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ORIGINAL ARTICLE

Green banana and ora-pro-nóbis mixed flours: nutritional and technological characteristics

Farinhas mistas de banana verde e ora-pro-nóbis: características nutricionais e tecnológicas

Hebert Teixeira Cândido[1*], Magali Leonel[1], Sarita Leonel[1,2], Lucas Felipe dos Ouros[1], Paulo Ricardo Rodrigues de Jesus[2], Maiqui Izidoro[3], Nicholas Zanette Molha[1], Vinícius Martins Domiciano[1]

[1]Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Centro de Raízes e Amidos Tropicais (CERAT), Botucatu/SP - Brasil
[2]Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Faculdade de Ciências Agronômicas (FCA), Botucatu/SP - Brasil
[3]Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Faculdade de Ciências Agrárias e Veterinária (FCAV), Departmento de Ciências da Produção Agrícola, Jaboticabal/SP - Brasil

***Correspondig author**: Hebert Teixeira Cândido, Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Centro de Raízes e Amidos Tropicais (CERAT), Avenida Universitária, CEP: 18610-034, Botucatu/SP - Brasil. e-mail: hebert.candido@unesp.br

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Abstract

The constant need for innovation in the food industries to meet the demands of consumers and the growing market for gluten-free and high-protein products have driven studies of mixed flour. In this study, 'BRS Platina' banana fruits were processed to obtain Whole Green Banana Flour (WGBF) and Green Banana Pulp Flour (GBPF) as well as leaves of Ora-pro-nóbis Flour (OPNF). Mixed flours were prepared by blending banana flours (WGBF or GBPF) with increasing levels of OPNF (from 5 to 25%). Flours were analyzed for physicochemical characteristics, mineral contents, Water Absorption Index (WAI), Water Solubility Index (WSI), and color. The main component of banana flours was starch, in which GBPF has the highest content. The WGBF had a higher mineral content, and in both flours, the potassium was at a greater level. OPNF showed the highest protein and mineral contents. Independent of the type of banana flour, mixed flours were darker, and had higher WAI and considerable increases in Mg, Fe, and Zn than no mixed ones. The blend of banana flours and Ora-pro-nóbis leaf flour can be a viable combination for preparing a variety of food products, due to its nutritional and technological properties.

Keywords: *Pereskia aculeata*; *Musa* spp.; Starch; Protein; Minerals; Gluten-free.

Resumo

A constante necessidade de inovação nas indústrias alimentícias para atender às demandas dos consumidores e o crescente mercado de produtos sem glúten e com alto teor proteico têm impulsionado os estudos de farinhas mistas. Neste estudo, frutos de banana 'BRS Platina' foram processados para obtenção de farinha integral de banana verde (WGBF) e farinha de polpa de banana (GPBF), e folhas de ora-pro-nóbis foram processadas para obtenção de farinha (OPNF). As farinhas mistas foram preparadas pela mistura de farinhas de banana (WGBF ou GPBF) com níveis crescentes de OPNF (5 a 25%). As farinhas foram analisadas quanto a características físico-químicas, teores de minerais, índice de absorção de água (IAA), índice de solubilidade em água (ISA) e cor. O principal componente das farinhas de banana foi o amido, com maior teor na GBPF. A WGBF apresentou maior teor de minerais, com o potássio em maior quantidade. A farinha de ora-pro-nóbis apresentou altos teores proteico e mineral. Independentemente do tipo de farinha de banana, as farinhas mistas mostraram-se mais escuras, tiveram maior absorção de água e aumentos consideráveis de Mg, Fe e Zn. Misturas de farinhas de banana e farinha de folha de ora-pro-nóbis podem ser uma combinação viável para a formulação de diversos produtos alimentícios, devido às suas propriedades nutricionais e tecnológicas.

Palavras-chave: *Pereskia aculeata*; *Musa* spp.; Amido; Proteína; Minerais; Sem glúten.

Highlights

- Ora-pro-nóbis flour (OPNF) increased by more than 85% the protein content in mixed banana flours
- The contents of K, Ca, Mg, Fe and Zn increased in mixed flours
- Ora-pro-nóbis flour (OPNF) is a good carrier of protein and minerals for gluten-free products

1 Introduction

The growing consumer interest for a healthier life has been boosting the food industries to develop products with natural and functional claims, valuing the phytochemical components of raw materials, in addition to highlights for sustainability and low cost (Martínez-Villaluenga et al., 2020).

Factors such as post-harvest losses, valorization of unconventionally edible parts of vegetables and aspects of gluten allergy and protein malnutrition have been listed as the keys to the production and characterization of mixed flours for application in various products (Arise et al., 2021; Komeroski et al., 2021).

