



Research article

Potential use of banana peel (*Musa cavendish*) as ingredient for pasta and bakery products

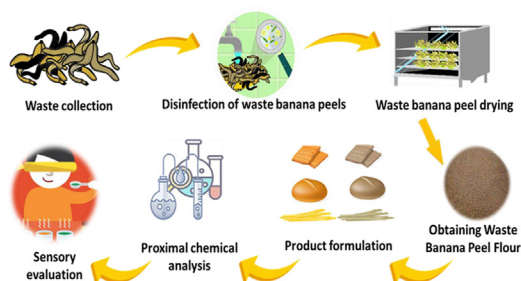
Orietta Segura-Badilla^a, Ashuin Kammar-García^b, Jeyne Mosso-Vázquez^c,
Raúl Ávila-Sosa Sánchez^c, Carlos Ochoa-Velasco^c, Paola Hernández-Carranza^c,
Addí Rhode Navarro-Cruz^{c,*}

^a Facultad de Ciencias de la Salud y de los Alimentos, Departamento de Nutrición y Salud Pública, Programa UBB Saludable, Universidad del Bío-Bío, Chile

^b Dirección de Investigación, Instituto Nacional de Geriátria, Mexico

^c Facultad de Ciencias Químicas, Departamento de Bioquímica y Alimentos, Benemérita Universidad Autónoma de Puebla, Mexico

GRAPHICAL ABSTRACT



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ABSTRACT

The consumption of fruits and vegetables involves the disposal of the inedible parts, conveying challenges such as waste management and environment pollution. In recent years, there have been multiple studies aimed at finding alternatives that reduce the negative impact of food/agricultural waste. Since most studies done with by-products recommend their careful selection, the aim of this study was to verify if discarded banana peels could be disinfected until microbiologically safe and to determine if they could still provide nutrients to formulate food products with sensory characteristics acceptable to a consumer market after disinfection. Banana peels were collected from markets, restaurants, and greengrocers. They were disinfected, dried, and pulverized to obtain a flour which was subjected to microbiological and proximal analysis. Once its microbial safety was assured, this flour was incorporated into bakery and pasta products, replacing wheat flour with 5–20% banana peel flour (BPF). The sensory evaluation of the different products was carried out and, after verifying that the products were sensory acceptable, the proximal analysis was implemented. The formulated products were suitable for the addition of BPF up to 10%, in which the Acceptability Index was higher than 80% and significant increases in fiber and fat were achieved. We conclude that waste banana peel flour can be incorporated into bread and pasta products for human consumption to provide nutrients which might contribute to reduce this type of waste and to recover nutrients from otherwise disposed banana peels.

* Corresponding author.

E-mail address: addi.navarro@correo.buap.mx (A.R. Navarro-Cruz).

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1. Introduction

The amount of organic waste from fruits and vegetables is constantly increasing, representing a problem in terms of waste disposal and environmental pollution. Organic residues can be an important source of nutrients and it has been suggested that they could be valued and used as ingredients or raw material in some production processes and to develop new products (González et al., 2015; Martínez-Fernández de Lara et al., 2017). However, most research focuses on the treatment of waste to obtain bioactive compounds, which implies additional processing that in turn generates other types of waste (Anhwange, 2008; Eshak, 2016; Castelo-Branco et al., 2017).

Bananas originated in South Asia, being known since 650 AD. Some species arrived in the Canary Islands in the fifteenth century and were introduced to America in 1516. Bananas are the largest cultivated tropical fruit in Mexico, with annual productions greater than 2 million tons/year, and all year long availability. A Mexican consumes an average of 14.2 kg of bananas per year (Secretariat of Agriculture and Rural Development, 2020). The banana from the Cavendish group—a soft and sweet banana commonly used for desserts—is the most exported and consumed product in Mexico (Sidhu and Zafar, 2018). The consumption of this fruit generates waste through its peel which constitutes approximately 30% of the weight of the fruit. The peel is rich in fiber, proteins, essential amino acids, polyunsaturated fatty acids, potassium, and phenolic compounds (Padam et al., 2014; Aboul-Enein et al., 2016; Gómez-Montañón et al., 2019).

Bananas have long been researched (Archibald, 1949) and have been found to possess considerable amounts of bioactive compounds with antioxidant and anti-inflammatory effects (Waghmare and Kurhade, 2014; Phuaklee et al., 2012; Mahloko et al., 2019), antibacterial and antifungal properties (Aboul-Enein et al., 2016; Waghmare and Kurhade, 2014; Vu et al., 2018; Loyaga-Castillo et al., 2020), and therapeutic effects (Sidhu and Zafar, 2018; Mosa and Khalil, 2015; Singh et al., 2016). Given their content of nutrients (Anhwange, 2008; Gómez-Montañón et al., 2019; Pereira and Maraschin, 2015; Ssonko and Muranga, 2020), banana peels have been used to produce cattle food (Hassan et al., 2018; Frog et al., 2018).

Prior works have reported the use of green banana peel flour or mixtures of green banana pulp paste in baked goods or chicken sausages (Eshak, 2016; Castelo-Branco et al., 2017; Zaini et al., 2020). The aim of this study was to verify if discarded banana peels could be disinfected until microbiologically safe and to determine if they could still provide nutrients to formulate food products with sensory characteristics acceptable to a consumer market after disinfection.

