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Physico-chemical and Sensory Quality of Biscuits based on Pulp and Peel of Green (banana) *Musa* spp. Flour

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ABSTRACT: Banana (*Musa* spp.) is a tropical fruit with excellent sensory characteristics in terms of aroma, flavor and texture, consumed worldwide and exploited in most tropical countries. Green banana flour is rich in flavonoids, which protect the gastric mucosa, has a high content of resistant starch, which acts in the body as a dietary fiber and thus has health benefits. The aim of this study was to assess the quality of biscuits made from banana pulp and peel flour. 5 biscuit formulations were developed with the partial replacement of wheat flour with green banana pulp and peel flour, sample (A), 100% wheat flour; (B), 10% green banana pulp flour; (C), 20% green banana pulp flour; (D), 5% green banana peel flour; (E), 10% green banana peel flour, in order to find out the physicochemical composition by determining pH by potentiometry, titratable acidity by titration, moisture content by dissection at 105ºC, ash by incineration, fat by Goldfish extraction, proteins by biuret, carbohydrates by difference calculation and calorific value by sum calculation and sensory analysis by affective methods. The data was evaluated using the RStudio 4.2.1 statistical package. No significant differences were found in terms of moisture content, lipids and calorific value. Differences were evident in the ash and protein content. The results of physico-chemical parameters shown pH ranging from 7.32 to 7.49, titratable acidity from 0.15 to 0.23%, moisture around 15.86 to 18.39 %, ash from 2.41 to 3.49 %, lipids from 1.53 to 2.34%, protein from 9.13 to 9.81%, carbohydrates from 66.83 to 69.47% and calorific value ranging from 324 to 338 Kcal. Sensory acceptance of the standard formulation was 82.22%. The results obtained show that green banana flour can be used as a partial substitute for wheat flour to produce biscuits with functional properties.

Keywords: Biscuit, banana flour, green banana peel flour, quality control.

Abbreviations: R, Yield, IP, Loss index, (GBF), Green Banana Pulp Flour; (GBPF), Green Banana Peel Flour; (WF), Wheat Flour.

INTRODUCTION

Biscuits composed of heat-moisture-treated banana flour exhibited reduced blood glucose response, glycemic index, and glycemic load owing to their content of resistant starch and slowly digestible starch. Incorporating pregelatinized banana flour into the instant porridge also enhanced its dietary fiber content, resistant starch (RS) content, and antioxidant capacity. However, further exploration of the physical modification of starch is needed, as it can preserve natural properties and enhance versatility in application (Kunyanee *et al*., 2024).

The quest to reduce the waste generated by marketing the fruit is another factor that favors the viability of business initiatives that exploit the banana industrialization process. Post- harvest losses can vary from 40 to 50 % of production. By processing the fruit, it is possible to generate many opportunities for utilization in the food industry, such as the bakery industry, the refrigeration industry, the juice industry, confectionery in general, commercial restaurants, hotels, school meals, among others. In addition, the production of flours is an alternative in the production of more stable foods with a longer shelf life (Castillo-Israel, 2015).

In the industrialization of bananas, the peels are generally discarded, serving only as animal feed. However, if properly treated, they can serve as a substrate for the production of yeasts and other ferments, as well as being an excellent product for making sweets and flour (Carvalho, 2015).

In a mixture of wheat flour and unripe banana flour, the added banana flour competes with wheat flour for available water. Due to its higher affinity for water, unripe banana flour can be argued to hydrate rapidly, leaving less water available for gluten proteins in wheat flour. This faster initial absorption can create a shorter hydration time. Consequently, additional time and effort may be required to achieve the ideal consistency of the dough (Bashmil *et al.,* 2025).

Banana peels, whether in a ripe or unripe state, can contribute to the improved nutritional and physicochemical characteristics of diverse food products, including baked goods, noodles, jellies, and meat items. Banana peels have higher nutrient content than pulp, including protein, fat, fiber, and other essential nutrients. Using them in food preparation can result in products with exceptional functionalities (Ismail *et al*., 2024).

The production of green banana flour (GBF) has a wide application in the food industry, mainly in the preparation of bakery products, dietary products and children's foods, as it is a source of resistant starch and mineral salts such as potassium, calcium, iron, magnesium and sulphur. In addition to the nutritional benefits, the production of GBF helps to reduce post-harvest losses, increase shelf life and add value to the fruit (Bezerra *et al.,* 2013).

The production of green banana flour (GBF) has garnered considerable attention due to its potential application in the food industry. This is attributed to its high content of resistant starch and bio-accessible phenolic compounds, which have the potential to inhibit starch digestion and subsequent intestinal glucose absorption. These attributes may contribute to the regulation of glucose homeostasis, reduced energy consumption, and increased satiety. Consequently, the low glycemic index of GBF demonstrates promise for nutritional intervention in diabetes mellitus and obesity (Martin Lorenzo *et al.*, 2024).

Many confectionery products are used as vehicles for incorporating nutrients and bioactive compounds. Among these, biscuits stand out due to the technological facilities they provide by allowing a wide variety of ingredients and formulations, as well as great flexibility in terms of raw materials and final product characteristics (Fortes *et al.,* 2020).

Pulp and peel flours can be derived from unripe bananas; however, GBPF is the most commonly utilized green banana flour for food applications, thus attracting substantial interest in the food industry primarily for its high concentrations of resistant starch and functional properties, such as thickening. Green banana peel flour (GBPF) is rich in minerals, bioactive compounds, and dietary fiber, yet it remains under-researched and underutilized (Viana *et al.*, 2024).

Green bananas have been extensively exploited as flour but there are numerous opportunities for studies on GBB, which indicates a current and relevant issue that has not been published in terms of review yet. Thus, moving from these considerations, this study presents an overview of the research carried out on GBB application as a food ingredient, providing in-depth information for a worthwhile discussion regarding the insights on recent trends and future perspectives (Oliveira *et al.*, 2024).

Although they are not a staple food like bread, biscuits are consumed and accepted by people of all ages. Their long shelf life allows them to be produced in large quantities and distributed widely. Partially replacing wheat flour with green banana and banana peel flour can contribute to consumer wellbeing due to the probiotic benefits of green bananas. Therefore, the production and physico-chemical constitutional characterization and sensory quality of biscuits made from green banana pulp and peel flour will be carried out, with a view to diversifying gluten-free functional products (probiotics) and minimizing post-harvest losses.