Banana plays a very important role in food and nutritional security due to the large volume produced and its nutrients. The pulp of immature banana fruits is rich in starch and phytonutrients, whereas the peel is rich in minerals, fibers and bioactive compounds, which makes them potential raw materials for obtaining flours (Aurore et al., 2009; Alkarkhi et al., 2011; Castelo-Branco et al., 2017; Leonel et al., 2021).

The development of whole flour (pulp and peel) from plantain and banana is a rapid method of flour production as well as improving the economic importance of the crops, with improved levels of nutrients (Adeniji et al., 2007). One concern regarding whole banana flours is that processing entire fruits increases the levels of antinutrients, which are present in banana peels, such as alkaloid, oxalate, saponin, and phytate. However, studies have shown that these compounds are present in safe amounts (Adeniji et al., 2007; Oyeyinka & Afolayan, 2019; Zaini et al., 2022).

Due to several factors, there has been an increasing consumption of gluten-free products even by individuals with Non-Celiac Gluten Sensitivity (NCGS), however, gluten-free flours most of the time show low protein content, which has nutritional and technological effects (Skendi et al., 2021).

Ora-pro-nóbis (*Pereskia aculeata* Miller) is a plant native found in Brazil, with geographic distribution from South America to the south of the United States of America (USA) (Kinupp & Lorenzi, 2014). Ora-Pro-Nóbis Flour (OPNF) contains high protein content (> 20%) and can be considered an excellent source to increase the protein content of mixed flours (Silva et al., 2014; Sobrinho et al., 2015; Souza et al., 2016). However, the applicability of mixed flours depends on their functional and technological properties as they influence the final quality of the product and consumer acceptance (Santana et al., 2017).

This study aimed to evaluate the physicochemical characteristics of WGBF, banana pulp flour and OPNF, as well as to verify the effect of different combinations of mixtures of these flours on the variables studied.

2 Material and methods

2.1 Site description and plant material

Immature fruits of banana plants of the cultivar BRS Platina grown in the orchard of the Department of Crop Production, School of Agriculture, *Universidade Estadual Paulista* (UNESP), located in the city of Botucatu, state of São Paulo, Brazil (22° 51' 55” S and 48 ° 26' 22” W and 810 m a.s.l.) were used to produce banana flours. BRS Platina cultivar is a tetraploid hybrid (AAAB-Prata/Pome type) from the crossing of 'Prata-anã' (AAB) with the diploid M53 (AA), developed by *Embrapa Cassava e Fruticultura*. This cultivar is resistant to Panama disease (*Fusarium oxysporum*) and Yellow Sigatoka (YS), *i.e.*, a leaf spot disease (*Mycosphaerella musicola*). The main disadvantage of BRS Platina is associated with its susceptibility to falling off, with reduced commercial value for the fresh market; however, this is not relevant for industrial processing (Nogueira et al., 2018), since it may be an indication of the use for flour processing, considering its high content of resistant starch (Leonel et al., 2021).

Ora-pro-nóbis (*Pereskia aculeata* Mill.), also called pereskia, has no registered varieties. It is a perennial, shrubby species. This species has long, prostrate branches, simple leaves with short petioles, elliptical, with a flat blade, with a fleshy texture (Madeira et al., 2016). Green leaves of Ora-pro-nóbis plants were harvested in the morning in a vegetable garden in the city of Botucatu, state of São Paulo, Brazil.

2.2 Preparation of flours

'BRS Platina' banana fruits harvested at stage 1 of maturation (totally green peel) (Von Loesecke, 1950) were processed to obtain WGBF (pulp and peel) and GBPF. Three banana bunches were collected, and their hands were separated into three samples. The fruits of each hand were separated, washed in water and left in a sieve to drain the excess water. The three batches of fruits were divided into two batches to produce banana flour (WGBF and GBPF), thus constituting three fruit samples for each type of flour.

The fruits of each sample were cut into slices of approximately 5 mm thick and subjected to treatment against enzymatic browning (immersion for 15 minutes in a solution of 0.1 g L^{-1} of ascorbic acid and 0.3 g L^{-1} of citric acid). After this period, the drained slices were dehydrated in a drying oven with air circulation at a temperature of 50 °C for 24 h (Reis et al., 2019).

In the preparation of OPNF, the totally green leaves collected from three plants were separated from the stems without petioles and without distinction of size. The leaves were washed in chlorinated water (100 ppm), rinsed, drained, and dried in an oven with air circulation at 50 ºC for 24 h. The dehydrated material was disintegrated in a knife mill, sieved (250 µm) and stored in hermetically closed glass jars in a dark environment.

Mixed flours were produced using increasing percentages of OPNF (0 to 25%) mixed with WGBF or GBPF. Flours were mixed in a Y-shaped mixer for 10 minutes. Figure 1 shows the steps of the experimental trial.