2. Materials and methods

2.1. Banana peels

Banana peels were sourced from local food establishments: a greengrocery, a restaurant, a juice and salad shop, and a local market in town. They were transported for disinfection and only peels with some degree of decomposition or evident microbial deterioration were discarded.

2.1.1. Banana peel flour (BPF)

Water jet washing was carried out to eliminate contaminating residues and excess dirt. Subsequently, peels were disinfected with a 200 ppm sodium hypochlorite (NaClO) solution for 30 min, after which peels were rinsed with drinking water (Ferreira et al., 2013). After cleaning and draining, banana peels were dried in a 5-tray Excalibur dehydrator (Mod. 3500 BLA, California, USA) for 24 h at 63 °C. They were subsequently ground in a Willey mill (General Electric, mod. 5MB 600B-0, New Jersey, USA) using a 20 mesh to obtain a homogeneous flour (Díaz-Vela et al., 2015).

2.2. Microbiological analysis

Evaluation of microbiological safety was investigated since banana peels that had not been disposed following specific disposal instructions. To evaluate the efficacy of the disinfection process, microbiological analysis of the banana peel flour was carried out. Samples were tested in triplicate for Mesophilic aerobic, coliforms, *Salmonella* sp., *Escherichia coli*, molds, and yeasts by the plate pour method (Official Mexican Standards 092-SSA1-1994, 113-SSA1-1994, 114-SSA1-1994, 210-SSA1-2014 and 111-SSA1-1994). The same analyses were performed on formulated foods.

2.3. Product formulation

Different products (biscuits, bread, and pasta) were prepared through traditional techniques. The formulations are shown in Table 1. The levels of BPF addition were selected according to prior works (Eshak, 2016; Castelo-Branco et al., 2017; Estrada-López et al., 2018). For the biscuits, BPF was added to replace 20% (w/w) of regular wheat flour. Since the color of the biscuits was too dark, a formulation with only 10% substitution was prepared. Substitution percentages of 10% and 5% (p/p) were used to bake bread, and 10% (p/p) for pasta.

Table 1. Formulations of biscuits, bread, and pasta with and without BPF substitution.

Ingredient	BPF substitution (%)								
	Biscuits			Bread		Pasta			
	0	10	20	0	10	0	5	10	
Wheat flour	100 g	90 g	80 g	100 g	90 g	100 g	95 g	90 g	
BPF	–	10 g	20 g	–	10 g	–	5 g	10 g	
Sugar	35 g	35 g	35 g	3 g	3 g	–	–	–	
Vegetable oil	25 g	25 g	25 g	9 ml	9 ml	–	–	–	
Egg	15 g	15 g	15 g	–	–	50 g	50 g	50 g	
Whole Milk	20 g	20 g	20 g	–	–	–	–	–	
Baking powder	0.5 g	0.5 g	0.5 g	–	–	–	–	–	
Active dry yeast	–	–	–	1.2 g	1.2 g	–	–	–	
Salt	–	–	–	2 g	2 g	–	–	–	
Water	–	–	–	54 ml	54 ml	–	–	–	

– Not added.



Figure 1. Waste banana peels and banana peel flour. A: Waste banana peels, B: Flour obtained from the waste banana peels.

Table 2. Chemical composition (%) of banana peel (*Musa cavendish*).

Moisture	3.56 (0.06)
Ashes	11.86 (0.37)
Protein	6.41 (0.72)
Fat	10.22 (0.58)
Crude fiber	14.38 (0.45)
Carbohydrates*	57.13 (0.15)

* By difference, values are presented as mean (standard deviation) (n = 3).

2.3.1. Biscuit preparation

Formulations were made by substituting 10–20% of wheat flour as shown in Table 1. Wheat flour, BPF, sugar, and baking powder were mixed manually in a bowl. Vegetable oil, milk and a whole egg were beaten for 60 s (Artisan, Mod KSM150PS, KitchenAid, Greenville, Ohio, USA) and slowly added to the dry ingredients to form a soft dough dry enough to handle it with the hands to a thickness of 0.35 mm. These were molded with a common cookie cutter and baked at 180 °C for 10 min. Once the cookies had cooled, they were stored in polyethylene bags at room temperature in an airtight plastic container for later analysis.

2.3.2. Bread preparation

A 10% BPF substitution flour was used as indicated in Table 1. The yeast and sugar were placed in a glass containing 50 ml of drinking water at 30 °C and left to stand at room temperature for 15 min. Wheat flour

(for both the control bread and the 10% BPF substituted bread), salt, and vegetable oil were mixed until there were no lumps in the dough. Pre-activated yeast and drinking water were added until obtaining an extensible and elastic dough that was left to ferment at 38 °C until doubling of its volume. Afterwards, gas was extracted from the dough and pieces of 30 g were formed and left to ferment again for 20 min. Lastly, they were baked at 180 °C until completely cooked (approximately 30 min). Breads were left to cool for two and a half hours and were subsequently stored in hermetic plastic bags at room temperature for later analysis.

2.3.3. Pasta preparation

Three preparations of pasta were made: a control pasta without the addition of BPF and two formulations with 5 and 10% BPF substitution. The ingredients were mixed manually to form a uniform dough and were laminated to level 4 thickness (approximately 2 mm) in a manual pasta machine (Imperia Sp150, Italy). The resulting sheets were dried in a ventilated drier at 60 °C for 1.5 h (Excalibur dehydrator Mod. 3500 BLA, California, USA) and stored in sterile plastic packages at 4 °C until analysis.

