Green banana biomass (*Musa* sp.) as an ingredient in the development of pasta

Biomassa de banana verde (Musa sp.) como ingrediente no desenvolvimento de massas alimentícias

Biomasa de plátano verde (Musa sp.) como ingrediente en la elaboración de pastas

Layla Pereira do Nascimento Tinoco
ORCID: https://orcid.org/0000-0003-3387-9341
Federal Rural University of Rio de Janeiro, Brazil
E-mail: laylatinoco@yahoo.com.br
Lorena de Sá Oliveira
ORCID: https://orcid.org/0000-0002-5598-3361
Federal Rural University of Rio de Janeiro, Brazil
E-mail: lorenaoliveira.sa@gmail.com
Ivanilda Maria Augusta
ORCID: https://orcid.org/0000-0002-5725-2431
Federal Rural University of Rio de Janeiro, Brazil
E-mail: ivanildamariaa@yahoo.com.br
José Lucena Barbosa Junior
ORCID: https://orcid.org/0000-0001-8496-1404
Federal Rural University of Rio de Janeiro, Brazil
E-mail: lucenadta@gmail.com
Maria Ivone Martins Jacintho Barbosa
ORCID: https://orcid.org/0000-0002-9624-9139
Federal Rural University of Rio de Janeiro, Brazil
E-mail: mivone@gmail.com

Abstract
Green banana biomass (GBB) can be used as a functional and technological ingredient in various food preparations, making them healthier and more nutritious. The aim of the present study was to determine the physicochemical compositions as well as color parameters of different GBB samples, and applying them to gnocchi pasta to determine the resulting technological and cooking properties. The bananas ('BRS Platina, 'Fhia 01,' and 'Fhia 18') were grown in an area of the Agroecological Production Integrated System, in Seropédica-RJ, Brazil; the bananas were harvested unripe and pressured cooked to obtain their biomass. The pH values, total titratable acidity, total soluble solids, reducing sugars, moisture, ash, proteins, lipids, total starch, total energetic value (TEV), vitamin C, total phenolic compounds (TPC), minerals, and color were significantly different among the different GBB samples used. Each GBB showed different values of certain analyzed parameters; for instance, 'BRS Platina' presented low contents of total starch, lipids, TEV and high levels of vitamin C and TPC. The GBB 'Fhia 01'presented the highest levels of moisture, proteins, and potassium. All GBBs provided good technological attributes (cooking time, weight increase, cooking loss, and volume increase) for the prepared gnocchi dough. Overall, the application of GBB as an ingredient in gnocchi formulation provided good technological quality and increased nutritional value, thus meeting the growing demand of the consumer market for products with greater health benefits.
Keywords: Unripe banana; Cooking quality; Functional ingredients.

Resumo
A biomassa de banana verde (BBV) pode ser utilizada como ingrediente funcional e tecnológico em diversas preparações de alimentos, tornando-os mais saudáveis e nutritivas. O objetivo do presente estudo foi determinar as composições físico-químicas, bem como os parâmetros de cor de diferentes amostras de BBV, e aplicá-las à massa de nhoque para determinar as propriedades tecnológicas e de cozimento resultantes. As bananas ('BRS Platina, 'Fhia 01' e 'Fhia 18') foram cultivadas em uma área do Sistema Integrado de Produção Agroecológica, em Seropédica-RJ, Brasil; as bananas foram colhidas verdes e cozidas sob pressão para obtenção de suas biomassas. Os valores de pH, acidez total titulável, sólidos solúveis totais, açúcares redutores, umidade, cinzas, proteínas, lipídios, amido total, valor energético total (VET), vitamina C, compostos fenólicos totais (CFT), minerais e cor foram significativamente diferentes entre as diferentes amostras de BBV usadas. Cada BBV apresentou diferentes valores dos parâmetros analisados; por exemplo, a BBV 'BRS Platina' apresentou baixos teores de amido total, lipídios, VET e altos teores de vitamina C e CFT. A BBV 'Fhia 01' apresentou os maiores teores de umidade, proteínas e potássio. Todas as BBVs forneceram bons atributos tecnológicos (tempo de cozimento, aumento de peso, perda de cozimento e aumento de volume) para a massa de nhoque preparada. De maneira geral, a aplicação da BBV como ingrediente na formulação do nhoque proporcionou boa

qualidade tecnológica e aumento do valor nutricional, atendendo assim a crescente demanda do mercado consumidor por produtos com maiores benefícios à saúde.