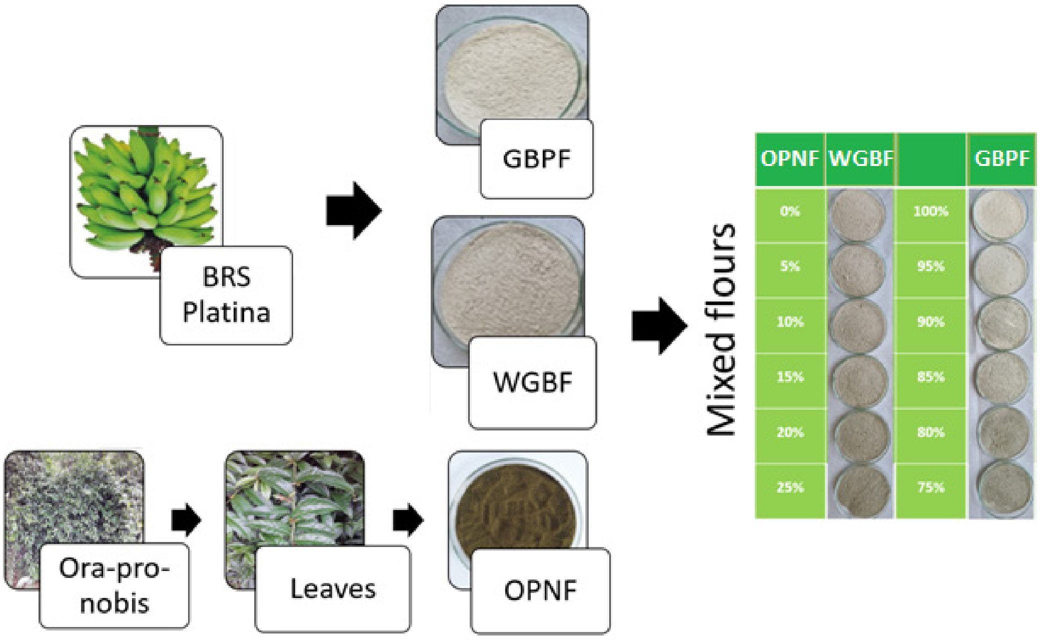

Figure 1. General diagram of the experiment.

2.3 Analysis of flours

2.3.1 Physicochemical characteristics of the flours

Physicochemical characteristics of the banana flours and mixed flours were determined according to American Association of Cereal Chemists (2018) methods as follows: moisture (method44-15.02); protein (method 46-13.01); ash (method 08–01.01); total starch (method 76-13.01); total sugars (method 80-10.01); and pH (method 02-52.01).

2.3.2 Minerals

Phosphorus [P], potassium [K], calcium [Ca], magnesium [Mg], iron [Fe], zinc [Zn] and sodium [Na]) in mixed flours were analyzed according to methodologies described by Malavolta et al. (1997).

2.3.3 Water absorption index and water solubility index

The Water Absorption Index (WAI) and the Water Solubility Index (WSI) were determined according to the methodology described by Santana et al. (2017) with adaptations. Initially, 250 mg of the sample was placed in a falcon tube and 12.5 mL of distilled water was added. The tube was vortexed for 60 seconds and then centrifuged at 2700 rpm for 10 minutes. After centrifugation, a 5 ml aliquot of the supernatant was placed in a Petri dish and placed in an oven with forced air circulation for drying. The wet sample with sediment in the tube was weighed. The WAI was calculated by the ratio between the initial sample and the sample with sediment, while the WSI was calculated by the ratio between the solubilized mass in the supernatant and the initial mass of the sample.

2.3.4 Color

Color of flours was evaluated on a Minolta CR-400 colorimeter (Konica Minolta, Ramsey, NJ, USA). The coordinates were L* indicating the luminosity, which varies on a scale from zero (black) to 100 (white); the parameters a* indicating the color range from -60 (green) to +60 (red) and b* indicating the color range from -60 (blue) to +60 (yellow). The Whiteness Index (WI) was determined according to Savlak et al. (2016).

2.4 Data analysis

The results obtained were submitted to analysis of variance (F test) and, when significant, to the Scott & Knott test, to compare the means. The statistical analysis of the tests of means was performed in the Agrostat software (Barbosa & Maldonado Junior, 2015), the Pearson correlation and analysis of the principal components in the Minitab 18® software. The bar graph was made using Sigma Plot software (Systat Software, 2011).

3 Results and discussion

3.1 Physicochemical characteristics of flours

The GBPF and WGBF were different for all analyzed parameters (Table 1). The peels represent about 35-40% of the total weight of banana fruits, with variations between cultivars (Anhwange, 2008; Alkarkhi et al., 2011; Vu et al., 2017) and due to their chemical composition had strong influence in the composition of banana flours with peels (Sardá et al., 2016).