2.4. Proximal analysis of BPF and products

BPF and formulated products were characterized for moisture, ash, fat, protein, and crude fiber content following the 934.01, 955.04, 920.39, 993.19, and 991.43 AOAC (2000) methods. Carbohydrates were

Table 3. Comparison of the composition of banana and plantain peel from various authors.

Variety used and state of maturity	Moisture	Ashes	Protein	Fat	Carbo-hydrates (by difference)	Fibre	Ref
Not shown	–	12.1	6.1	8.7	63.1	10	Archibald (1949)
<i>Musa sapientum</i> , Ripe	11.48	2.36	2.30	1.64	73.15	3.50	Horsfall et al. (2007)
<i>Musa sapientum</i> , Unripe	6.70 (2.22)	8.50 (1.52)	0.90 (0.25)	1.7 (0.10)	59.00 (1.36)	31.70 (0.25)	Anhwange (2008)
<i>Musa sapientum</i> , Ripe, lyophilized powder	3.31 (0.05)	13.22 (0.11)	5.50 (0.27)	2.24 (0.12)	76.58 (0.11)	18.91 (1.90)	Lee et al. (2010)
<i>Musa</i> AAB, Ripe	–	7.4	8.6	3.6	–	37.3	Emaga et al. (2011)
<i>Musa</i> AAA, Ripe	–	10.7	7.9	10.9	–	47.9	
Not shown	–	12.45 (0.38)	10.44 (0.38)	8.40 (1.15)	43.40 (0.55)	11.81 (0.06)	Feumba-Dibala et al. (2016)
<i>Musa balbisiana</i> , Unripe	2.21 (0.11)	2.33 (0.01)	7.52 (1.13)	9.04 (0.42)	70.00 (1.67)	8.89 (0.01)	Castelo-Branco et al. (2017)
<i>Musa cardaba</i> AAB, Unripe	10.20	1.09	3.47	2.34	79.93	2.96	Ohizua et al. (2017)
Not shown	6.39	22.2	8.74	4.54	46.93	11.20	Eshak (2016)
<i>Musa sapientum</i>	–	9.60 (0.02)	1.95 (0.14)	5.93 (0.13)	11.82 (2.17)	8.37 (0.18)	Hassan et al. (2018)
Maturity not indicated							
<i>Musa acuminata</i> , Ripe	8.10 (0.10)	7.13 (0.15)	6.47 (0.06)	0.37 (0.06)	74.7 (0.10)	3.20 (0.10)	Oguntoyinbo et al. (2020)
<i>Musa cavendish</i> , Ripe	–	13.08 (0.09)	6.9	12.55 (0.06)	57.74	9.73 (0.56)	Gómez-Montaña et al. (2019)
<i>Musa cavendish</i> , Ripe	10.03 (0.17)	25.19 (0.12)	15.10 (0.19)	7.04 (0.08)	44.64 (0.19)	–	Ahmed et al. (2021)

– Not reported.

Table 4. Chemical composition of foods supplemented with BPF.

% BPF added		Moisture	Protein	Fat	Carbohydrates (a)	Fiber
Bread	0	36.8 (1.7)	12.2 (0.98)	8.1 (1.21)	40.7 (1.34)	2.4 (0.45)
	10	34.5 (1.3)	12.6 (0.87)	10.7 (1.08) *	38.9 (1.25)	2.7 (0.23)
Pasta	0	12.8 (0.65)	11.1 (0.78)	1.1 (0.05)	73.6 (3.21)	1.4 (0.58)
	5	12.9 (0.94)	10.4 (0.58)	1.5 (0.02) ***	73.3 (3.25)	1.9 (0.67)
	10	12.3 (0.75)	10.9 (0.74)	2.3 (0.05) ***	72.1 (2.89)	2.4 (0.69)
Biscuit	0	7.4 (0.80)	12.1 (0.56)	28.3 (0.99)	50.7 (3.25)	1.5 (0.89)
	10	6.2 (0.87)	12.3 (0.45)	30.2 (0.89)	48.1 (2.74)	1.8 (0.97) *
	20	5.3 (1.30)	13.1 (0.54)	31.5 (0.85) **	46.1 (2.51)	2.6 (0.84) ***

^aBy difference, mean of triplicates (SD), Comparisons made by t-test or ANOVA with Dunnett poshoc test (*p < 0.05, **p < 0.001, ***p < 0.0001).

determined by differences with respect to protein, fat, moisture, ash, and crude fiber concentrations. Analyses were performed in triplicate.

2.5. Sensory evaluation

After verifying that peels were microbiologically safe and that they could still provide nutrients, sensory evaluations were carried out. The five-point hedonic scale described by [Lawless and Heymann \(1999\)](#) was used since it is the most used affective method in sensory tests for its informative results. Tastings were held in the same places where the banana peels were collected (markets, restaurants and greengrocery). An isolated area was set up in each place, at room temperature (23–25 °C in spring, 2020), with adequate ventilation, natural light, and isolated from establishment-emitted odors where the tests were carried out to avoid alterations of perception. To participate in the sensory evaluation, untrained judges aged between 20 and 40 years had to be willing to participate after signing the informed consent form. Sixty panelists for each panel of products were recruited. Judges determined their degree of acceptance through the five-point hedonic scale: 1 = I don't like it very much; 2 = I moderately dislike it; 3 = I don't like or dislike it; 4 = I moderately like it, and 5 = I like it very much. The panelists were given drinking water to rinse between each tasting.

