The substitution of wheat flour with flour made from *Dialium Guianense* and *Nephelium Lappaceum* L. Fruit peel in muffins

Substituição da farinha de trigo pela farinha das cascas de *Dialium Guianense* e *Nephelium Lappaceum* L. na elaboração de muffins

Sustitución de la harina de trigo por harina de conchas de *Dialium Guianense* y *Nephelium Lappaceum* L. en la preparación de muffins

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ABSTRACT  
Food waste generated by the lack of proper processing of fruit parts, such as peels and seeds, is a global problem, although these by-products could enrich the nutritional value of food products. Thus, this study aimed to develop, characterize, and perform a sensory analysis of functional muffins enriched with flour made from Dialium guianense and Nephelium lappaceum L. fruit peels. Four
muffin formulations were developed with different substitution levels (0, 2.5, 5, and 7.5%) of wheat flour with the fruit peel flour. The muffins were analyzed for proximate composition, weight reduction, color, texture profile, sensory profile (color, odor, flavor, texture, and overall appearance), and purchase intention. The results showed that the formulations with flour produced from the fruit residues had higher fiber and lipid content, less weight loss during baking, and darker coloration than standard samples. The sample with 2.5% wheat flour replaced with fruit peel flour showed better sensory parameters and purchase intention. Hence, the physical, chemical, and sensory analyses presented a positive increase in the nutritional and sensory quality of the developed products.

**Keywords:** sensory analysis, chemical composition, fruit, residue, texture.

**RESUMO**
O desperdício de alimentos gerado pela falta de processamento adequado de partes de frutas como cascas e sementes é um problema mundial. No entanto, estes subprodutos poderiam ser utilizados para enriquecer o valor nutricional de produtos alimentícios. Dessa forma, o objetivo desse trabalho foi desenvolver, caracterizar e avaliar sensorialmente muffin funcionais enriquecidos com farinha das cascas de rambutan e pororoca. Foram desenvolvidas quatro formulações de muffins com diferentes níveis de substituições (0; 2,5; 5 e 7,5%) da farinha de trigo por farinha das cascas de rambutan e pororoca. Os muffins desenvolvidos foram analisadas quanto a composição centesimal, redução de peso, cor, perfil de textura, perfil sensorial (cor, odor, sabor, textura e aparência global) e intenção de compra. Os resultados evidenciaram que as formulações com adição da farinha de resíduos de frutas apresentaram maior conteúdo de fibra e lipídios, menor perda de peso durante o forneamento e coloração mais escura em relação a amostra padrão. A amostra com 2,5% de substituição da farinha de trigo por farinha das cascas de rambutan e pororoca apresentou melhor avaliação dos parâmetros sensoriais e intenção de compra. Assim, as análises físicas, químicas e sensoriais evidenciaram um incremento positivo na qualidade nutricional e sensorial dos produtos desenvolvidos.

**Palavras-chave:** análise sensorial, composição química, fruta, resíduo, textura.

**RESUMEN**
El desperdicio de alimentos generado por la falta de procesamiento adecuado de partes de frutas como cáscaras y semillas es un problema global. Sin embargo, estos subproductos podrían utilizarse para enriquecer el valor nutricional de los productos alimenticios. En consecuencia, el objetivo de este trabajo fue desarrollar, caracterizar y evaluar mollete sensorialmente funcional enriquecido con harina de cáscaras de rambután y pororoca. Se desarrollaron cuatro formulaciones de magdalenas con diferentes niveles de sustitución (0, 2,5, 5 y 7,5%) de harina de trigo por harina de rambután y cáscaras de pororoca. Se analizó la composición centesimal, reducción de peso, color, perfil de textura, perfil sensorial (color, olor, sabor, textura y aspecto general) y la intención de compra de los muffins desarrollados. Los resultados mostraron que las
formulaciones con la adición de harina de residuos frutales presentaron mayor contenido de fibra y lípidos, menor pérdida de peso durante el suministro y coloración más oscura en relación a la muestra estándar. La muestra con 2,5% de sustitución de harina de trigo por rambután y harina de cascos de pororocca presentó mejor evaluación de parámetros sensoriales y de intención de compra. Así, los análisis físicos, químicos y sensoriales mostraron un incremento positivo en la calidad nutricional y sensorial de los productos desarrollados.

**Palabras clave:** análisis sensorial, composición química fruta, residuos, textura.

**1 INTRODUCTION**

Food waste impacts society, correlating with the population’s nutritional quality and environmental sustainability. These food losses can be observed throughout the entire production chain, leading to the need to fully utilize food and waste to create new food products (FAO *et al.* 2022; Conrad *et al.* 2018). Hence, food waste management is one of the approaches of agricultural policies encouraged by the Food and Agriculture Organization (FAO) to make healthy diets more accessible to the population and thus contribute positively to food and nutrition security in the world (FAO *et al.* 2022).