MATERIALS AND METHODS

According to Mae (2014), Chókwè district is located in the south of Gaza province, on the middle course of the Limpopo River. To the north it is bordered by the Limpopo River, which separates it from the districts of Massingir, Mabalane and Guijá, to the south by the district of Bilene and the Mazimuchope River through the districts of Bilene, Chibuto and Xai-Xai, to the east by the districts of Bilene and Chibuto and to the west by the districts of Magude and Massingir.

Purchase of raw materials. The bananas were bought from local producers in Chókwè city and packed in plastic bags. Wheat flour, salt, sugar and biological yeast were purchased from the Limpopo supermarket and sent to the food processing laboratory at the Higher Polytechnic Institute of Gaza.

Production stages for flour from green bananas and banana peel

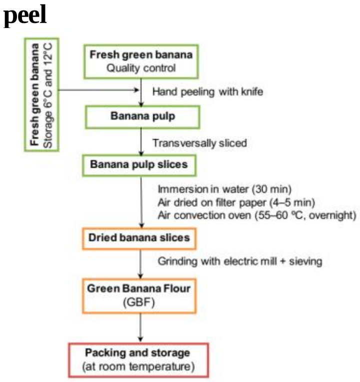


Fig. 1. Flowchart for obtaining flours of pulp and peel of green banana.

Source: Martin Lorenzo *et al.* (2024).

The bananas were cleaned in stainless steel basins by immersing them in chlorinated water (50 ml of chlorine concentration per 5 liters of water) for 10 minutes to clean them, to remove residues and reduce the microbial flora. They were then washed under running water and weighed on an analytical balance (ADAM Nimbus®). The bananas were peeled manually using a knife and then immersed in a 5.0 g/L citric acid solution for 3 minutes in order to delay enzymatic browning. This process was carried out manually with the aid of a knife, cutting it crosswise into slices in order to facilitate the dehydration process and then placed on stainless steel trays and taken to the oven to dry. After cutting the bananas into slices, they were placed on stainless steel grids and either dehydrated or dried in an oven (Eco Therm) at 55ºC for 24 hours. After the dehydration stage, the bananas were removed from the oven and cooled to room temperature. The dehydrated slices were crushed and sieved through a 3 mm mesh sieve and weighed to calculate the yield of the product obtained. After weighing, the banana flour was packed in glass containers and stored at room temperature for the analyses and production of banana flour enriched biscuits.

Yield of flour from banana pulp and peel. The yield of flour obtained was determined according to equation 1 below

$$R = \frac{F}{P} \times 100$$

Where
R- Yield (%);
F- Amount of flour obtained (g);
P- Amount of banana pulp (g).

Production of the biscuits. The production of biscuit followed several stages shown in Table 1.

Table 1: Formulations for obtaining biscuits based on banana pulp and peel flour.

Ingredients (%)	Forms				
	A	B	C	D	E
Wheat flour	100	90	80	95	90
Green banana pulp flour	0	10	20	0	0
Green banana peel flour	0	0	0	5	10
Sodium chloride	1	1	1	1	1
Dry yeast	4	4	4	4	4
Sugar	10	10	10	10	10
Butter	20	20	20	20	20
Egg	5	5	5	5	5

Preparation of biscuits based on banana pulp and peel flour green. The Fig. 2 show the production of biscuit based in pulp and peel of green banana.

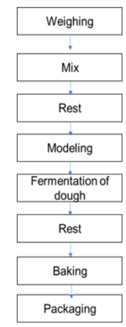


Fig. 2. Shows the flowchart used in the production of banana flour biscuits.

The ingredients were weighed on an ADAM Nimbus® scale and the butter and eggs were homogenized in a bowl. Wheat flour, green banana pulp and peel, sugar, yeast and salt were added and slowly homogenized. Once the dough was homogeneous, standard biscuit molds were made, placed on baking trays and baked in a preheated oven at 180°C for 45 minutes. After this period, the biscuits were removed from the oven, allowed to cool to room temperature and packaged in glass containers duly labelled according to the respective formulations. Once this process was complete, the jars containing the biscuits were stored in a dry place at room temperature.

Physicochemical analyses. The physicochemical quality of the formulations produced was assessed in terms of the following parameters: moisture, ash, fat, protein and carbohydrates. The analyses were carried out in triplicate using the methods recommended by the Analytical Standards of the Lutz Adolfo Institute (2008); Silva *et al.* (2020).

Moisture. Moisture content was determined using the heat gravimetric method. To do this, 5 grams of the sample were weighed into petri dishes and placed in an oven with circulating air at 105 ºC for 2 hours, after which they were removed with tweezers, allowed to cool to room temperature and weighed again. Equation 1 for determining the percentage of moisture is shown below

$$\text{Moisture} = \frac{(\text{Weight of plate} + \text{sample}) - \text{Final weight}}{\text{Weight of sample}} \times 100$$

Ash determination. Ash determination was carried out by weighing 5 grams of the sample in porcelain crucibles on an analytical balance, after which they were carbonized on a hotplate, then placed in a muffle furnace at 550°C for 4 hours using tweezers until complete incineration was verified. The crucibles containing the ash were transferred to an oven at 105ºC for 30 minutes to lower the temperature, followed by weighing them with the incinerated sample in inorganic matter. Equation 2 for determining the percentage of incinerated residue is shown below

$$\text{Ash} = \frac{(\text{Wecrucible} + \text{incinerated sample}) - \text{cucible weight}}{\text{Weight of sample}} \times 100$$

Fat determination. The fat content was determined using the Gofdfish method, which is based on the direct extraction of fat from the sample by heating it with petroleum ether in a continuous flow with a hot solvent under initially washed metal capsules, which were then placed in an oven for 1 hour and then dried at room temperature. 5 g of the sample was weighed out on tryptic filter paper and placed inside a basket inserted into a capsule (reboiler) containing the petroleum ether solvent. The samples were then rebolted in the goldfish apparatus to extract the fat by heating at a temperature of 50ºC for 4 hours and the reboilers were dried in an oven at 105ºC for 30 minutes and then weighed.

$$\text{Fat content} = \frac{(\text{Weight of plate} + \text{sample}) - \text{Final weight}}{\text{Weight of sample}} \times 100$$

Determination of protein content. Protein determination was carried out using the Biuret method, where the extracts were prepared in the proportion of 10 g of the sample to 90 ml of distilled water, mixed with 200 ml of Biuret reagent and left in a dark place for 30 minutes to give a purple complex color, followed by an absorbance reading at 540 nm on a spectrophotometer previously calibrated with distilled water. The protein content of the samples was determined by extrapolation using a calibration curve made up of casein in proportions of 0 to 10 mg/ml.

Determination of pH. The pH was determined using electrometric procedures involving potentiometric apparatus, making it possible to determine the pH directly using a pH meter, where 5g of the sample was weighed into a 50ml flask and 25ml of distilled water was added, followed by potentiometric titration by immersing the pH meter electrode.