For biscuits, whole pieces of the different formulations were served in a disposable plate so that the panelist could properly observe the characteristics. For bread small pieces (30 g) were prepared and presented

uncuted in a disposable plate without any additional ingredients to taste (jam, butter, etc.). Pasta was previously cooked in boiling water and seasoned with olive oil and garlic. Both the pasta with and without BPF were offered in separate small disposable plates. All samples were coded with three randomly designated digits. In addition to the mean score for each product, the Acceptability Index (AI) was calculated as described by [Castelo-Branco et al. \(2017\)](#).

$$AI (\%) = (\text{Mean Score})/(\text{Maximum Score}) \times 100$$

The method which had been applied for cakes in other studies (AACC 2002 referred by [Salama et al., 2013](#)) was employed for breads. It considers six quality parameters: taste, crust color, crumb color, odor, texture, and mouthfeel for a maximum total score of 100, where 86–100 is excellent; 76–85, very good; 75–61, good, and <61, poor.

2.6. Statistical analysis

Data are presented as mean and standard deviation. The comparisons of nutritional composition and results of the sensory analysis, as well as the Acceptability Index between the different products according to their BPF composition were performed through Student's t-test and one-way ANOVA. Dunnett's post-hoc test was used to determine differences between the formulated products, considering the group without addition of BPF as the control group. All statistical analysis were performed with

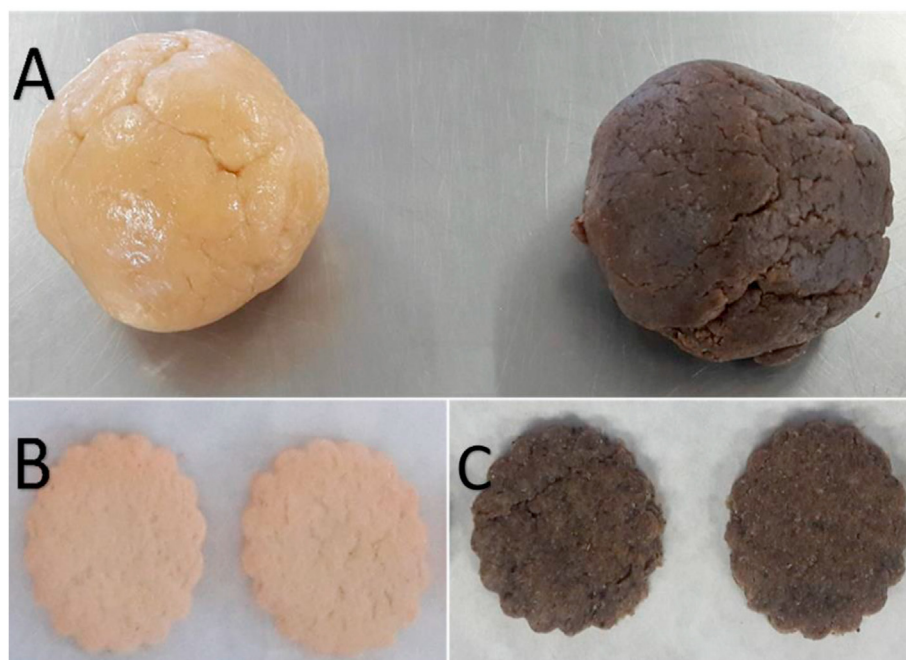


Figure 2. Biscuits with 20% banana peel flour (BPF) and bread without added BPF. A: Comparison between the dough for the biscuits without BPF (left) and with 20% BPF (right); dough added with BPF was drier and more difficult to handle. B: Baked biscuits made with flour without BPF. C: Baked biscuits made with BPF.