Results obtained in the analysis of banana flour showed that WGBF had higher ash content, which was also observed in other studies, with contents varying from 2.45 to 2.59% in pulp flour and from 3.58 to 4.27% in flour with peel (Fasolin et al., 2007; Borges et al., 2009; Bezerra et al., 2013; Sardá et al., 2016; Reis et al., 2019; Khoza et al., 2021).

The OPNF had an ash content of 13.0%, *i.e.*, a content below those reported in other studies (15.5 and 18.8%) (Sobrinho et al., 2015; Silva et al., 2014, respectively), which may be due to the soil, harvest season, type of leaves, among others. Due to the considerable ash content in the OPNF, higher percentages increased by up to 73.4% and 48% the ash content in the mixed flours with GBPF and WGBF, respectively (Table 1).

The protein levels of banana flours were 3.1% for GBPF and 3.3% for WGBF (Table 1). These levels were lower than those observed by Sardá et al. (2016) who reported protein contents of 3.72% for pulp flour and 5.51 for banana peel flour. These same authors observed varying levels of protein in commercial banana flours that ranged between 4.01 and 5.79%.

Ora-pro-nóbis leaves stood out for their considerable protein content. Takeiti et al. (2009) reported 89.5% of moisture in the fresh leaves of Ora-pro-nóbis and a content of 28.4% of protein (dry basis).

The OPNF protein content was 16.2 ± 0.16% (17.7% on a dry basis) (Table 1), a content very close to those obtained by Silva et al. (2014), who reported 17% of protein in OPNF. The protein content of OPNF can be compared to that of bean flours. Marquezi et al. (2016), analyzing flours obtained by processing six bean cultivars, observed protein contents ranging from 17.72 to 20.27%. This result points to the potential of this flour as a protein ingredient. In agreement with Takeiti et al. (2009) among essential amino acids, tryptophan was the most abundant in Ora-pro-nóbis leaves (5.52 g/100 g d.w.) and considering the essential amino acids score, lysine and sulfur-amino acids (Met+Cys) were limited.

In mixed flours, the increase in the percentage of OPNF allowed an increase above 100% of protein with contents of 20 and 25% in the mixture with GBPF or WGBF, reaching 6.3 to 7.2% of protein (d.w.) (Table 1).

Skendi et al. (2021) reported that studies attempted to improve the protein content of gluten-free products using appropriate sources. Protein levels in mixed flours are below the levels reported by Akharume et al. (2021) for bean, soy and wheat protein flours. Authors described that protein ingredients in trade fell into three categories as following: protein flours; protein concentrates; and protein isolates that contain 10-20%, 55-60% and more than 80% protein content, respectively.

Starch was the main component of unripe banana flours (Table 1). The green banana pulp flour had higher starch content, which is due to the lower starch content in the peel flour and the percentage of peel in the whole flour. Khoozani et al. (2019) in their review of banana flour reported that banana pulp and peel flours have higher starch contents in stages 1 and 2 of ripening and lower in ripe fruits (ripening stages 6-7). The authors reported results from several studies showing that the starch in green banana pulp flour ranges from 64-75% and in the peel from 10.1 to 11.7%. In ripe banana flours, starch contents range from 56 to 63% in pulp flour and from 3.5 to 6.3% in peel flour.

Table 1. Chemical components (d.w) of whole green banana flour and green banana pulp flour associated or not with Ora-pro-nóbis flour.

OPNF	Ash (%)		Protein (%)		Starch (%)		Total Sugars (%)	
	13.0 ± 0.05		17.7± 0.18		nd		nd	
	GBPF*	WGBF*	GBPF*	WGBF*	GBPF**	WGBF*	GBPF*	WGBF*
0%	3.34^{f}	4.19^{d}	31^{f}	3.3^{f}	85.5^{a}	71.0^{a}	2.91^{a}	2.49^{b}
5%	3.91^{e}	4.49^{d}	4.0^{e}	4.2^{e}	83.9^{a}	64.4^{b}	2.75^{a}	2.85^{a}
10%	4.29^{d}	5.07^{c}	4.9^{d}	5.0^{d}	81.9^{a}	63.1^{b}	2.99^{a}	2.83^{a}
15%	4.82^{c}	5.46^{b}	5.6^{c}	5.5^{c}	78.3^{a}	65.0^{b}	2.58^{b}	2.52^{b}
20%	5.33^{b}	5.87^{a}	6.4^{b}	6.3^{b}	75.0^{b}	62.0^{b}	2.55^{b}	2.36^{b}
25%	5.81^{a}	6.20^{a}	7.1^{a}	7.2^{a}	67.6^{b}	57.4^{b}	2.40^{b}	2.25^{b}

OPNF: Ora-Pro-Nóbis Flour; GBPF: Green Banana Pulp Flour; WGBF: Whole Green Banana Flour; nd: not determined. Means followed by the same letters in the column, in banana flours and in mixed flours do not differ by Scott & Knott mean test ($p < 0.01$)* and ($p < 0.05$)**.