In contrast, one of the biggest challenges of the fruit and vegetable processing industry is directly linked to the large quantities of post-harvest losses and organic waste, such as peels and seeds, generated by this activity. According to Conrad *et al.* (2018), food waste by Americans represents 30% of the daily calories available for consumption and 7% of the annual cultivated area. Regrettably, the alternatives for using these wastes to add economic value are still limited, and these are mostly discarded in the environment, used as organic fertilizers, or even in animal feed without any treatment (Miguel *et al.* 2008). According to Bhatia *et al.* (2023), effective and advanced waste management systems should have a sustainable, ecological, and economical approach.

To maximize the use of food resources, the integral utilization of food is a way of providing a better-quality nutritional consumption using the waste that would be discarded as a source of bioactive compounds beneficial to health
In this context, producing flour from food waste is a viable alternative to reusing waste as ingredients for various food products, including bread, cake, and pasta, achieving the nutritional enrichment of such products (Alves et al. 2021; Oliveira et al. 2021; Ferrão et al. 2020).

In this context, fruit and vegetable production stands out as it requires small cultivation areas to provide food of higher nutritional quality, although it also requires substantial amounts of agricultural inputs and water for irrigation. Thus, a practical solution for this problem is to foster consumer knowledge about storing and preparing fruits to optimize their nutrients (Conrad et al. 2018). Among the vast quantity of fruit species, promoting knowledge about the ones with little data and exotic flavors, such as pororoca and rambutan, is highly relevant.

*Dialium guianense*, popularly known as ‘pororoca,’ is a tree species of the Fabaceae family and found throughout Mexico, Central America, and the Brazilian Amazon, occurring most frequently in the northern and northeastern states of Brazil, especially in Pará (Centurión-Hidalgo et al. 2019; Segura et al. 2018; Vargas-Simon et al. 2018; Herrero-Jáuregui et al. 2009). The wood of this tree is widely used for various purposes and is its main product; however, the fruits have a fleshy and edible mesocarp commonly found in fruit stalls and farmers’ markets (Pereira et al. 2005). Machado et al. (2021) analyzed pororoca fruits from Pará State and reported that they are small (21.09 x 12.18 mm and 0.82 g) with brown skin and orange-colored pulp. Their pulp showed a chemical composition of 28.26% moisture content, 3.37% ash content, 0.45% lipids, 2.77% crude protein, 5.07% crude fiber, and 60.07% carbohydrates.

*Nephelium lappaceum* L., popularly known as ‘rambutan,’ is a plant that originated in Asia and is also produced in various tropical countries such as Brazil, mainly in the northern and northeastern states (Hernández-Hernández et al. 2019; Andrade et al. 2008). The rambutan belongs to the Sapindaceae family; its fruits are ovoid with a red pericarp covered by soft spines, measuring 3–6 cm long and 3–4 cm wide. The fruit, its pulp, peel, and seeds present chemical composition and functional properties (antioxidant and anti-inflammatory) that can add nutritional quality to food products. The fruit pulp is consumed raw or
used to produce many products, including jellies, liquor, canned food, and juice, while the seeds are used to manufacture chocolate. Nonetheless, these processed forms produce a significant amount of peel and seed waste, making it crucial to employ these wastes in industrial applications (Hernández-Hernández et al. 2019; Palanisamy et al. 2008).

Given this context, this study sought to develop, characterize, and perform a sensory analysis on functional muffins enriched with flour from rambutan and pororoca peels as a substitute for wheat flour.

2 MATERIALS AND METHODS

2.1 SAMPLE PREPARATION

Rambutan fruit samples were purchased locally in Roraima State (northern Brazil), while pororoca samples were provided directly by a producer in Pará State (northern Brazil). The fruits were selected, and the healthy fruits were first immersed in 0.025% sodium hypochlorite sanitizing solution for 15 min. After sanitization, the peels were separated manually and stored in polypropylene containers in a freezer at -20 °C until processing and analysis (30 days).

2.2 FLOUR PRODUCTION

The rambutan and pororoca peels were dried in an oven with forced air circulation at 60 °C for 16 and 10 h to prepare the fruit by-product flours. After drying, the peels of the two fruits were ground in a knife mill and homogenized in a 1:1 ratio.