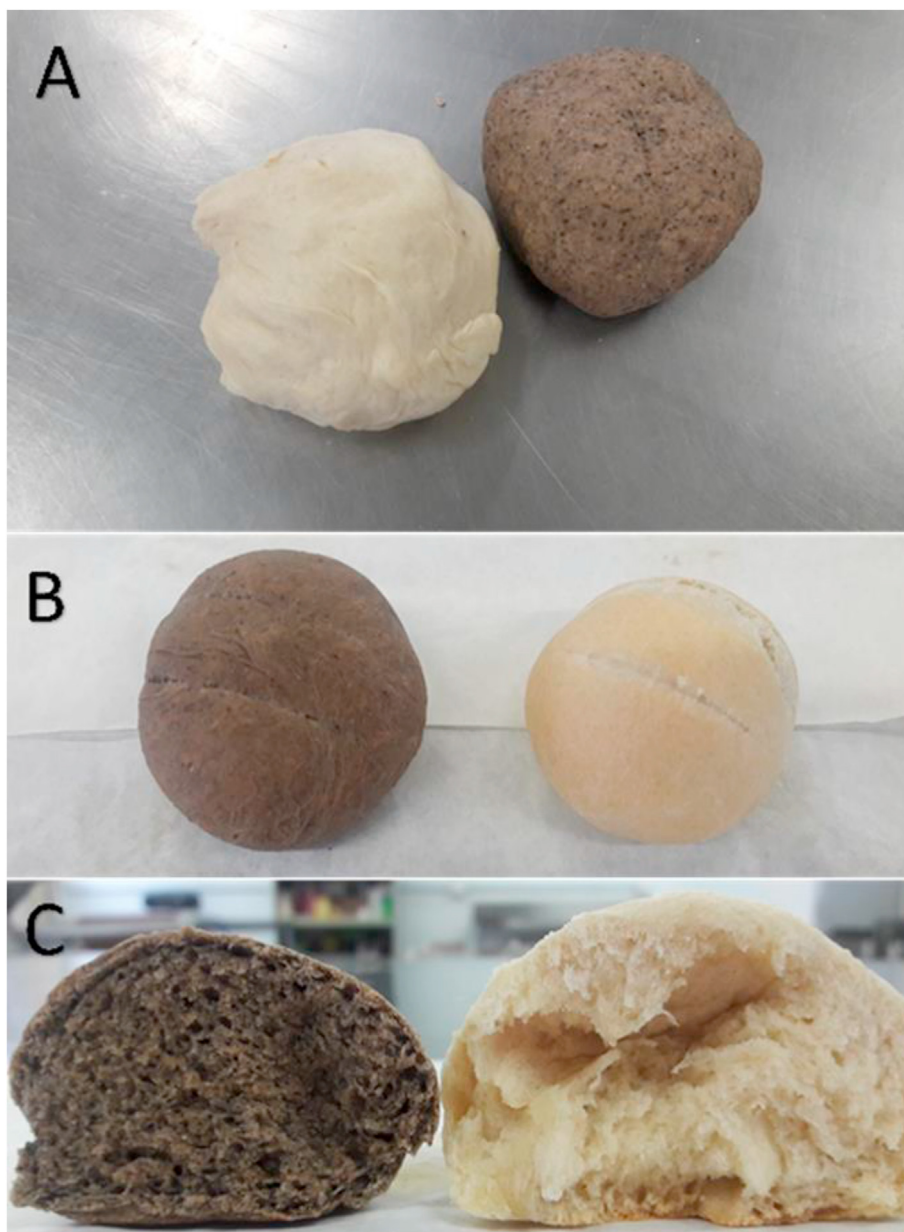


Figure 3. Bread with 10% banana peel flour (BPF) and bread without BPF addition. A: Comparison between regular dough (left) and 10% BPF dough (right). B: Comparison of crust color and general appearance of both types of BPF (left) and regular (right) breads. C: Crumb comparison of BPF (left) and regular (right) breads.

GraphPad Prism for Windows (La Jolla, CA, USA). Statistically significant differences were considered if $p < 0.05$.

2.6.1. Ethical aspects

This study was evaluated and approved by the Postgraduate in Technology and Food Safety Review Board. All panelists signed the informed consent forms before performing sensory analyses.

3. Results and discussion

3.1. Banana peels and BPF

Unlike other studies in which banana peel flour was carefully selected and treated to prevent oxidation or green banana peel was used together with fruit pulp, the present work focused on the use of discarded peels from different food stores. Based on the high activity of the *Musa cavendish* polyphenol oxidase (Wohlt et al., 2021), we expected that the brown color of the obtained flour could limit the acceptance of the products. Figure 1 shows banana peel residues and BPF.

Banana peel waste has a high microbial load, reason why guaranteeing sanitary safeness of the BPF is required. To that end, the combination of physical and chemical methods for washing serves to eliminate the dirt and microorganisms responsible for quality loss. The use of hypochlorite at 200 ppm is very effective and differs from other decontamination technologies in that, together with direct decontamination, a residual disinfection capacity is also generated (Gil et al., 2009). After treatment, BPF and all formulated food products met the Mexican Official Microbiological Standards for every category and were negative for *Salmonella* sp., Coliforms (at 35 °C and 45 °C), and *Escherichia coli* (<0.3 MPN g^{-1}). Therefore, BPF is safe for use.

3.2. BPF proximal analysis

Table 2 shows proximal analysis of BPF. The *Musa* genus includes fifty recognized species and dozens of hybrids, which complicates comparing results against prior studies. Moreover, the words banana and plantain are used to refer to desserts and other edible products from bananas.

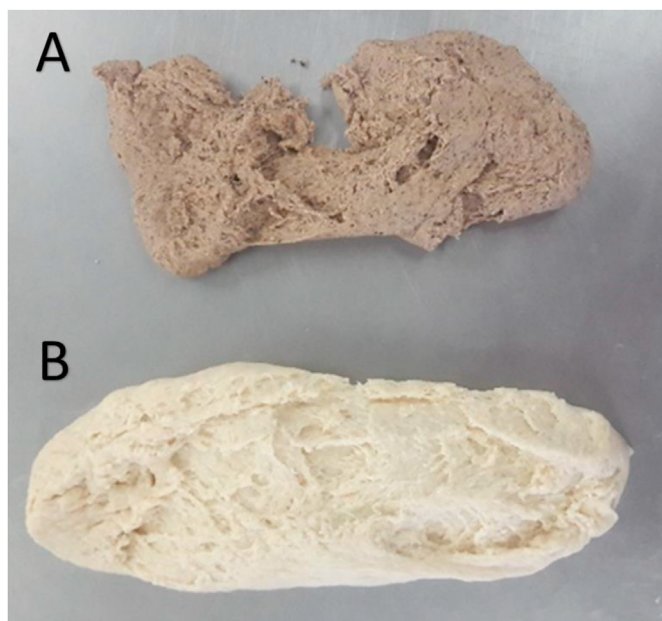


Figure 4. Texture of pasta dough with and without banana peel flour (BPF). A: Dough for pasta added with BPF. B: Dough for pasta without added BPF.