The WGBF had a lower starch content than those cited by Khoozani et al. (2019) in their revision which ranged from 84.62 to 85.26 (d.w. g/100 g) in banana flours dried by different methods.

Mixed flours with low percentages of OPNF had similar starch contents to flours from green bananas of different cultivars: 73.8% (Grand Naine); 74.6% (BRS SCS Belluna); 78.5% (BRS Platina); and 79.8% (PrataAnã) (Reis et al., 2019). The mixed flours with higher OPNF contents, despite lower starch content, had levels similar to those reported by Sardá et al. (2016) in four green banana flours, sold in Brazilian markets (64.2% - 68.9%).

Total sugar levels in banana flour were 2.49 g/100 g d.w. for WGBF and 2.91 g/100 g d.w. for GBPF. The sugar content in the WGBF was similar to that observed by Sardá et al. (2016) who observed 2.64%. However, the authors observed lower contents in the green banana pulp flour (0.64%). In the analysis of commercial banana flours, the levels of total soluble sugars observed in the study ranged from 0.05 to 5.66%, with sucrose as the main differentiating factor.

The mixed flours of GBPF and WGBF showed a tendency to decrease the pH according to the addition of OPNF, with a variation of 5.66 to 5.45 for GBPF/OPNF and from 5.83 to 5.58 for WGBF/OPNF (Table 2). Despite the variation, these pH values are similar to those presented by green banana flour, with values ranging from 5.0 to 5.78 obtained from five cultivars (Kumar et al., 2019) and from 5.58 to 5.56 in four other flours (Savlak et al., 2016).

Table 2. Hydrogen ion activity (pH) of whole green banana flour and green banana pulp flour associated or not with Ora-pro-nóbis flour.

	0%	5%	10%	15%	20%	25%
OPNF	5.45	-	-	-	-	-
GBPF*	5.66 ^{a}	5.60 ^{a}	5.54 ^{b}	5.49 ^{b}	5.47 ^{b}	5.45 ^{b}
WGBF**	5.83 ^{a}	5.80 ^{a}	5.68 ^{b}	5.70 ^{b}	5.72 ^{b}	5.58 ^{c}

OPNF: Ora-Pro-Nóbis Flour; GBPF: Green Banana Pulp Flour; WGBF: Whole Green Banana Flour. Means followed by the same letters in the line do not differ by Scott & Knott mean test ($p < 0.01$)* and ($p < 0.05$)**.

3.2 Minerals

The overall concentration of macro-minerals was higher than that of trace minerals (Table 3). Potassium (K) was the most abundant mineral (1163 mg/100 g d.w. to GBPF and 1539 mg 100 g^{-1} d.w. to WGBF), while zinco (Zn) was the least abundant (1.4 mg/100 g d.w. to GBPF and 1.6 mg 100 g^{-1} d.w. to WGBF).

The mineral contents in green banana flours are quite variable. Khoza et al. (2021) analyzing the mineral profile in green banana flours from five cultivars (Grande Naine, Pisang Awak, Finger Rose, FHIA-01 and Du Roi) obtained variations of: Ca, 8.7 to 28.25 mg /100 g; Mg, 92.4 to 118.5 mg /100 g; K, 290.95 to 1033.25 mg /100 g; P,31.72 to 99.25 mg /100 g; Zn,0.18 to 0.93 mg /100 g and Fe, 1.33 to 2.88 mg /100 g in dry weight.

The OPNF showed 152, 1566, 2217, 981, 10.4, 2.5 and 17.2 mg /100 g in dry weight of P, K, Ca, Mg, Fe, Zn e Na, respectively. The mineral profile of Ora-pro-nóbis leaves is variable with influence of soil type and climatic conditions. K levels have been reported ranging from 689.41 to 3740 mg/100 g, Ca from 427.08 to 3420 mg/100 g, Mg from 88.84 to 1900 mg/100 g (Takeiti et al., 2009; Oliveira et al., 2013; Barreira et al., 2021). In the study by Barreira et al. (2021), it could be also observed contents of 13.89 mg/100 g of Fe, 0.05 mg/100 g of Zn and 1.19 mg/100 g of Na.

