pm 0.34$
Firmness (N)	$2.47^a \pm 0.58$	$1.80^a \pm 0.55$	$2.24^a \pm 0.57$
Cohesivity	$0.48^a \pm 0.07$	$0.46^a \pm 0.1$	$0.41^b \pm 0.06$
Elasticity (mm)	$0.87^a \pm 0.11$	$0.74^b \pm 0.1$	$0.76^b \pm 0.08$
Masticability (N.mm)	$0.92^a \pm 0.35$	$0.65^a \pm 0.37$	$0.78^a \pm 0.3$
Water activity	$0.925^a \pm 0.03$	$0.931^a \pm 0.02$	$0.951^a \pm 0.03$
Specific volume ($cm^3.g^{-1}$)	$4.13^a \pm 0.1$	$3.35^b \pm 0.14$	$3.18^b \pm 0.13$
Diameter (cm)	$10.34^a \pm 0.08$	$9.35^b \pm 0.05$	$8.98^b \pm 0.06$

*Same letters in the same line do not differ at a significance level of 95% ($p \leq 0.05$), by Tukey test.

We verified significant difference ($p < 0,05$) for the proximal composition of the breads according to the formulation regarding the values of ashes, protein, carbohydrate, and calories. The moisture content of the different breads developed present values within the limit of 38.0 percent of moisture established in Regulation n 90/00 [23]. With an increase in the levels of PPF incorporation, we observed an increase in the content of ashes against the standard. Fernandes et al. [24] found, in average, contents of 1.78 g.100 g^{-1} for breads with potato peel flour. These values were relatively higher than those in the breads produced with PPF, which were possibly influenced by the remaining ingredients used to develop the breads. The flours may have variation in the mean content of total ashes according to the origin of raw material.

The substitution of 2.5 percent and five percent of wheat flour with PPF increased the content of total proteins in the breads, which is interesting from the nutritional point of view. In contrast, considering technological aspects, it could be unpleasant since these proteins do not form gluten generating weak protein structure of the mass reducing elasticity and viscosity. A similar result was observed by Doxastakis et al. [24], Maforimbo et al. [25], Ribotta et al. [26], and Roccia et al. [27] assessed the influence of the addition of other protein sources (lupine, soy, and cacao) mixed with wheat flour in the rheological properties of the mass. According to the authors, these proteins promote the interruption in the tridimensional structure of the gluten, damaging its capacity to retain gases, which, along with other components of linseed flour, benefit the elucidation of the alterations observed in this study.

According to Queji et al. [28], carbohydrate performs an important function in the bakery process for contributing to the structure formation, consistence and bread crumb, the increase in volume, and ageing. However, the results corroborate with those verified by Oliveira et al. [29] by employing whole linseed flour to produce salt bread (49.72 g.100 g^{-1}). Škrbic et al. [30] also obtained reduced carbohydrate content by producing breads from mixed flours with whole and refined wheat. For the authors, whole flours and derived products generally present lower amount of this component. Regarding the estimated value, we observed a decrease in the measure that increased the concentration of pumpkin peel flour.

The texture parameters revealed significant difference ($p < 0.05$) among the formulations regarding cohesivity and elasticity; the parameters of hardness and masticability did not have influence of PPF addition. A study carried out by Couto [20] on the use of pequi peel flour in the production of bread states that the higher the addition of pequi peel flour the higher the content of fibers, which increases hardness. In the case of the breads in that study, the amount with substitution did not alter hardness.

Breads with low elasticity tend to get broken or suffer irreversible rupture. The addition of pumpkin peel flour favored the decrease in elasticity demonstrated in Table 3, resulting in lower elasticity values for both the formulations in comparison with the standard bread. According to Szczesniak [31], low cohesiveness indicates lower force required to stretch a food until its rupture. The results of this parameter for the bread with 5.0 percent PPF point out to a low cohesiveness, that is, less cohesive breads than the standard bread. Therefore, the bread (5.0 percent PPF) presented lower force to rupture than the standard, which can be considered easily crumbled.

The activity of water in the breads presented no significant difference ($p > 0.05$) among the formulations. The three breads produced presented an activity of water above 0.90, which is a high value, providing softness and freshness. Moreira [32] also found values above 0.90 for breads produced with flours of rice and soy.

The specific volume of the breads presented significant differences ($p < 0.05$) according to the formulation with PPF against the standard bread. The specific volume is the most important measure to verify the capacity of the flour to expand and retain the gas inside the mass while in the oven. According to the values in Table 3, we observed that the specific volumes of the breads with PPF had influence of the amount added.

The formulations with PPF resulted in lower specific volume, which is directly associated with gluten dilution and structure weakening. Mohammed et al. [33] also verified that low volume resulted from the use gluten-free flours, in their study, substituted with chickpea flour. Morris and Morris [34] explain that such results may be attributed to the presence of fiber in the mass by physically interrupting the protein structure and favoring the loss of gases during fermentation, which hampers the formation of a net able to expand and leading to breads with lower volume, as illustrated in Figure 1. In studies conducted by Gutkoski et al. [35] and Freitas et al. [36] on the use of mixed flour to produce salt bread revealed specific volume values of 3.20 $cm^3.g^{-1}$ for a formulation containing ten percent cassava flour.