2.3 MUFFIN PREPARATION

Four muffin formulations were prepared with different levels of substituting the wheat flour with flour produced with pororoca and rambutan peels (0, 2.5, 5,
and 7.5%). The dough was prepared according to Bender et al. (2016) using the ingredients listed in Table 1. The ingredients (except for the yeast) were mixed in a domestic mixer for 4 minutes at high speed, at which time the yeast was added and mixed for 30 s at low speed. After homogenizing the ingredients, 90 g of the prepared dough was put into individual molds and baked in an industrial oven for 25 min at 220 °C. The baked muffins were cooled to room temperature and packaged in polypropylene containers until the analyses (day 1).

Table 1. Formulation of the muffins produced with fruit-peel flour.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Formulations</th>
<th>0% 1</th>
<th>2.5%</th>
<th>5%</th>
<th>7.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue flour (g) 2</td>
<td>-</td>
<td>3.8</td>
<td>7.5</td>
<td>11.5</td>
<td></td>
</tr>
<tr>
<td>Wheat flour (g)</td>
<td>150</td>
<td>146.3</td>
<td>142.5</td>
<td>138.8</td>
<td></td>
</tr>
<tr>
<td>Margarine (g)</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Chocolate powder (g)</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Chemical yeast (g)</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Egg (g)</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Sugar (g)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Milk (mL)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

1 Level of substitution of wheat flour by mixing the same proportions of flour from rambutan and pororoca peels. 2 The waste flour was mixed in a 1:1 ratio of flour from pororoca and rambutan peels. Source: authors.

2.4 PHYSICAL ANALYSES

Physical analyses of the muffins were performed according to Martínez-Cervera et al. (2015) on four samples of each formulation. The ratio between the individual weights of the baked doughs and the weights of the raw doughs determined the weight yield. Weight loss on baking was evaluated by the formula: \[\frac{(\text{weight of raw dough} - \text{weight of baked dough} \times 100)}{\text{weight of raw dough}}.\]

The color of the products was measured using a Konica Minolta CR-300 colorimeter and the CIE Lab color system with a 10° observation angle. The parameters measured were L*, a*, b*, chroma, and Hue angle. Texture profiles of slices of the muffins (10 mm) were analyzed according to Bender et al. (2016) in a TA-XTPlus texturometer using a 75-mm cylindrical aluminum probe (P/75).
The muffins were evaluated for hardness, elasticity, cohesiveness, lumpiness, and chewiness.

2.5 CHEMICAL ANALYSIS

The analysis of the proximate composition of the products was determined in triplicate according to the following procedures described in AOAC (2005): moisture content, ash content, protein, crude fiber, and lipids. The moisture content was calculated by the difference in weight of crucibles with samples before and after being submitted to an oven at 105 °C until constant weight. The mineral content was analyzed by incinerating the samples in a muffle furnace at 550 °C for 5 h. The Micro-Kjeldahl method determined the protein content following digestion with sulfuric acid, distillation with boric acid indications in a Kjeldahl distiller, and titration with sulfuric acid. The crude fiber was evaluated by digestion in sulfuric acid followed by digestion with sodium hydroxide. The lipid content was analyzed by adapting the method described by Bligh and Dyer (1959). The carbohydrate content was calculated by the difference of 100 minus the sum of the percentage of the other nutritional fractions determined in the sample (moisture content, ash content, lipids, protein, and crude fiber).

2.6 SENSORY ANALYSIS

Samples of the different muffin formulations (10 g) were individually served in polypropylene containers, identified with three-digit codes, to 50 untrained judges of both sexes in individual booths for sensory testing, according to Bender et al. (2016). The sensory parameters evaluated were color, odor, flavor, texture, and overall acceptance through an acceptance test using a 7-point hedonic scale (1 = I disliked it very much; 7 = I liked it very much). The judges also indicated their intention to purchase the products using a 5-point hedonic scale (5 = I would definitely buy it; 4 = I would probably buy it, 3 = I would maybe (not) buy it, 2 = I would probably not buy it, and 1 = I would definitely not buy it). The present study
was approved by the Research Ethics Committee in its ethical and methodological aspects, under protocol n° 76014223.0.0000.5302.

2.7 STATISTICAL ANALYSIS

The experimental data were submitted to analysis of variance (ANOVA) and Tukey’s test (p < 0.05) using the Statistica 7.0 software (Tulsa, USA, 2004).

3 RESULTS AND DISCUSSION

3.1 PHYSICAL ANALYSIS

The weight reduction of the muffins after baking presented in Table 2 showed that the muffins made with flour from rambutan and pororoca peels had a lower weight reduction when compared to the standard formulation. There was no difference in weight reduction between the formulations. The lower weight reduction values are possibly due to the higher amount of fiber in the fruit peels, which increases the water retention in the dough, increasing the product’s weight. Consequently, the dough yield in all treatments was significantly higher than the standard sample. Thus, the greater the substitution of wheat flour for fruit waste flour, the greater the dough yield of the muffins.