Mixed flours 75% GBPF and 25% OPNF had increased contents of Mg (270.48%), Ca (141.44%), Fe (88.04%), Zn (19.64%), K (8.66%). Due to the higher mineral content of whole green banana flour (WGBF), the 75% WGBF/ 25%OPNF mixed flours showed increases of 235.9%, 130.7%, 67.9%, 14.1% and 0.4% in Mg, Ca, Fe, Zn and K contents, respectively (Table 3). These results show that mixed banana and OPNF can be considered good carriers of minerals for gluten-free products.

Table 3. Mineral concentration in banana flours, Ora-pro-nóbis flour and mixed flours.

	P	K	Ca	Mg	Fe	Zn	Na
				mg/100 g d.w.			
OPNF	152 ± 13	1566 ± 118	2217 ± 139	981 ± 68	10.4 ± 0.2	2.5 ± 0.1	17.2 ± 0.6
GBPF	163 ± 2.8	1163 ± 50.7	333 ± 23.5	83 ± 8.9	2.3 ± 0.2	1.4 ± 0.4	21.0 ± 2.9
WGBF	173 ± 2.4	1539 ± 32.1	356 ± 8.5	94 ± 11	2.8 ± 0.4	1.6 ± 0.5	20.7 ± 4.0
				Mixed flour GBPF/OPNF*			
5%	162.4	1183.1	427.2	127.9	2.70	1.4	20.8
10%	161.9	1203.3	521.4	172.8	3.11	1.5	20.6
15%	161.3	1223.4	615.6	217.7	3.51	1.6	20.4
20%	160.8	1243.6	709.8	262.6	3.92	1.6	20.2
25%	160.2	1263.7	804.0	307.5	4.32	1.7	20.0
				Mixed flour WGBF/OPNF*			
5%	171.9	1540.3	449.0	138.3	3.2	1.6	20.5
10%	170.9	1541.7	542.1	182.7	3.6	1.7	20.3
15%	169.8	1543.0	635.1	227.1	3.9	1.7	20.2
20%	168.8	1544.4	728.2	271.4	4.3	1.8	20
25%	167.7	1545.7	821.2	315.7	4.7	1.8	19.8

OPNF: Ora-Pro-Nóbis Flour; GBPF: Green Banana Pulp Flour; WGBF: Whole Green Banana Flour. *Obtained by calculation.

Increases in Mg, Fe and Zn contents in mixed flours are important differentiating factors of these flours. Micronutrient deficiencies or hidden hunger are often less visible than energy or protein deficiencies, but they bring serious health problems. Magnesium is one of the most important body elements and the second most abundant intracellular cation. Mg deficiency can affect bone directly by reducing bone stiffness, increasing osteoclasts and decreasing osteoblasts. But it can also affect indirectly, interfering with parathyroid hormone (PTH) and vitamin D, promoting inflammation/oxidative stress and subsequent bone loss (Capozzi et al., 2020). Fe participates in nucleic acid biosynthesis, cell development and growth. It also acts in the respiratory chain and in several enzymatic and metabolic processes. Fe deficiency can cause several diseases, and one of them is anemia, in addition to reducing the body's immune capacity (Okwuonu et al., 2021). Zn has many functions in the human body. Zinc deficiency affects about a third of the world population and leads to physiological disorders that affect the immune, gastrointestinal, epidermal, central nervous, skeletal, and reproductive systems (Roohani et al., 2013).

3.3 Water absorption index and water solubility index

The WAI is influenced by the physical state of starch, dietary fiber and protein. The WSI is linked to the soluble solid contents in flours (Pereira et al., 2020; Khoza et al., 2021).

The WAI results of banana flours, 3.98 g g^{-1} (GBPF) and 3.72 g g^{-1} (WGBF) (Table 4) were similar to the value of 3.39 g g^{-1} observed by Campuzano et al. (2018) and those obtained by Savlak et al. (2016) in green banana flours (Dwarf Cavendish), 2.92 g g^{-1}, 3.58 g g^{-1}, 3.70 g g^{-1} and 4.60 g g^{-1}.

There was an increase in the water absorption capacity in mixed flours, with WAI ranging from 4.84 to 6.73 g g^{-1} (5 to 25% OPNF) in the mixed flour of GBPF and from 3.90 to 5.86 g g^{-1} (5 to 25% 25% OPNF) in WGBF mixed flour (Table 4).

Table 4. Water Absorption Index (WAI), Water Solubility Index (WSI) of banana flours and mixed flours.

	WAI (g g^{-1} farinha)		WSI (%)	
	GBPF	WGBF	GBPF^{ns}	WGBF ^{ns}
0%	3.98^b	3.72^b	4.28	4.17
5%	4.84^b	3.90^b	4.60	4.53
10%	4.99^b	5.32^a	3.95	5.56
15%	5.72^a	5.86^a	4.31	4.80
20%	6.71^a	5.69^a	5.21	5.43
25%	6.73^a	5.85^a	4.86	3.68

Means followed by the same letters in the column, in banana flours and in mixed flours do not differ by Scott & Knott mean test ($p < 0.05$).
^{ns}: not significant.