Plantain is the name of a group of banana cultivars for cooking (Plantain subgroup in Musapedia). Another factor that complicates the comparisons is that other works have been carried out under different conditions (banana varieties, different maturity stages). Furthermore, mixtures of skin and green banana pulp have been used to take advantage of the resistant starch and pectin contained in the pulp (Falcomer et al., 2019). Table 3 summarizes works by different authors and the diversity of varieties and conditions used in these studies.

The value obtained for ashes was 11.86% (SD 0.0.37), similar to that reported by Gómez-Montaño et al. (2019), Feumba-Dibala et al. (2016), and Archibald (1949). Gómez-Montaño refers to *Musa cavendish* whereas other studies do not specify the variety or state of maturity. Ahmed et al. (2021) reported ash content up to 25.19%, which contrasts greatly with other studies in which the ash content fluctuates between 1 and 2% (Horsfall et al., 2007; Castelo-Branco et al., 2017; Ohizua et al., 2017). Something similar happens with protein, which goes from 1% (Anhwange, 2008; Hassan et al., 2018) to contents similar to that found in our study (6.41%, SD 0.72) (Lee et al., 2010; Emaga et al., 2011; Oguntoyinbo et al., 2020). Fiber values which have been reported are highly variable, ranging from 2.96% (Ohizua et al., 2017) to greater than 30% (Anhwange, 2008; Emaga et al., 2011). In our study, the crude fiber content was 57.13% (SD 0, 15) which was higher than other studies since some studies only determines soluble fiber, whereas others did not report dietary fiber.

The chemical composition shown in Table 2 shows that BPF is a good source of minerals, fiber, and fat (11.86%, 14.38%, and 10.22% respectively). Thus, it would be possible to increase the content of these nutrients in foods by adding this flour to foods.

3.3. Chemical composition of supplemented foods

According to some authors, suitable results have been achieved by supplementing cereal-based products (Eshak, 2016; Castelo-Branco et al., 2017; Mahloko et al., 2019; Estrada-López et al., 2018; Gouda, 2018). Therefore, biscuits, bread and pasta were formulated with various supplementation levels. Table 4 shows the chemical composition of the three products made with BPF. Fiber was increased by 12.5% in bread with BPF and 20% in biscuits with 10% BPF. For pasta, the fiber content increased by 35.7% and 71.4% with 5% BPF and 10% BPF, respectively.

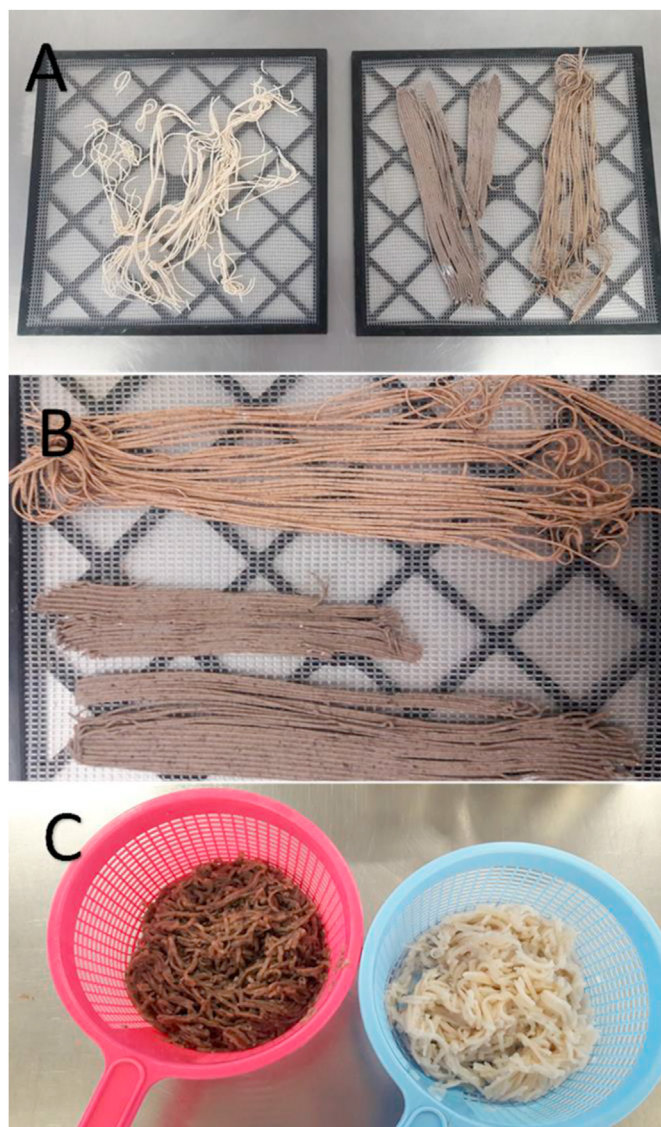


Figure 5. Pasta without supplementation and supplemented with 5% and 10% BPF. A: Comparison between traditional pasta (left) and substituted 5% and 10% BPF pasta, B: Pasta with 5% (up) and 10% (down) BPF addition, C: Cooked 10% BPF pasta (left) and traditional pasta (right).