Table 2. Physical analyses of muffins produced with fruit-peel flour.

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Weight reduction (%)</th>
<th>Yield by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>12.33 a&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.88 b</td>
</tr>
<tr>
<td>2.5%</td>
<td>7.33 b</td>
<td>0.93 a</td>
</tr>
<tr>
<td>5.0%</td>
<td>6.54 b</td>
<td>0.93 a</td>
</tr>
<tr>
<td>7.5%</td>
<td>6.36 b</td>
<td>0.94 a</td>
</tr>
</tbody>
</table>

<sup>1</sup>Level of substitution of wheat flour by the mixture in the same proportions of flour from rambutan and pororoca peels. <sup>2</sup>Means followed by the same letter in the same column do not differ statistically by Tukey’s test at 5% probability. Source: authors.

The values of the color parameters of the prepared muffins are listed in Table 3, which shows that adding the fruit-peel flour increased the color intensity.
(chroma) and reduced the brightness. These values indicate that the fruit-peel flour made the muffin dough darker, possibly due to the brown coloration of the flour from the rambutan and pororoca peels.

Table 3. Color analysis of muffins made with fruit-peel flour.

<table>
<thead>
<tr>
<th>Sample</th>
<th>L</th>
<th>a*</th>
<th>b*</th>
<th>Chroma</th>
<th>Hue angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>42.045a</td>
<td>11.943a</td>
<td>20.343a</td>
<td>22.880b</td>
<td>59.500a</td>
</tr>
<tr>
<td>2.5%</td>
<td>38.250b</td>
<td>12.147a</td>
<td>21.780a</td>
<td>24.940b</td>
<td>60.840a</td>
</tr>
<tr>
<td>5.0%</td>
<td>38.050b</td>
<td>12.175a</td>
<td>21.230a</td>
<td>24.580a</td>
<td>61.485a</td>
</tr>
<tr>
<td>7.5%</td>
<td>36.403b</td>
<td>12.430a</td>
<td>21.085a</td>
<td>24.360a</td>
<td>59.023a</td>
</tr>
</tbody>
</table>

1L = luminosity. 2Level of substitution of wheat flour by mixing the same proportions of flour from rambutan and pororoca peels. 3Means followed by the same letter in the same column do not differ statistically by Tukey’s test at 5% probability. Source: authors.

The muffins’ texture profile showed that the elasticity and cohesiveness of the different muffins did not present statistically significant changes (Table 4). The hardness, gumminess, and chewiness were not affected by adding up to 5% peel flour, significantly reducing these parameters in the muffin with a 7.5% substitution. Hence, the results of the texture analysis showed that the inclusion of up to 5% of flour from pororoca and rambutan peels did not affect the texture of the muffins, despite a probable favorable increase in the content of dietary fiber and minerals due to the addition of the peels.

Table 4. The texture profile of muffins made with fruit-peel flour.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Hardness (N)</th>
<th>Elasticity</th>
<th>Cohesivity</th>
<th>Lumpiness</th>
<th>Chewability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>5364.65 a</td>
<td>0.86a</td>
<td>0.71a</td>
<td>3795.39a</td>
<td>3284.64a</td>
</tr>
<tr>
<td>2.5%</td>
<td>5280.79a</td>
<td>0.88a</td>
<td>0.69a</td>
<td>3614.25a</td>
<td>3177.59a</td>
</tr>
<tr>
<td>5.0%</td>
<td>4647.46ab</td>
<td>0.90a</td>
<td>0.72a</td>
<td>3342.31a</td>
<td>3008.39a</td>
</tr>
<tr>
<td>7.5%</td>
<td>3906.84b</td>
<td>0.88a</td>
<td>0.67a</td>
<td>2610.28b</td>
<td>2303.06b</td>
</tr>
</tbody>
</table>

1Level of substitution of wheat flour by the mixture in the same proportions of flour made from rambutan and pororoca peels. 2Means followed by the same letter in the same column do not differ statistically by Tukey’s test at 5% probability. Source: authors.

Changes in the texture attributes of muffins were also reported by Loncar et al. (2022), who concluded that the percentage addition of apple powder (10 to 30%) decreases the hardness and elasticity of muffin samples. According to Younas et al. (2015), variations in the texture of bakery products directly affect consumer acceptance or rejection, with hardness being the main texture
parameter for muffin acceptance. Thus, the lower hardness values reveal an advantage in the texture profile of the muffins produced with the flour rambutan and pororoca peels compared to the standard formulation (Table 4).