Palavras-chave: Banana verde; Qualidade de cozimento; Ingredientes funcionais.

Resumen

La biomasa de banano verde (BBV) puede ser utilizada como ingrediente funcional y tecnológico en diversas preparaciones alimenticias, haciéndolas más saludables y nutritivas. El objetivo del presente estudio fue determinar las composiciones fisicoquímicas así como los parámetros de color de diferentes muestras de BBV, y aplicarlos a la masa de ñoquis para determinar las propiedades tecnológicas y de cocción resultantes. Los bananos ('BRS Platina, 'Fhia 01' y 'Fhia 18') fueron cultivados en un área del Sistema Integrado de Producción Agroecológica, en Seropédica-RJ, Brasil; los bananos se cosecharon verdes y se cocieron bajo presión para obtener su biomasa. Los valores de pH, acidez titulable total, sólidos solubles totales, azúcares reductores, humedad, cenizas, proteínas, lípidos, almidón total, valor energético total (TEV), vitamina C, compuestos fenólicos totales (CFT), minerales y color fueron significativamente diferentes. entre las diferentes muestras de BBV utilizadas. Cada BBV presentó valores diferentes de los parámetros analizados; por ejemplo, BBV 'BRS Platina' mostró bajos niveles de almidón total, lípidos, VET y altos niveles de vitamina C y CFT. Y el BBV 'Fhia 01' mostró los niveles más altos de humedad, proteína y potasio. Todos los BBV proporcionaron buenos atributos tecnológicos (tiempo de cocción, ganancia de peso, pérdida de cocción y aumento de volumen) para la masa de ñoquis preparada. En general, la aplicación de BBV como ingrediente en la formulación de ñoquis proporcionó buena calidad tecnológica y mayor valor nutricional, atendiendo así la creciente demanda del mercado consumidor por productos con mayores beneficios para la salud.

Palabras clave: Plátano verde; Calidad de horneado; Ingredientes funcionales.

1. Introduction

Over the last few years, interest in bananas has increased, mainly in the ripening stage, owing to research on the application of its biomass as a powerful ingredient for preparing different pasta products (Dias et al., 2011; Oliveira, 2015; Castelo-Branco et al., 2017; Marques et al., 2016; Silva et al. 2017; Souza et al., 2018). This fact is correlated with the functional and technological properties of GBB attributed to the presence of resistant starch in its matrix (Mastro et al., 2007; Cassettari et al., 2019).

Its technological properties are related to its action as an emulsifying, thickening, and gelling agent in foods in which it is used, in addition to not altering the original sensory characteristics, and maintaining its color, flavor, and odor (Padam et al., 2014; Ranieri & Delani, 2014; Costa, 2017). Therefore, green banana biomass (GBB) can be used to formulate various sweet and savory preparations (Marques et al., 2016).

With regard to functional properties, GBB promotes a prebiotic effect on the intestinal microbiota, stimulating its growth and development, in addition to enhancing the immune system, reducing the incidence of inflammation in the intestinal mucosa and constipation as well as reducing and controlling the development of chronic non-communicable diseases, such as type 2 diabetes, high blood pressure, dyslipidemia, and obesity (Oliveira; Santos; Santos, 2016; Costa et al., 2017; Vogado et al., 2018; Cassettari et al., 2019). It is important to highlight that the incidence of these diseases has been increasing in the population over the last few years, accounting for approximately 70% of mortality rates globally (World Health Organization, 2018).