Determination of acid content. Titratable acidity was determined using the titrimetric method, which consists of titrating the sample with NaOH (0.1 N) in the presence of the phenolphthalein indicator. 5 ml of the sample, 50 ml of distilled water and 3 drops of phenolphthalein indicator were placed in an erlernmeyer flask and the titration was carried out until a light pink color appeared. Total acidity was calculated using equation 4.

$$\text{Titrable acidity } \frac{V \times N \times F \times M}{P} \times 100$$

Where:

V - Volume of NaOH used in the titration;

N - Normality of the NaOH solution;

f - Sodium hydroxide correction factor;

F - Alkali factor = 0.064 for citric acid;

P - Sample weight in ml.

Determination of carbohydrates. Carbohydrates were determined by difference calculation, the principle of which consists of adding the percentages of moisture, fat, ash and protein in 100 g of the sample and subtracting the maximum percentage (100%), as shown in equation 5.

Carbohydrates (%) = 100-(%moisture +%fat + %protein+ %ash)

Determining calorific value. The calorific or energy value of the samples was determined using the sum calculation method, using the factors: 4 for proteins and carbohydrates and 9 for lipids, as shown in equation 6.

Caloric value = lipids × 9 + carbohydrates + proteins × 4

Sensory evaluation. In the sensory test, the affective method (acceptance test) was applied using a structured 9- point hedonic scale anchored with verbal terms at the extremes I disliked it very much (1) and I liked it very much (9). Fifty untrained tasters were recruited, randomly selected from the Higher Polytechnic Institute of Gaza, where they evaluated the acceptance of the products in terms of taste, aroma, appearance and conducted in a study environment in individual booths at room temperature in a room free from unwanted odors and noise.

The Acceptability Index (AI) was calculated by taking the maximum score achieved by the product analyzed as 100% and the average score in % as AI, and products with AI equal to or greater than 70% were considered acceptable. Equation 7 for determining the acceptability index percentage is shown below.

$$\frac{A}{B} \times 100\,\% = \%\text{ acceptance index}$$

Where

A - Average score obtained for the product;

B - Maximum score given to the product.

Statistical analysis. The data analysis was based on the Randomized Block Design (RBD) for 5 treatments in triplicates, where sample A being (100% wheat flour), B (10% green banana pulp flour), C (20% green banana pulp flour), D (5% green banana peel flour) and E (10% green banana peel flour). The data was subjected to analysis of variance (ANOVA), in cases of significant effects the means of the experimental units were determined using the Tukey test at a significance level of 5%, using the Rstudio 4.2.1.

RESULTS AND DISCUSSION

Yield of green banana pulp and peel flour. The processing yields for green banana flour and peel, as well as the loss rate for each stage, are shown in Table 2. The green banana pulp and peel selection stage had a loss rate of 55%, which was related to peeling and removing damaged parts of the banana. The drying stage is related to the loss of water in the product through the oven dehydration process, although this loss is negligible, the removal of water means that the food is preserved for longer and the absence of free water also means that undesirable microorganisms are extinguished. In the grinding stage, the loss (0.032%) is related to the ability of the fibers present in the green banana pulp flour to absorb water and also due to losses resulting from the grinding itself.

Table 2: Yield (R) and loss index (IP) of green banana pulp and peel flour.

Raw materials	Stage	Mass (kg)	Losses (kg)	IP (%)	R (%)
Pulp	Raw materials	5.072	-	-	-
	Select/drop	2.272	2.8	55.20	-
	Drying	0.688	1.584	-	-
	Crushing	0.656	0.032	4.8	28.8
	Peeling	1.806	-	-	-
Bark	Drying	0.230	1.576	-	-
	Crushing	0.190	0.04	2.21	10.52

R - Yield; IP - Loss index.

The yields of green banana pulp flour and green banana peel flour were 28.8% and 10.5%, respectively. These values are relatively acceptable when compared to the results found by Júnior *et al.* (2023a) when carrying out the physicochemical and sensory characterization of bread based on green banana flour (*Musa* spp.). obtained yields of around 29.5%. Vargas *et al*. (2012) studying the physicochemical composition of banana peel and pulp flour reported a yield of 11.15% for the peel and 30.87% for the pulp, ranges of values close to those found in this study. Bertolini *et al.* (2010), studying the pulp and peel of the Nanicão variety of green banana, dried in an oven at 42°C for 72 hours, obtained a yield of 28.5% for the pulp and 12.2% for the peel, these values being close to those found in this study. These values may vary according to the processing used (mechanical or manual), with manual processes causing greater losses.

Physicochemical composition of flours. The results obtained in relation to the chemical composition of green banana pulp flour (GBF), green banana peel flour (GBPF) and wheat flour (WT) are shown in Table 3.

Table 3: Composition of wheat flour and flour based on green banana pulp and peel (100g).

Parameters	Flour		
	GBF	GBPF	WT
Moisture	11.36±0.03^{a}	8.26±0.05^{c}	9.70±0.10^{b}
Ashes	2.71±0.01^{b}	6.42±0.02^{a}	0.77±0.01^{c}
pH	5.72±0.03^{a}	5.47±0.46^{ab}	4.91±0.01^{b}
Fat	2.66±0.02^{a}	1.53±0.15^{c}	2.35±0.01^{a}
Protein	4.92±0.02^{c}	5.36±0.02^{b}	7.57±0.02^{a}
Acidity	0.13±0.01^{b}	0.14±0.01^{b}	0.21±0.01^{a}
Carbohydrates	78.10±0.10^{b}	78.36±0.25^{b}	79.29±0.25^{a}
Calorific Value	356.00±1.00^{b}	348.36±0.40^{c}	369.23±0.25^{a}

Means ± standard deviation followed by the same letter in the same column do not differ significantly from each other at the 5% significance level. (GBF), Green banana pulp flour; (GBPF), Green banana peel flour; (WT), Wheat flour.

With regard to moisture content, the following values were found: for green banana peel flour 8.26%, wheat flour 9.70% and green banana pulp flour 11.36%, these values differed statistically at a significance level of 5%. The highest moisture content was observed in green banana pulp flour and the lowest in green banana peel flour.

Results according to those obtained in this study was found by Sawant *et al*. (2023), around 9.5%, when developed of cookies from banana (*Musa* spp.) flour.

Lower results were reported by Munir *et al*. (2024), studying green banana resistant starch: A promising potential as functional ingredient, reported moisture content ranging from 3.75 to 6.51%.