Comparisons between products were carried out to determine which products contained higher amounts of nutrients by type. Statistical differences were found in protein content between the following foods: bread 10% vs pasta 5% ($p = 0.01$), pasta 5% vs biscuit 10% ($p = 0.03$), pasta 5% vs biscuit 10% ($p = 0.004$), and pasta 10% vs biscuit 20% ($p = 0.01$). Regarding fiber, no differences were found between the products. Thus, fiber was high in all the products.

Another significant enrichment of nutrients with the addition of BPF was the fat content, which could also represent an advantage. The main fatty acids in banana peel are linoleic acid (ω -6) and linolenic acid (ω -3), which comprise almost 40% of the total amount of fatty acids (Gómez-Montaño et al., 2019). These are considered essential for humans and are predominantly found in nuts and seeds. Both have shown important roles in health, such as the anti-inflammatory effects associated with linoleic acid and the cardioprotective, neuroprotective and anti-inflammatory effects of linolenic acid (Gonzales-Condori et al., 2021).

3.3.1. BPF supplemented biscuits

For biscuits, wheat flour was substituted with 10% BPF. By containing ingredients such as milk, egg, oil, and sugar, the BPF flavor

Table 5. Acceptability Index (%) of the products in their different formulations.

%BPF added	Appearance	Flavor	Color	Smell	Texture
Biscuits 0%	90.67 (10.15)	90.67 (10.15)	82.67 (6.91)	84.67 (8.60)	82.67 (6.91)
10%	81.33 (5.07) ***	87.33 (9.80)	81.33 (5.07)	81.33 (5.07)	86.00 (9.32)
20%	42.67 (6.91) ***	20.00 (0.00) ***	20.00 (0.00) ***	62.00 (6.10) ***	39.33 (6.40) ***
Bread 0%	92.67 (9.80)	93.33 (9.59)	96.00 (8.14)	94.67 (9.00)	94.00 (9.32)
10%	90.67 (10.15)	93.33 (9.59)	92.67 (9.80)	94.67 (9.00)	89.33 (10.15)
Pasta 0%	98.67 (5.07)	100 (0.00)	98.67 (5.07)	98.67 (5.07)	100 (0.00)
5%	96.67 (7.58)	100 (0.00)	94.67 (9.00)	98.67 (5.07)	100 (0.00)
10%	96.67 (7.58)	98.67 (5.07)	94.67 (9.00)	98.67 (5.07)	98.67 (5.07)

Comparisons made by t-test or ANOVA with Dunnett poshoc test (* $p < 0.05$, ** $p < 0.001$, *** $p < 0.0001$) (SD).

could be perceived less and increase the contribution of nutrients, reason why a 20% substitution was also considered. Substitutions of up to 40% have been made with BPF formulations, reporting improvements in fiber and fat content, although they reduce sensory quality (Abu-Bakar et al., 2018). Table 4 shows that the addition of 20% BPF significantly increased fiber similar to what has been described in other studies (Oguntoyinbo et al., 2020), without significant modifications in the rest of the nutrients. Figure 2 shows biscuit doughs with and without the addition of 20% BPF. A higher content of BPF increased dough dryness which toughened handling of the dough. The dough also became brittle with a visibly intense dark color. Despite this, a darker color likely does not represent a limitation in biscuits acceptance since people associate them with healthier integral products (Castelo-Branco et al., 2017).

3.3.2. BPF supplemented bread

Two types of breads were prepared: a control without BPF and a 10% BPF-substituted bread. The content of protein and fat were not significantly different between both breads, while moisture content was also similar (36.8% in the control bread and 34.5% in the BPF-substituted bread). Fiber content increased significantly, coincident with other studies in which 5–10% substitutions with BPF were used and recommended as the maximal substitution (Bandal et al., 2014). The addition of 10% fiber enhances yeast growth during dough fermentation (), which can improve the height of the loaf. Nonetheless, when BPF is added the dough becomes dry and requires more work for its development and acquiring a dark brown color. Despite this, sensory acceptance was not affected (Figure 3). The panelists assigned a quality evaluation according to the parameters described by Salama et al. (2013) of 63 for the BPF bread and 74 for the control bread. Both scores fell within the “Good” category.

3.3.3. BPF supplemented pasta

Figure 4 presents pasta made with additions of 5% and 10% BPF, as well as the control pasta made with unaltered wheat flour. Figure 5 shows that the resulting dough could be shaped into thin sheets and subsequently sliced without problems. The 5% BPF pasta had a similar color to integral pasta. Castelo-Branco made tagliatelle-type pasta with 15–30% BPF (Castelo-Branco et al., 2017) and only found significant differences in the content of minerals for both substituted formulations compared against the control pasta. However, fat only increased with respect to the control when the substitution level was 30%. There were no differences for any other nutrients. We limited the substitution level to 10% in our study since the pasta darkens with higher BPF contents. Nevertheless, higher BPF substitution could have likely been possible since panelists commented that a dark color gives the impression of a complex pasta with greater nutritional value, resembling the addition of vegetable extracts to increase the content of vitamins and minerals. Furthermore, the pasta added with BPF released less starch than the control pasta. Ramli reported that the addition of BPF to noodle pasta improved elasticity and regulated starch hydrolysis which lowers its glycemic index (Ramli et al., 2009). This would be an added benefit of BPF substitution since eating pasta in the context of low GI dietary pattern does not negatively affect adiposity and even reduces body weight and BMI compared to when it is done under high GI dietary patterns (Chiavaroli et al., 2018).