The addition of OPNF may increase the water holding capacity, possibly due to its protein content, as the protein showed a positive correlation with WAI (0.771 $p < 0.000$) in GBPF and WGBF (0.593, $p = 0.009$). Thus, the addition of OPNF improves the characteristics of green banana flours for use in meat products or dough for breads and cakes, as it allows the addition of water, which prevents drying and improves handling (Santana et al., 2017).

There was no interference of OPNF levels on WSI in mixed flours, GBPF ($p = 0.4367$) and WGBF ($p = 0.1434$) (Table 4), demonstrating that the addition of OPNF up to 25% maintained the characteristics found in the unmixed green banana flours.

3.4 Color

Color attributes have an impact on food quality for both consumers and industries. The results of the color properties of banana flours and OPNF (Figure 2) presented that GBPF was whiter, with luminosity similar to wheat flour according to Kumar et al. (2019) (L* = 88.50). Due to the presence of peel in WGBF, L* was lower. The b* value showed yellowing for the three flours (Figure 2).

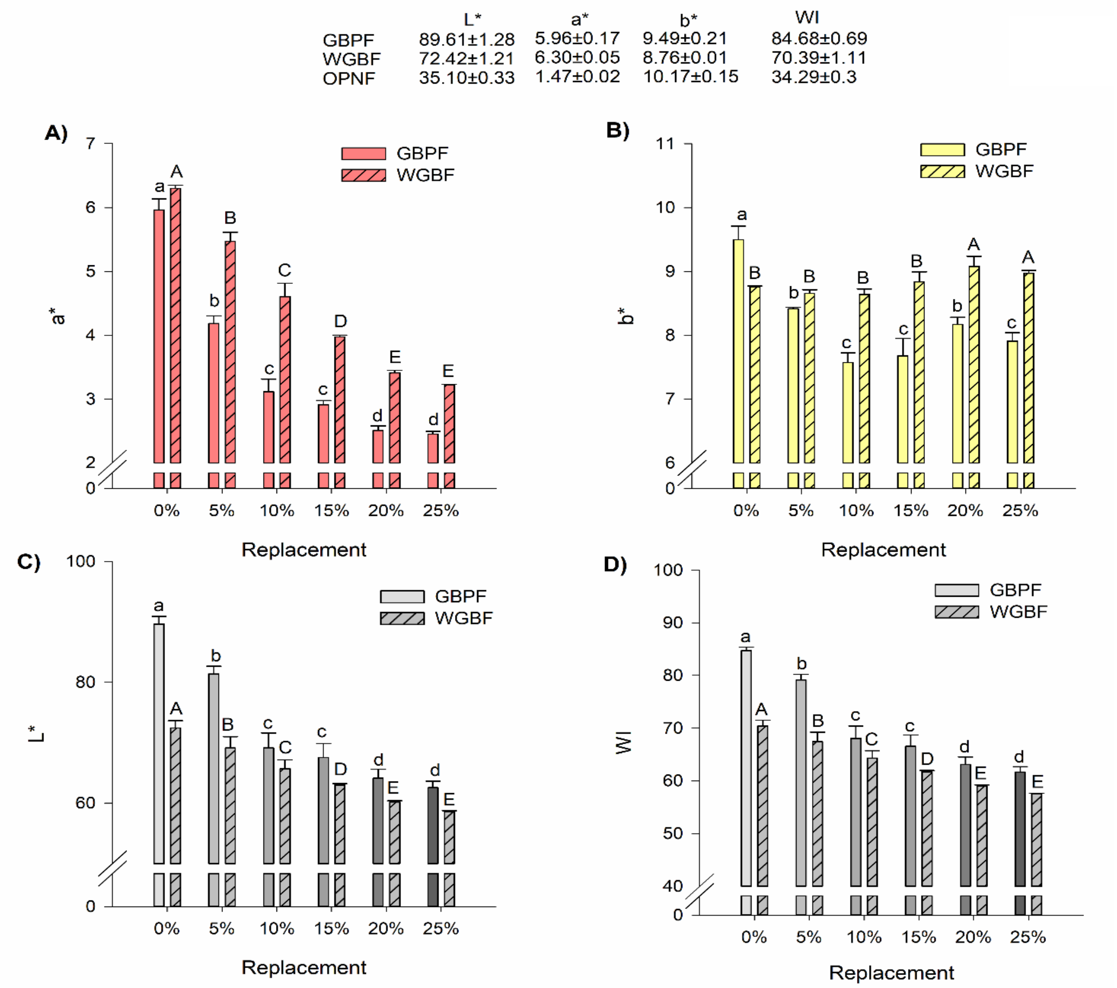

Figure 2. Color parameters of unmixed and mixed flours. Different lowercase letters for Green Banana Pulp Flour (GBPF) and uppercase letters for Whole Green Banana Flour (WGBF) differ significantly by Scott & Knott mean test ($p < 0.01$). L*=luminosity; a* (green to red); b* (blue to yellow); WI= whiteness index.