Castro (2019), studying the production of gluten-free cookies using green banana flour, obtained 10.48% of moisture, result proxime of this study.

Higher values were found by Silva *et al.* (2020) studying green banana peel flour, cv. Prata, dried in an oven for 36 hours, when mentioning 12.5% moisture. This difference is due to the drying methods used for green banana pulp and peel flour.

In relation to the fixed mineral residue (ash), the results for wheat flour, green banana pulp flour and green banana peel flour were 0.77, 2.71 and 6.41%, respectively, and these values differed statistically from each other at a 5% significance level.

Results in line with this research was related by Sawant *et al.* (2023) in his study about development of cookies from banana (*Musa* spp.) flour, obtained ashes of 3.45%.

Vargas *et al.* (2012) studied the physicochemical composition of green banana peel and pulp flour, analyzing banana flour and banana peel flour and found 3.03% and 6.88% very close to those found in this study.

Lower result was reported by Ngaha *et al.* (2023), when formulated low glycaemic index biscuits suitable for diabetics from banana, found 0.9% of ashes. According to Arquelau (2018), fruit peels have a high mineral content and their cell walls have a high fiber content, justifying their greater presence when compared to fruit pulp.

The average pH recorded for banana pulp flour was 5.77, green banana peel flour was 5.77, and wheat flour was 4.49. This behavior ratifies some studies carried out, such as the study carried out by Andrade (2018) in which he obtained a pH of 5.67 for green banana pulp flour, 5.76 for green banana peel flour, and 6.09 for wheat flour. Similarly, *Vasundhara et al.* (2021), analyzing the proximate Composition of Banana fruit Peel of Varieties Grand Naine (AAA), Rajapuri (AAB) and Ney Poovan (AB) at different stages of Ripening, reported pH from 5.63 to 5.91 in the banana peel of banana flour.

These values are higher than those found by Miri (2020) who in his study reported pH values of around 4.04 for pineapple flour and 5.18 for green banana flour.

The acidic pH favors the preservation of the final product, as it does not allow the proliferation of microorganisms in pH ranges below neutrality.

The acidic pH favors the preservation of the final product, as it does not allow the proliferation of microorganisms in pH ranges below neutrality.

The values found were 0.14% for banana pulp flour, 0.16% for banana peel flour and 0.23% for wheat flour, which differed statistically from each other. Miri (2020) reported values of 3.56% for pineapple flour and 0.65% for green banana flour. Mydhili *et al*. (2022), when evaluate proximate composition of different varieties of banana pseudostem powder for nutritional and biochemical properties, found titrable acidity ranged from 0.018 to 0.072%.

In terms of fat content, the values found were 2.69% for wheat flour, 1.5% for green banana peel flour and 2.36% for green banana pulp flour. These values differed statistically at a significance level of 5%. Wheat flour had the highest fat concentrations, while banana peel flour had the lowest. Higher values were obtained by Lion and Yanaze (2018) who, in a study on obtaining and characterizing flour from green and ripe banana peels, found 6.52% and by Vargas *et al.* (2012) the values found for fat content in peel and pulp flours were 8.13%. Lower results were reported by Andrade *et al.* (2018) who, in their study on the production of green banana flour (*Musa* spp.) for use in whole meal wheat bread, found a value of 0.3%.

The protein content of pulp flour was 4.91%, of green banana peel flour 5.38% and of wheat flour 7.59%, so the protein content found in wheat flour is much higher than that of pulp and peel flour. The values found in this study are higher than those reported by Borges *et al.* (2009) who reported a value of 4.50% of GBPF. Vargas *et al.* (2012) reported a protein content of 5.09% for the peel flour and 3.04% for the pulp flour, these values differing from those found in this study. Mydhili *et al.* (2022), when evaluate proximate composition of different varieties of banana pseudostem powder for nutritional and biochemical properties, related 5.0%, and Júnior *et al.* (2023b) found protein ranging from 5.99 to 7.09%, in his study aimed to evaluate the quality of fortified *zea mays* L (maize) and triticum durum (wheat) flours.

Martín Lorenzo *et al.* (2024), obtained protein content of 5.36, in his study about physicochemical and Nutritional Characterization of Green Banana Flour from Discarded Cavendish Bananas.

The carbohydrate value obtained from the pulp flour was 78.2%, from the banana peel flour 78.4%, and from the wheat flour 79.47%. These values differed statistically from each other. Respectively, these values are higher than those reported by Vargas *et al.* (2012), who found a value of 75.13% in green banana pulp flour and 88.13% in banana peel flour and similar to those reported by Oliveira *et al.* (2013) in his study on the preparation and characterization of sweet biscuits produced with pacovã banana peel flour (*musa paradisiaca)* obtained a value of 88.1%, and lower than those reported by Franco (2016) who obtained values of around 75.2%, 73.71%, 44.24% of FT, FPBV, FCBV.

Lower results than those obtained in this study were reported by Mydhili *et al.* (2022), when evaluate proximate composition of different varieties of banana pseudostem powder for nutritional and biochemical properties, 20.5 to 38.8%.

The calorific value found for the pulp flour was 357 Kcal, for the banana peel flour 348.8 Kcal and for the wheat flour 369.5. Oliveira *et al.* (2013) reported values 468.05 Kcal higher than those found in this study. However, Borges *et al.* (2009) found an average calorific value of 373 Kcal for green banana flour, close to that found in this study.

Centesimal composition of the biscuits. The centesimal composition of the biscuits made by partially replacing wheat flour with green banana peel and pulp flour in different concentrations is shown in Table 4.

Table 4: Physicochemical characteristics of biscuits produced with different concentrations of green banana pulp flour and green banana peel flour (100g).

Parameters	Formulations				
	A	B	C	D	E
Moisture	15,86±0,03[d]	16,55±0,08[c]	18,39±0,06[a]	17,65±0,14[b]	17,63±0,45[b]
Ashes	2,41±0,10[c]	2,48±0,40[c]	2.65±0.12[bc]	3.30±0.51[ab]	3,49±0,18[a]
pH	7,49±0,01[a]	7.46±0.08[ab]	7,32±0,02[b]	7.46±0.07[ab]	7,49±0,04[a]
Lipids	2,30±0,01[a]	2,26±0,00[a]	2,34±0,01[a]	1,53±0,11[c]	1,82±0,02[b]
Protein	9.54±0.03[bc]	9,13±0,05[d]	9,41±0,00[c]	9.69±0.10[ab]	9,81±0,01[a]
Acidity	0,15±0,00[c]	0,14±0,01[c]	0,20±0,00[b]	0.22±0.01[ab]	0,23±0,00[a]
Carbohydrate	69,47±0,01[a]	69,10±0,01[b]	66,84±0,04[d]	68,46±0,05[c]	66,83±0,11[d]
Calorific value	338,13±0,05[a]	334,64±2,90[a]	326,16±0,20[b]	326,43±0,35[b]	324,06±2,72[b]

Means ± standard deviation followed by the same letter on the same line do not differ significantly from each other at the 5% significance level. (A), 100% wheat flour; (B), 90% wheat flour and 10% green banana pulp flour; (C), 80% wheat flour and 20% green banana pulp flour; (D), 95% wheat flour and 5% green banana peel flour; (E), 90% wheat flour and 10% green banana peel flour.