### 3.2 CHEMICAL ANALYSIS

The proximate composition of the muffins is presented in Table 5, which lists the muffins’ ash content, crude protein content, lipids, crude fiber content, and carbohydrates. The results showed that the muffins made with fruit-peel flour had significantly higher lipid and crude fiber content than the standard formulation.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ash</th>
<th>Lipids</th>
<th>Crude protein</th>
<th>Crude fiber</th>
<th>Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>1.45a</td>
<td>4.35d</td>
<td>7.58a</td>
<td>3.30d</td>
<td>83.31</td>
</tr>
<tr>
<td>2.5%</td>
<td>1.56ª</td>
<td>4.54c</td>
<td>7.72ª</td>
<td>3.52c</td>
<td>82.65</td>
</tr>
<tr>
<td>5.0%</td>
<td>1.57ª</td>
<td>4.89b</td>
<td>8.02ª</td>
<td>3.82b</td>
<td>81.70</td>
</tr>
<tr>
<td>7.5%</td>
<td>1.59a</td>
<td>4.91ª</td>
<td>7.91ª</td>
<td>3.93a</td>
<td>81.66</td>
</tr>
</tbody>
</table>

1Level of substitution of wheat flour by the mixture in the same proportions of flour made from rambutan and pororoca peels. 2Means followed by the same letter in the same column do not differ statistically by Tukey’s test at 5% probability. Source: authors.

Various studies have also shown that using vegetable peels in foods increases fiber and lipid content. Becker and Krüger (2010) prepared and characterized cereal bars made with flour from various vegetable residues, including passion fruit, pumpkin seeds, and peel, and also evidenced higher fiber content. Anjos et al. (2017) evaluated bread elaborated with flour from pumpkin seeds and peels and found that these wastes increased the fiber, protein, and lipid content.

Fiber is considered the primary component of fruits, cereals, and vegetables, and this has led these foods to be included in the category of functional foods because their consumption within a balanced diet can reduce the risks of certain diseases. Dietary fiber intake has been associated with health
maintenance and prevention of certain diseases, such as coronary heart disease and certain types of cancer (Mauro et al. 2010).

According to Silva et al. (2020), consumers’ increasing demand for foods beneficial to health has been accompanied by a growing demand for processes that generate the lowest possible volume of solid waste or enable their use. In this context, food processing waste used as a source of fiber in food, together with the growing group of foods known as functional foods that benefit human health, is an exciting alternative with great potential for expansion.

3.3 SENSORY ANALYSIS

The 2.5 and 5.0% of fruit-peel flour muffins obtained higher scores than the standard formulation in all sensory parameters (color, odor, flavor, texture, and overall appearance). Among these treatments, the formulation with a 2.5% replacement of wheat flour with fruit-peel flour obtained the best sensory scores, according to the judges, except for odor.

Figure 1. Sensory analysis of muffins prepared with different substitution levels (0, 2.5, 5.0, and 7.5%) of wheat flour by mixing the same proportions from rambutan and pororoca peels. Mean scores of 50 judges on a seven-point hedonic scale.

Source: authors.
Figure 1 illustrates that, except for the texture of the standard sample, all other evaluations obtained average scores between “I slightly liked it” (5) and “I liked it very much” (7). The lower sensory evaluation of the texture of the standard formulation is possibly due to the higher hardness value presented by this sample in the texturometer analysis since hardness is a crucial factor in muffins’ sensory acceptance (Younas et al., 2015). Figure 2 shows the results of the evaluation of purchase intention for the muffins and shows that the 2.5% formulation of wheat flour substitution by fruit-peel flour was the best-evaluated sample.

Figure 2. Purchase intention for the muffins made with flour from rambutan and pororoca peels. Mean scores of 50 judges on a five-point hedonic scale.

In a study on the potential of using tropical fruit coproducts in the preparation of new food products, Guimarães et al. (2023) listed various studies that showed the possibility of incorporating fruit peels into various bakery products while maintaining good sensory quality and contributing to increasing the functional properties and nutritional value of these foods.

4 CONCLUSIONS

Muffins produced with flour from rambutan and pororoca peels made it possible to produce a product with high nutritional value by increasing the fiber
content and lipids compared to the standard sample. In addition, the samples, including the fruit-peel flour, showed less weight loss during baking and darker coloration than the standard sample. The sample with a 2.5% substitution of wheat flour for fruit-peel flour was the best-evaluated sample in terms of sensory parameters and purchase intention. Thus, the chemical and sensory analyses showed a positive increase in the nutritional and sensory quality of the products developed.

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