The Whiteness Index (WI) of the GBPF was 84.6 while that of the WGBF was 70.4. Savlak et al. (2016) found whiteness indices that ranged from 80.8 to 75.4 for four green banana flours.

The OPNF showed low luminosity, which contributed to the color differences in the mixed flours.

The color parameter graphs showed that regardless of the type of banana flour (GBPF or WGBF), in mixed flours the increase in the percentage of OPNF decreased luminosity (L*), a*, b* and WI. GBPF/OPNF mixed flours showed higher WI than WGBF, which may be a favorable characteristic for use in some food products.

3.5 Principal components analysis

Two-component analysis accounted for 84.7% of the variability of the data obtained (Figure 3). The first component correlated better with ash (0.472), proteins (0.466), [WI] (-0.445) and [WAI] (0.424), whereas the second component had a better correlation with the pH (-0.700) and starch (0.541). The [WSI] showed no relationship with components 1 and 2. All GBPF mixtures were above the reference line (Figure 3A), showing that they have higher starch contents and are lighter (Figure 3B), whereas the WGBF mixtures were below this line (Figure 3A), with a higher relationship with pH, tending to have a higher pH for the same percentage of substitution and a negative relationship with the whiteness index, being, therefore, darker. GBPF and WGBF flours could tend to increase the ash and protein content and the ability to absorb water, and both were darker, as the OPNF content in the mixture increases (Figures 3A and 3B).

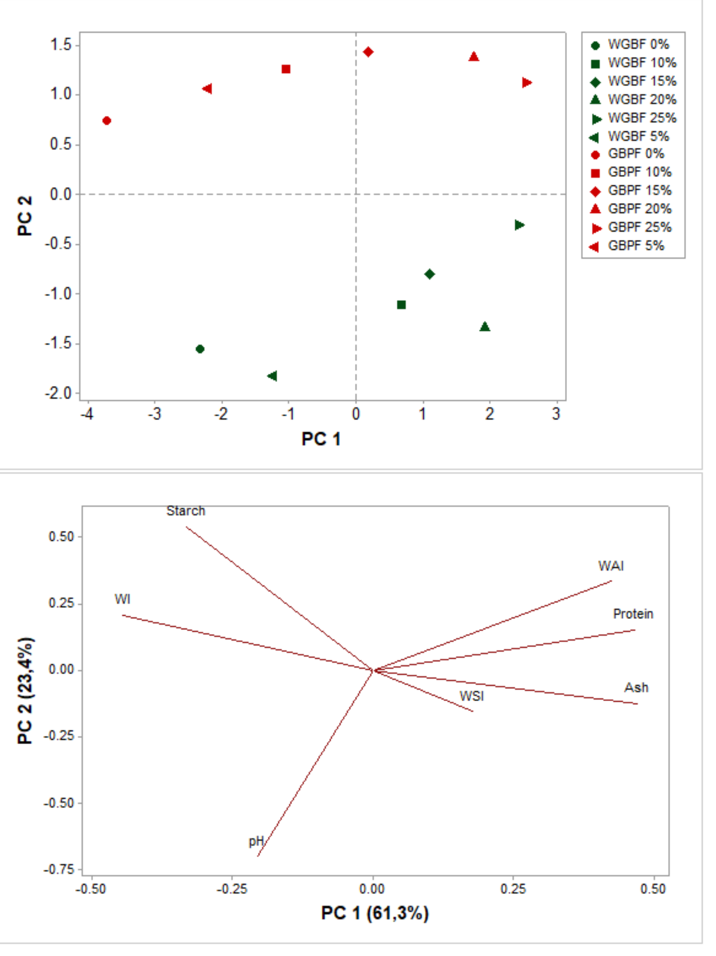

Figure 3. Principal component analysis regarding the flours.

4 Conclusion

The green banana pulp flour was distinguished by its higher starch content and clarity. The WGBF had higher ash, fiber, and protein contents. The mixture of OPNF with banana flours increased the protein and minerals content, mainly Mg, Fe, and Zn, and these were darker and with higher water absorption rates. Mixed banana and OPNF can be ingredients for gluten-free products, due to their nutritional and technological properties.

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