Moisture content. The results ranged from 15.86 to 18.39 % moisture. It was clear that the incorporation of green banana pulp and peel flour had a direct effect on increasing the moisture content of the biscuits produced. Formulation A obtained a moisture content of 15.86%, B 16.55%, formulation C around 18.39%, D 17.65% and E around 17.63%. Of the formulations developed, the standard formulation had the lowest moisture content and formulation C had the highest moisture content. According to Andrade *et al.* (2018), the addition of green banana flour results in greater water absorption. On the other hand, this differentiation may be correlated with the hydrophilic capacity of banana constituents, inferring greater retention of water molecules.

Lower results than those found in this study were reported by Silva *et al.* (2020) when they obtained moisture of around 2.60 to 2.80 in their research on biscuits produced with banana flour: chemical, physical and sensory evaluations, by Oliveira *et al.* (2013), in their study aimed at preparing and characterizing biscuits and sweets based on pacovã banana peel flour (*Musa paradisiaca*), they obtained 4.01% moisture, by Castro (2019), in his study on the production of gluten-free cookies using green banana flour and rice flour, reported moisture content of 11.90%, also Ranawati *et al.* (2023), found moisture ranging from 5.27 to 5.72%, when evaluating biscuits from a combination of banana flour. These differences can be justified by the variety of banana used in the production of these products, as well as the hydrolytic capacity of proteins, starch and lipids promoting the repulsion of water molecules.

Ash content. The results obtained showed a variation of between 2.41 and 3.49 %. The ash content increased with the addition of green banana pulp and peel flour, which led to an increase in the ash concentration due to the higher concentration of minerals in these flours. The lowest ash content was observed in formulation A with 2.41%. The highest ash content was evident in formulation E with 3.49%, followed by formulations B, C and D with 2.48, 2.65 and 3.30%, respectively. Statistically, the treatments (A, B and C) did not differ significantly ($p>0.05$) from one another. Significant differences ($p<0.05$) were found between treatments (A and C).

Ngaha *et al.* (2023), when formulated low glycaemic index biscuits suitable for diabetics from banana, found 0.9% of ashes, obtained 2.4 to 2.6% of ashes, results according to those obtained in this study.

Lower results than those obtained in the present study were reported by Neris *et al.* (2018) in their study on biscuits produced with banana flour: chemical, physical and sensory evaluations, in which they obtained 1.51% of incinerated.

Oliveira *et al.* (2013) described in their study on the preparation and characterization of sweet biscuits produced with pacovã banana peel flour (*Musa paradisiaca*), that the results of inorganic matter were 3% ash in the formulation added with 10% green banana peel flour, 3.5% ash for the formulation added with 20% banana peel flour, 3.9% ash for the formulation composed of 30% green banana flour, results above those found in the present study

Carvalho *et al.* (2019), in their study on banana cake with oligosaccharide fruit, obtained ash contents in the range of 45.7% in the formulation of 58% wheat flour and 42% banana flour, 42.11% ash content in the formulation of 57% wheat flour and 37% green banana flour and 42.71% in the formulation of 50% wheat flour and 50% green banana flour, these higher Values than those found in this study.

pH. The results obtained showed a variation of between 7.32 and 7.49. The highest percentage pH values were found in formulations A and E, followed by formulations B, D and C, respectively. Statistically, the formulations (A, B, D and E) did not differ significantly ($p>0.05$) from one another. A significant difference ($p<0.05$) was seen in formulation C.

In the study carried out by Andrade (2013), with the aim of evaluating biscuits enriched with green banana flour, he obtained pH values in the range of 6.05 to 7.05, which is close to those obtained in this research.

In the study carried out by Miri (2020), on the development of cake mixes with the addition of green banana flour (*Musa spp*), acidity was obtained in the range of 6.95 in the 100% pineapple peel flour formulation, 7.83 in the 100% banana flour formulation.

Fat. In terms of fat content, the results showed that there was a significant difference ($p>0.05$) between the two formulations. 0.05) between them, with formulations A, B and C having a higher fat content of around 2.30 % in treatment A, 2.26 % in treatment B and 2.35 % in treatment C compared to formulations (D and E) which had a lower fat content of 1.53 % and 1.82 %, respectively. This variation is possibly due to the fact that banana peel flour has a low lipid content in its constitution, with 1.5 % fat, while green banana pulp flour and wheat flour have a fat content of around 2.69 % and 2.36 %, respectively,5 % fat, while the green banana pulp and wheat flour have lipid contents of around 2.69 and 2.36 %, factors that influence the differences obtained in the fat content of the biscuits produced.

In the evaluation carried out by Oliveira *et al.* (2013), in their study on the preparation and characterization of sweet biscuits produced with pacovã banana peel flour (*Musa paradisiaca*), they obtained a lipid content of around 17% for the formulation produced with the incorporation of 10% green banana peel flour, 19% lipids in the formulation incorporated with 20% green banana peel flour and 20% in the formulation with the incorporation of 30% green banana peel flour.

In the evaluation carried out by Castro (2019) in his study on the production of gluten-free cookies using green banana flour and rice flour, he revealed that the lipid content found for biscuits incorporating 50% green banana flour and 50% rice flour was 11.65%, for the formulation of 70% green banana flour and 30% rice flour was 11.3%, and the formulation with 100% green banana flour was 9.19%, lower results than those obtained in the present study.

Protein content. The results show that the protein content of the formulations varied from 9.13 to 9.81 %, with the formulation containing 20 % GBPF having the highest average and the formulation containing 10 % FPBV having the lowest average. According to Ormenese (2010), this variation is possibly related to the fact that green banana flour (GBF) has a lower protein content than wheat flour (WT). Statistically, the formulations (D and E) did not differ significantly ($p>0.05$) from each other. Significant differences ($p<0.05$) were seen in formulations A, B and C in relation to the others.