Therefore, it is appropriate to consider the application of GBB in conventional pasta products as a substitute for commonly used industrial ingredients that are rich in saturated fats, hydrogenated fats, and simple sugars (Izidoro et al., 2008; Dinon et al., 2014; Souza et al., 2018). Pastas are consumed worldwide, and are prepared using durum wheat flour and semolina or flour from other cereals and/or tubers as the main ingredients (Punia et al., 2019). However, they have a high content of simple carbohydrates and high caloric value in addition to a low content of minerals and fibers, which are essential nutrients for maintaining human health (Omeire et al., 2014).

Based on the increasing incidence of diseases as mentioned above, a worldwide market trend has been observed regarding the search for healthier foods (Shammakh et al., 2020), which has been promoting the mobilization of food industries

to adapt their products, reduce the use of additives, chemicals, artificial colors, sugars, sodium, and fats (Pires, 2020; Boukid, 2021; Wan et al., 2021; Santos et al., 2021; Souto et al., 2021).

GBB is a food ingredient that fits in this context by increasing the healthiness of the preparations to which it is added, in addition to having great potential for improving the functional and technological properties of pasta. However, the effects of different banana cultivars on the physicochemical, nutritional, and cooking qualities of pasta containing GBB remain unclear. The aim of the present study was to develop three cultivars of green banana, to determine their mineral and physicochemical compositions, as well as color parameters, and applying them to gnocchi pasta to evaluate their technological quality.

2. Methodology

2.1 Elaboration of green-banana biomass

Organic bananas (*Musa* sp.) of 'BRS Platina,' 'Fhia 01,'and 'Fhia 18'cultivars were used in the first ripening stage, including unripe banana peels (Loesecke, 1950).

The bananas were cultivated in the Agroecological Production Integrated System, located in Seropédica, Rio de Janeiro, Brazil (22° 48'00''S and 43° 41'00''W).

The studied GBBs were obtained as described by Marques et al. (2016), with minor modifications. Bunches of bananas were dismembered manually and using a knife, and the peels were visually inspected to scrutinize the presence of defects (discolored spots on the peels and lesions that reached the pulp).

Selected bananas (1 kg of each cultivar) were sanitized using sodium hypochlorite solution (200 ppm) for 15 min and rinsed in tap water. The samples were then cooked in a pressure cooker (Polished Pressure Cooker 10 L 24 cm, Tramontina®, São Paulo, Brazil) with a capacity of 10 L for 20 min in boiling water. The bananas were then peeled using cutlery and processed in a blender (PH900, Philco®, São Paulo, Brazil) until a smooth homogeneous cream was obtained. The biomass was transferred to airtight glass containers, and stored at 4 °C in a refrigerator (TC41, Continental®, Curitiba, Brazil) until further analysis.

2.2 Determination of mineral and physicochemical composition

The pH value was determined as described by Anyasi et al. (2015) using a digital potentiometer (8255, DIGILAB, São Paulo, Brazil). The total soluble solid content was determined using a portable refractometer (RT-280, Instrutherm, São Paulo, Brazil) as described by Youryon e Supapvanich (2017). Total acidity was determined by direct titration using a NaOH solution (0.1 mol/L) according to AOAC (2010). The total reducing sugar content was determined as described by Somogy (1945) and Nelson (1944). The total starch content was determined through prior acid hydrolysis of starch to sugars followed by quantification as described by Lane e Eynon (ASEAN Manual of Food Analysis, 2011). The moisture, ash, lipid, and protein contents were determined according to the guidelines of AOAC (2010). The total phenolic compound contents were determined by spectrophotometry using the Folin-Ciocalteu calorimetric method as described by Swain & Hillis (1959). The vitamin C content was determined according to the method of Strohecker e Henning (1967). The mineral content was determined using the USEPA 3050 method (Edgell, 1989). The total energetic value (TEV), expressed in calories (kcal), was determined using the conversion factors described in RDC 360 of the National Health Surveillance Agency (ANVISA) (Brazil, 2003), as per the following equation:

$$\text{TEV} = 4 \times (\text{g proteins} + \text{g carbohydrates}) + 9 \times (\text{g lipids})$$

2.3 Determination of color parameters

The color parameters (coordinates L*, a*, b*) and chroma (C*) were determined as described by Ndangui et al. (2014) using a colorimeter (MiniScan EZ, São Paulo, Brazil).