3.4. Sensory evaluation

The hedonic scale is a neutral-focused balanced bipolar scale with phrase-labeled categories representing various degrees of likeability. Its ability to capture likeability data has been extensively tested in consumer research works. Researchers have recommended that the number of

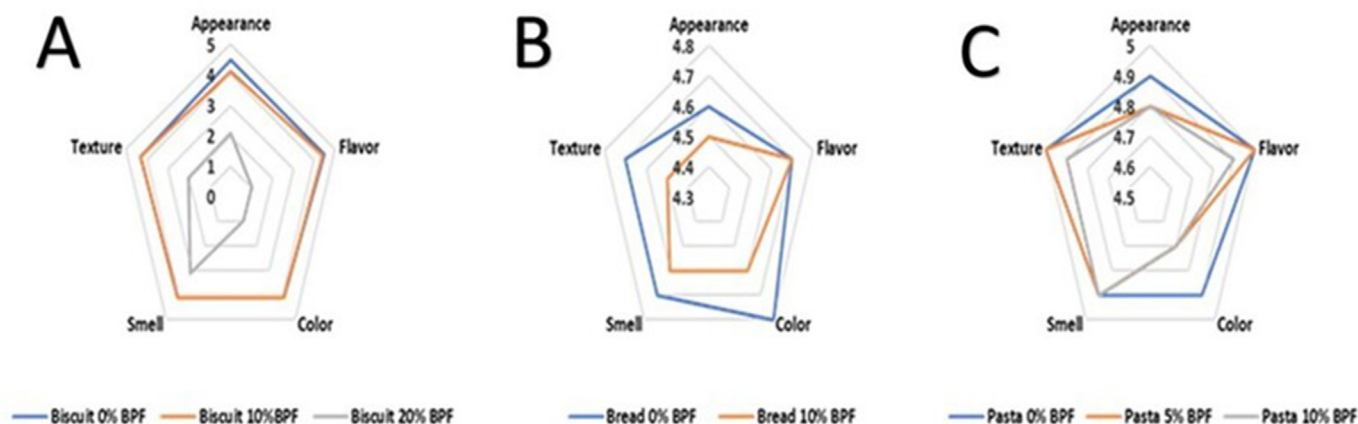


Figure 6. Sensory evaluation of banana peel flour (BPF) biscuit, bread, and pasta. A: Biscuit, B: Bread, C: Pasta.

target consumers needed for a hedonic scaling test should be between 50 and 100 (Gacula and Rutenbeck, 2006). The results presented in this study are indicative and important enough to be reported and discussed due to the number of judges that participated.

Table 5 shows the acceptability index of the product, defined as the average value of every parameter evaluated divided by the maximum possible value to be obtained, and multiplied by one hundred to be presented as a percentage. The minimum acceptance value is 20%, whereas the maximal value is 100%. To be considered acceptable, the bread had to achieve an acceptability index greater than 60%. Figure 5 shows the mean score obtained on the hedonic scale where the minimal acceptable value is 4. Bread with BPF had acceptability indices higher than 80%, indicating good acceptance of the products compared to the control. Biscuits with 20% BPF had a maximum acceptability index of 62% in the odor parameter, whereas taste and color acceptability was not higher than 20%. This formulation is significantly different from the rest with maximum levels of addition (10%). This could be explained by expectations of the panelists who could have associated the dark color to the taste of chocolate. Pasta with 5% and 10% BPF content had similar acceptability parameters than control pasta. Similar to what has been discussed in other studies, pasta could be the product in which higher BPF addition percentages could be achieved (Castelo-Branco et al., 2017). For bread with BPF (Figure 6), the acceptability area is similar to that of the control ($p < 0.05$). Therefore, the BPF percentage could possibly be increased even more. Noteworthy, no differences were found between control pasta, 5% BPF pasta, and 10% BPF pasta. Pasta products received the best evaluations and could allow higher percentages of BPF addition. Waste banana peel flour is a good option to enrich cereal-based products by increasing fiber and unsaturated fat contents with substitution percentages starting from 10%.

4. Conclusions

Banana peel wastes can be transformed into a biologically safe flour. BPF incorporated into some foods at 5–10% levels can provide extra nutritional value without affecting its acceptability. The dark color imparted by the addition of BPF did not affect the acceptance of the products by panelists. Therefore, it could be possible to further increase the levels of addition of BPF in products derived from cereals like biscuits, bread, and pasta. Despite this study not being focused on functional compounds, it would be interesting to quantify these compounds in products supplemented with wasted banana peels since there is a growing interest in the health benefits of a wide range of bioactive ingredients.

Declarations

Author contribution statement

Segura-Badilla Orietta: Conceived and designed the experiments; Wrote the paper.

Kammar-García Ashuin: Analyzed and interpreted the data; Wrote the paper.

Mosso-Vázquez Jeyne: Conceived and designed the experiments.

Ávila-Sosa Sánchez Raúl, Ochoa-Velasco Carlos: Performed the experiments.

Hernández-Carranza Paola: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Navarro-Cruz Addí Rhode: Conceived and designed the experiments; Performed the experiments.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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