In their study, Fasolin *et al.* (2007) obtained 7.61% protein in the wheat flour formulation, subsequently finding 6.77% for the formulation produced with the addition of 10% banana pulp flour and 19.07% protein for the formulation incorporating 20% banana pulp flour, results higher than those obtained in the present study. Andrade (2018), reporting in his study with the aim of producing green banana flour (*Musa* spp.) for application in whole meal wheat bread with the addition of green banana flour (GBF) at 10, 15 and 20%, obtained results around 11.3, 10.9 and 10.1% protein, respectively, ranges of values above those found in this study.

Lower values ranges than those reported in this study were reported by Oliveira *et al.* (2013), who found protein of 1.13, 3.7 and 4.1 %, respectively, in biscuits containing 10, 20 and 30 % green banana peel flour. In the same vein, Bassetto *et al.* (2013) in his study on the use of beetroot waste in biscuit production obtained a protein concentration of 7.14%.

In the evaluation carried out by Castro (2019) in his study on the production of gluten-free cookies using green banana flour and rice flour, he reported protein of 6.44% in the formulation of 50% green banana flour and 50% rice flour, 5.03% protein in the formulation of 70% green banana flour and 30% rice flour and 4.89% protein in the formulation administered with 100% green banana flour, ranges of values relatively lower than those found in this study.

Acidity. The acidity showed results ranging from 0.15 to 0.23 % in the formulations. Values in agreement with those reported in this study were found by Andrade (2013), who mentioned titratable acidity of 0.20% in the formulation with 10% green banana pulp flour, 0.24 % in the formulation with 20% green banana pulp flour and 0.17% in the formulation with 30% green banana pulp flour.

In the assessment carried out by Miri (2020), on the development of cake mixes with the addition of pineapple peel flour (*Ananas comuns* L. *merril*) and green banana flour (*Musa* spp), the acidity obtained was 1.42 milligrams per square metre in the 100% pineapple peel flour formulation, 0.34 milligrams per square metre in the 100% banana flour formulation and 0.87 milligrams per square metre in the 50% formulation. The presence of low acidity can influence the delay in the development of microorganisms (Aquino, 2010).

Carbohydrates. With regard to carbonates, the values found in the formulations for this parameter ranged from 66.83 to 69.47 %, with formulation A standing out with the highest percentage (69.47 %) followed by formulation B (69.10 %). Statistically, there were significant differences ($p>0.05$) between the two.

In the research carried out by Oliveira *et al.* (2013), in their study on the preparation and characterization of sweet biscuits produced with pacovã banana peel flour, they found 88.7%, 77.3% and 75.6% protein in the biscuit (10, 20 and 30%) made with green banana peel flour, respectively, a range of values comparatively higher than those found in this study. Still in the same strain, Andrade *et al.* (2018) in their study on the production of green banana flour (*Musa spp.)* for use in whole meal wheat bread with the addition of 10%, 15% and 20% green banana pulp flour obtained results of around 83.0%, 83.3% and 83.9% carbohydrates, respectively. Carvalho *et al.* (2019), in their study on banana cake with fructooligosaccharide, obtained carbohydrate contents in the range of 78.6% in the formulation of 58% wheat flour and 42% banana flour, 77.25% carbohydrate in the formulation of 57% wheat flour and 37% green banana flour, 79.86% carbohydrate in the formulation of 50% wheat flour and 50% green banana flour.

Lower values than those mentioned in this study were found by Castro (2019), in his study on the production of gluten-free cookies using green banana flour and rice flour, when he reported 24.1% carbohydrates in the biscuit incorporating 50% GBF and 50% rice flour, 32.1% carbohydrate in the 70% GBF and 30% rice flour formulation and 23.6% carbohydrate in the 100% GBF formulation.

Calorific value. The calorific value stood out in formulation A, with the highest result (338.13 Kcal/100g) and the lowest in formulation D (324.0 Kcal). Statistical differences were recorded at 5% significance in this parameter. Increasing the concentration of pulp and peel flour to partially replace wheat flour resulted in a reduction in calorific value. It was also found that the calorific value is reduced when the wheat flour is gradually replaced by GBF and GBPF.

Higher Values than those reported in the present study were mentioned by Reis *et al.* (2018), in their study on the production of biscuits with enriched cassava starch and green banana flour, when they recorded a calorific value of 447.34 Kcal in the cassava starch formulation and 441.74 Kcal in the formulation with 50% banana flour. Carvalho *et al.* (2019), when producing cake with partial substitution of 45.7, 57.50% green banana flour reported values around 445.50 to 453.72 Kcal. Oliveira *et al.* (2013), in their study on the preparation and characterization of sweet biscuits produced with pacovã banana peel flour (Musa paradisiaca), found a calorific value of 484.82 Kcal in the 10% green banana peel flour formulation, 495 Kcal in the 20% banana peel flour formulation and 501.5 Kcal in the 30% green banana flour formulation.

Sensory analysis. Fig. 3 shows the average acceptability of the attribute's appearance, color, aroma, flavor, crunchiness, aftertaste and overall impression of each biscuit sample produced with the partial substitution of wheat flour.

Means ± standard deviation followed by the same letter on the same line do not differ significantly from each other at the 5% significance level. (A), 100% wheat flour; (B), 90% wheat flour and 10% green banana pulp flour; (C), 80% wheat flour and 20% green banana pulp flour; (D), 95% wheat flour and 5% green banana peel flour; (E), 90% wheat flour and 10% green banana peel flour.

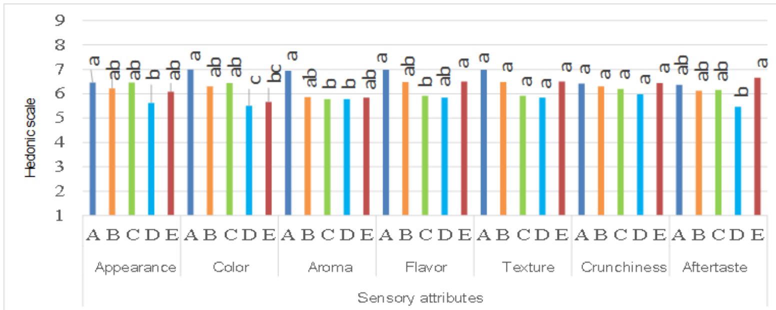


Fig. 3. Acceptance levels of the biscuit formulations made from green banana pulp and peel on a hedonic scale of 1 to 9 points.

Appearance. In terms of appearance, the results showed that treatments A and C had the highest averages of around 6.5 and treatment D had the lowest average of around 5.8, followed by a non-significant difference in the averages of treatments A, B and C of around 6.2 to 6.5. There were no statistical differences between treatments B, C, D and E, and at the significance level ($p>0.05$) formulation A differed statistically ($p<0.05$) from the other formulations.