2.4 Preparation of gnocchi enriched with GBB

For preparing gnocchi, which was prepared according to the method of preparing english potato gnocchi described in the Brazilian Food Composition Table (TACO, 2011), 49% p/p of GBB (for each cultivar), 40% p/p of brown rice flour, 10% p/p of olive oil, and 1% p/p of salt were homogenized until a consistent and homogeneous mixture was obtained; this was modeled in cubic shapes (approximately 3 cm edges) and then cooked in boiling water. At the end of cooking, the gnocchi were placed in airtight containers and stored in a freezer at-18 °C.

2.5 Cooking qualities

Cooking time was determined according to methods n° 66–50 from AACC (1989), and the weight and volume increases were determined as described by Silva, Rossini & Carvalho (2016). Loss of soluble solids was determined as described by Fradique et al. (2010).

2.6 Statistical analysis

All analyses were performed in triplicate and the final data were expressed as mean value and standard deviation and were analyzed using the analysis of variance (ANOVA). When the results differed significantly among groups, the Tukey test was applied at a 5% significance level ($p \leq 0.05$) using Statistica 7.0® software.

3. Results and Discussion

3.1 Physicochemical characterization of green banana biomass

The values of pH, total soluble solids (SST), total titratable acidity (ATT), and reducing sugars were directly related to the fruit maturation stage. The main organic acids found in bananas include malic, citric, and oxalic acids. The pH and acidity of fruits influence their sensory qualities (Adi et al., 2019).

The parameters of pH, SST, and reducing sugars, which were related to the ripening stage of bananas, affected the GBB ($p \leq 0.05$) based on the banana cultivar used (Table 1).

Table 1. Physicochemical characteristics of green banana biomass.

Parameters* (g/100 g)	Green banana biomass 'BRS Platina'	'Fhia 01'	'Fhia 18'
pH	5.06 ± 0.025^c	5.63 ± 0.015^a	5.47 ± 0.016^b
Total soluble solid (°Brix)	4.00 ± 0.01^a	4.00 ± 0.01^a	3.90 ± 0.01^b
[1]Total titratable acidity (%)	0.130 ± 0.001^a	0.140 ± 0.003^a	0.140 ± 0.003^a
Reducing sugars (%p/v)	4.6 ± 0.01^b	4.4 ± 0.02^b	3.8 ± 0.02^a
Moisture	78.79 ± 0.45^c	81.62 ± 0.5^a	80.63 ± 0.09^b
Ash	$0.61 \pm 0,0^a$	$0.52 \pm 0,13^c$	$0.57 \pm 0,02^b$
Lipids	$0.13 \pm 0,02^b$	$0.18 \pm 0,01^b$	$2.50 \pm 0,31^a$
Proteins	2.13 ± 0.12^c	3.78 ± 0.13^a	3.16 ± 0.12^b
Total starch	16.51 ± 0.06^b	16.34 ± 0.06^c	21.50 ± 0.10^a
TEV (Kcal)	75.73 ± 0.25^c	82.10 ± 0.24^b	121.14 ± 0.31^a
Ascorbic acid (mg/100 g)	16.87 ± 0.70^a	14.26 ± 0.60^c	15.87 ± 0.06^b
TPC (mg GAE/100 g)	24.57 ± 0.09^a	15.77 ± 0.22^b	11.71 ± 0.23^c
Minerals (mg/100 g)			
Calcium	12.71 ± 0.05^c	15.91 ± 0.20^b	16.14 ± 0.07^a
Potassium	63.79 ± 0.08^b	96.09 ± 0.10^a	59.98 ± 0.25^c
Magnesium	11.68 ± 0.12^b	10.83 ± 0.05^c	13.06 ± 0.23^a
Manganese	0.13 ± 0.07^a	0.12 ± 0.19^b	0.08 ± 0.35^c
Iron	0.12 ± 0.10^b	0.08 ± 0.23^c	0.14 ± 0.16^a
Copper	0.07 ± 0.20^b	0.08 ± 0.16^a	0.04 ± 0.39^c
Zinc	0.42 ± 0.34^a	0.26 ± 0.67^b	0.14 ± 0.46^c
Sodium	7.37 ± 0.06^b	8.01 ± 0.19^a	7.28 ± 0.28^b
Color			
L*	50.84 ± 0.76^c	$57,36 \pm 0.20^a$	59.59 ± 0.24^a
a*	15.94 ± 0.24^a	$9,60 \pm 0.09^b$	9.83 ± 0.06^b
b*	17.73 ± 0.51^a	$10,72 \pm 0.,25^c$	15.18 ± 0.26^b