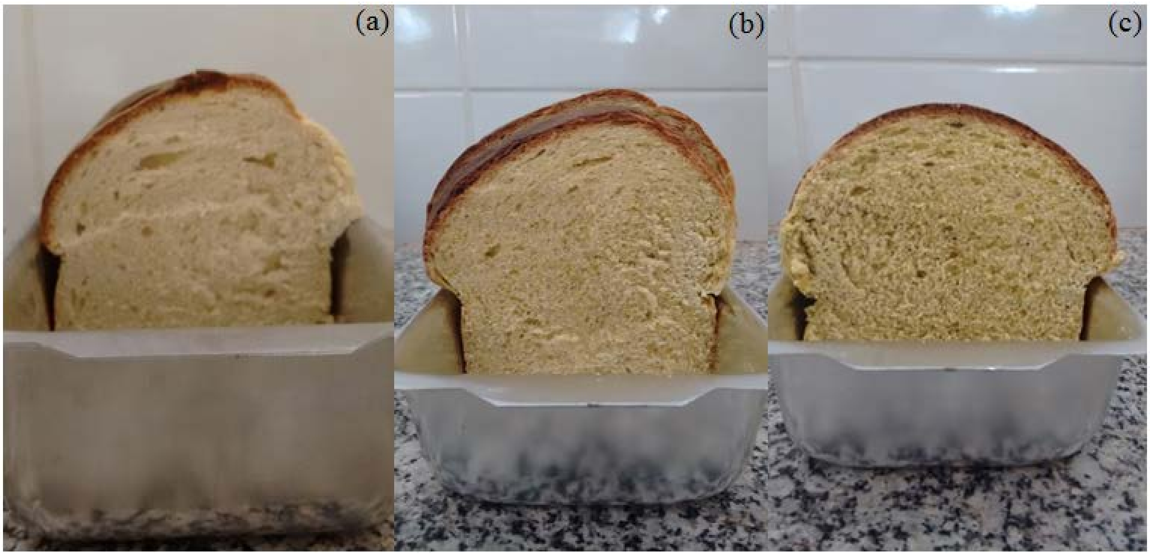

Figure 1. Visual aspects of the breads: (a) standard; (b) with 2.5% of pumpkin peel flour substituting wheat flour; (c) with 5% of pumpkin peel flour substituting wheat flour. Authors' own source

The diameter of the breads indicated significant difference ($p < 0.05$) according to the formulation with PPF in relation to the standard bread. The diameter presented variation of 1.45 cm from the standard bread in relation to the bread with five percent PPF. According to Oliveira et al. [29], in the case of breads, the presence of fibers in the formulation can promote decreased parameter and consequently volume due to the increase in water absorption and lower tendency to fermentation.

Figure 2 presents the scanning electron microscopy analyses of the fracture of both the control breads and those added with PPF, revealing that the higher the addition of PPF the higher the presence of fibers. Furthermore, as exposed by Morris & Morris [34], we observed that the net was not able to expand due to the lower amount of gluten in the mass.

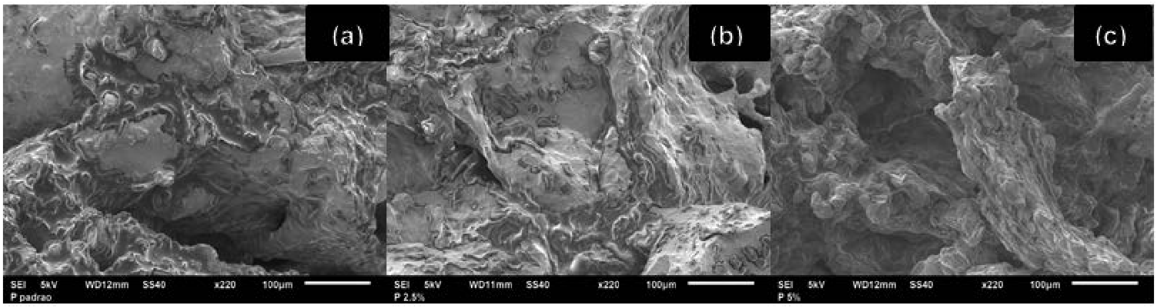

Figure 2. Micrograph observed through (MEV) of bread with pumpkin peel flour with control (a), 2.5% of PPF (b) and 5% of PPF (c) (increase of 220x)

4. Conclusions

The partial substitution of wheat flour with pumpkin peel flour in breads influenced their mass growth, as well as color, the content of raw fiber and protein. The bread produced with five percent of pumpkin peel flour substituting wheat flour, for presenting higher content of protein and raw fiber, may become a viable alternative to the market by offering a new type of food variation with a functional, healthy character, in addition to contributing to reduce food waste by reusing the commonly discarded pumpkin peels.

Statement of Competing Interests

The authors have no competing interests.

Abbreviation

PPF = pumpkin peel flour
ISA = water solubility index
IAA = water absorption index
IAL = milk absorption index
ISL = milk solubility index
IAL = oil absorption index.

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