Carvalho *et al.* (2019) in their study on the production of banana cake with oligosaccharide fruit, the cake formulation with the addition of 30% banana flour had the highest average score of 8, classified as "I liked it very much", followed by the cake formulation with the addition of 50% banana flour, which had a score of 7.5, and the formulation with 60% banana flour, which had the lowest average score of 6.9, classified on the "I liked it moderately" scale.

Andrade (2013) produced biscuits with the addition of 10, 20 and 30 % green banana flour, with the result that the biscuit with 10 % green banana flour had the highest average of 7.93 classified on the "I liked it very much" scale and the biscuit with 30 % green banana flour had the lowest average of 7.55 "I liked it moderately", similar to those found by Neris *et al*. (2018) in their study on the effect of adding linseed in the processing of cracker- type biscuits.

Silva *et al.* (2015) produced biscuits enriched with pumpkin seed flour as a source of fiber, with the formulation containing 25% pumpkin seed flour showing the highest average (7.61) on the "slightly liked" scale and the formulation containing 100% pumpkin seed flour showing the lowest average (6) on the "slightly liked" scale, similar to the results reported in this study.

Color. With regard to the color attribute, the results obtained indicated that formulation A had the highest average (7) classified as "moderately liked" and formulation D had the lowest average of around 5.66 classified as "neither liked nor disliked". Statistically, formulation A differed from formulations D and E at the significance level ($p<0.05$). The amount of pulp flour and peel flour may have influenced the tasters' scores.

According to Andrade *et al.* (2018), the higher the addition of green banana flour, the lower the scores given by the evaluators due to the darker color. Mashau *et al.* (2022), reported color score of 5.63, when studying the influence of unripe banana flour incorporation on the physical, antioxidant properties and consumer acceptability of biscuits.

in the assessment made by Neris *et al.* (2018) regarding simple cakes made with watermelon rind flour (*Citrullus vulgaris, Sobral*): chemical, physical and sensory evaluation with the highest average 4.5 classified as "I liked it slightly". Andrade (2013) elaborated biscuits produced with the addition of 10, 20 and 30% green banana flour, having found an average of 8.02, 7.85 and 7.35, respectively. Carvalho *et al.* (2019) in their study on the production of banana cake with oligosaccharide fruit with 30 and 60% in their formulations, reported averages of 7.40 and 7.20, respectively, results that differ from those found in this study.

Aroma. With regard to the aroma attribute, formulations A, B and E showed no significant difference at a significance level of ($p<0.05$), formulation A showed the highest average (6.94) and differed statistically from formulations D and E.

In the assessment made by Miri (2020) in his study on the development of cake mixes with the addition of 50% pineapple peel flour and 50% green banana flour, he obtained an average score of 7 on the "moderately liked" rating scale and the formulation with 33% pineapple peel flour, green banana flour and pineapple flour obtained an average score of 9 on the "extremely liked" rating scale. Similar results were reported by Neris *et al.* (2018) when they mentioned an average aroma score of 7.31 for the formulation with 60% green banana flour, 6.77 for the formulation without green banana flour and 6.75 for the formulation with 45% green banana flour, a range of values relatively higher than those found in this study.

Flavor. With regard to the aroma attribute, formulations A, B, C and E showed no significant difference at a significance level of ($p<0.05$), with formulation A (6.98) having the highest average.

Borges (2007), when carrying out sensory tests on cakes containing 0%, 15%, 30%, 45% and 60% green banana flour as a partial substitute for wheat flour, found no statistical difference in their flavor. This finding differs from that of the present study, demonstrating that the use of green banana flour and green banana peel significantly alters the flavor of the biscuits, presenting different characteristics to formulations B and C. This makes the use of green banana flour viable, as it makes the food more nutritious without altering this sensory attribute.

Results that are close to those mentioned in this study were reported by Andrade (2013) when he produced biscuits with the addition of 10%, 20% and 30% green banana flour, finding averages of 7.92 and 7.58 for flavor.

In agreement with the results of this study, Santucci *et al.* (2003) stated that mixing flours from non-conventional products with wheat flour improves the nutritional quality of food products, including their palatability, making them more acceptable to consumers.

Texture. Regarding the texture attribute, all the formulations did not show any significant difference at the significance level of ($p<0.05$), formulation A showed the highest average (6.98) and formulation D showed the lowest average (5.84). The use of green banana pulp flour and green banana peel flour did not significantly alter the sensory quality of the biscuits in terms of texture. It can be said that the use of green banana pulp flour and green banana peel flour does not significantly alter the sensory quality of biscuits in terms of texture.

In the evaluation carried out by Sanguinetti (2014), the texture of the standard cake scored the highest (7.46), followed by the cake with 20% green banana flour (6.90), the cake with 35% green banana flour (6.50) and the cake with 50% green banana flour. These formulations scored "I liked it moderately" and "I liked it slightly".

Carvalho *et al.* (2019) in their study on the production of banana cake with oligosaccharide fruit in terms of texture, the cake formulation with the addition of 30% banana flour had the lowest average of 6.8, followed by the cake formulation with the addition of 60% banana flour, which had 7.20, and the formulation with 50% banana flour, which had the highest average of 7.30, different from the results found in this study. Fortes *et al.* (2020) define texture as an extremely relevant factor in the quality of biscuits, as it directly affects their acceptability and intention to consume or purchase.

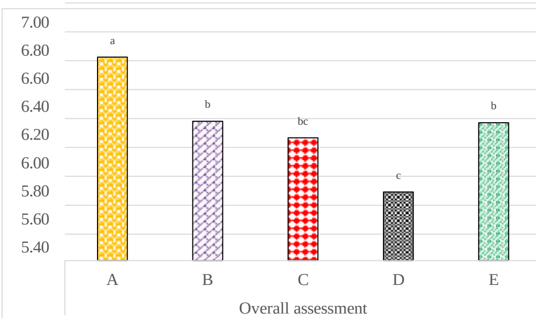
Crunchiness. With regard to the "crunchiness" attribute, all the formulations showed no statistical difference ($p>0.05$) between them, and had an average score of 6.18, corresponding to "I liked it slightly". The formulation with the highest score for this criterion was A with a score of 6.42 and D had the lowest score (6.44).

Ramos *et al.* (2018), studying the acceptability of cookie-type biscuits enriched with jatoba flour, mentioned that for the crunchiness attribute, the biscuits did not show a significant difference in the formulations made with 10% and 20% jatoba flour, agreeing with the results of this study.

In the evaluation carried out by Neris *et al.* (2018) in their study on the preparation and sensory analysis of grape pomace and oat flour biscuits, an average of 7.56 was obtained for the formulation with 70% wheat flour, 15% oats and 15% grape pomace, an average of 7.55 for the formulation with 60% wheat flour, 20% oats and 20% grape pomace and an average of 7.4 for the formulation with 50% wheat flour, 25% oats and 25% grape pomace, averages classified in the "I liked it moderately" range.

Aftertaste. In terms of flavor, the biscuits in the formulations (A, B, C and E) did not differ statistically from each other at a significance level of ($p <0.05$). Formulation D differed statistically from the other formulations: it (formulation D) had the lowest average (5.46) and formulation E had the highest average (6.66) compared to the others. Miranda *et al.* (2013) who checked the acceptability of cakes enriched with passion fruit peel flour and found a slight aftertaste.

Overall impression. Fig. 4 shows the overall impression of the biscuit formulations made from green banana peel flour and pulp flour in terms of the attributes assessed.



Means ± standard deviation followed by the same letters in the same column do not differ significantly from each other at the 5% significance level. (A), 100% wheat flour; (B), 10% green banana pulp flour; (C), 20% green banana pulp flour; (D), 5% green banana peel flour; (E), 10% green banana peel flour.

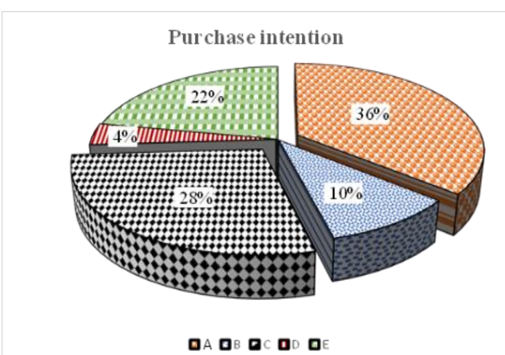
Fig. 4. Overall impression of the biscuit made from green banana peel and pulp flour.

The results of the overall assessment showed that the highest score was found for formulation A (6.73), followed by formulations B (6.25), E (6.24), C (6.13) and D (5.72), respectively, with significant differences at the level of significance ($p>0.05$). Formulation A differed statistically from the other formulations.

In the assessment carried out by Silva *et al.* (2020) regarding the overall assessment of the biscuits, the formulations were acceptable and did not differ significantly from each other.

The results described above are different to those found by Ormenese (2010) in his study on obtaining green banana flour by different drying processes and its application in food products.

Purchase intent. Fig. 5 shows the results of the intention to buy biscuits with the addition of 5% and 10% green banana peel flour, biscuits with the addition of 10% and 20% green banana pulp flour and biscuits with wheat flour biscuit.



(A), 100% wheat flour; (B), 10% green banana pulp flour; (C), 20% green banana pulp flour; (D), 5% green banana peel flour; (E), 10% green banana peel flour.

Fig. 5. Intention to buy the biscuit.

The standard biscuit obtained the highest percentage according to the tasters' evaluation, registering 36% acceptance of intention to purchase, and the lowest was seen in formulation D (4%).

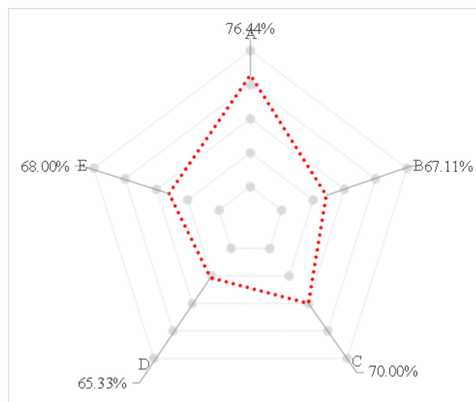
Andrade (2013) produced biscuits with the addition of 10% 20% 30% green banana flour and reported a 47% "would certainly buy" purchase intention for biscuits with 30% green banana flour, a percentage that is around the same as that found in this study.

Sachini (2011) produced biscuits based on rice flour incorporated with 20 and 30 % green banana flour, and obtained a result of "maybe would buy and maybe wouldn't buy", while the biscuit sample produced with rice flour, cinnamon and 10 % (GBF) obtained an evaluation close to "possibly would buy".

Oliveira *et al*. (2013), in his study on the preparation and characterization of sweet biscuits made with banana peel flour (*Musa paradisíaca*), produced sweet biscuits with 10% 20% 30% banana peel flour, and the sweet biscuit with an addition of 10% banana peel flour had the highest percentage of purchase intention (60%).

Castro (2019), who developed a gluten-free biscuit using green banana flour and rice flour, obtained a 49% purchase intention.

Acceptance index. The graph shows the results obtained in the acceptance test for biscuits produced with the partial replacement of wheat flour with green banana pulp and peel flour.



Means ± standard deviation followed by the same letters in the same column do not differ significantly from each other at the 5% significance level. (A), 100% wheat flour; (B), 10% green banana pulp flour; (C), 20% green banana pulp flour; (D), 5% green banana peel flour; (E), 10% green banana peel flour.

Fig. 6. Acceptance rate of the biscuit.

Based on the results obtained, formulation A had the highest acceptance rate of 76.44%, followed by formulation C with 70%, acceptance rates considered ideal because they were ≥70%. Formulations B, D and E showed values of 67.11%, 65.33% and 68% respectively, relatively low percentages of the recommended percentage (70%) for a product to be considered accepted.

Fortes *et al*. (2020) in their study of different formulations of cakes enriched with banana flour, found that the cake with 30% substitution of wheat flour by

FBV was more acceptable Silva *et al.* (2020) in their study on sensory analysis of food, reported that the acceptability index of a product must be higher than 70%, which is indicated as the minimum value for good acceptance in the consumer market.

CONCLUSIONS

The yield of banana pulp flour and green banana peel flour was 28.8% for GBF and 10.5% for GBPF. Formulations D and E did not differ statistically in terms of moisture content, ash, fat, protein, acidity, carbohydrates, pH and calorific value. Formulations A, B and C did not differ statistically in terms of fat content, but they did differ statistically in terms of the other parameters; the 10% GBPF formulation had a higher concentration of ash and protein.

The standard biscuit made with 100% wheat flour was the formulation that achieved a sensory acceptance rate of 76.44%. It is feasible to use banana pulp flour and banana peel flour since wheat flour had a low ash content compared to banana pulp flour and green banana peel flour. This difference is related to the amount of minerals present in green banana flour. It can therefore be concluded that the production of biscuits based on wheat flour and partial substitution of WT with GBPF proved to be a viable alternative for biscuit production.

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Conflict of Interest. None.

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