Values expressed as triplicate average $\pm$ standard deviation; Values in the same line followed by different letters differ significantly from each other in the Tukey Test ($p \leq 0.05$). [1]Expressed as malic acid; [2]TEV: total energetic value (expressed as calories per 100 g of sample); [3]Ascorbic Acid: Values expressed as mg per 100 g of sample; [4]TPC: Total Phenolic Compounds: Values expressed as mg gallic acid equivalent per gram of dry sample (mg GAE/g of dry sample); L: brightness, a*: variation in color from green (-a*) to red (+ a*), b*: Variation in color from blue (-b*) to yellow (+ b*), C*: Degree of color saturation. Source: Authors (2022).

The low content of reducing sugars presented in the GBBs is attributed to the fact that during the initial stages of maturation in the green banana, there is almost no degradation of starch to reducing sugars by enzymatic processes in its pulp. This process occurs as the banana ripens, reducing the amount of starch and increasing simple sugars with a sweet taste, such as sucrose, glucose, and fructose (Mohan et al., 2014). The GBB 'Fhia 01' (Table 1) had a lower content of reducing sugars ($p \leq 0.05$) and these values were similar to those determined by Salih et al. (2017) in green banana pulp (*Musa Cavendish*) with 3.21% reducing sugars.

The types of banana cultivars ($p \leq 0.05$) influenced and affected the content of moisture, protein, starch, and TEV in GBB (Table 1). The nutrient content can also vary according to the pre- and post-harvest treatment of the fruit and the climatic variations of the environment in which they were grown.

The highest level of vitamin C was observed ($p \leq 0.05$) in GBB 'BRS Platina', followed by that in GBB 'Fhia 18' and 'Fhia 01' (Table 1). These contents were lower than those reported by Riquette et al. (2019), who obtained values of 23.10–54.40 mg/100 g in GBB (*Musa Cavendish*) with different cooking times.

Phenolic compounds confer several health benefits owing to their antioxidant activity, slowing the premature aging of cells and tissues, and reducing the development of cancer (Singh et al., 2016). GBB 'BRS Platina' had the highest content of phenolic compounds (Table 4), but lower than 189.90 to 334.40 mg of GAE / 100 g in GBB (*Musa Cavendish*) as reported by Riquette et al. (2019).

Minerals are essential nutrients for the proper functioning of organism and maintenance of human health; some of them are also necessary for body structure formation and maintenance, thus making their adequate nutritional intake necessary (Hazell, 1985). The mineral content analysis showed that none of the GBBs supplied the recommended daily intake requirements for children and adults indicated by the Institute of Medicine (2001) and RDC 269 of ANVISA (Brazil, 2005).

Color is one of the main attributes for measuring food quality and is a fundamental aspect of its appearance, which influences its acceptance for consumption, indicating its level of freshness, quality, and expectations regarding its flavor (Fradique et al., 2010).

GBB 'BRS Platina' had the lowest luminosity parameter (L*) compared with the GBB of 'Fhia 01' and 'Fhia 18' ($p \leq 0.05$) (Table 4). The luminous tone of the 'Fhia 18' GBB was the closest to the value of 64.33% L* as reported in green banana flours by Campuzano et al. (2018).

GBB 'BRS Platina' showed a greater tendency for reddish coloring (a*) in relation to GBB 'Fhia 01' and 'Fhia 18' ($p \leq 0.05$) (Table 1), whose values were higher than those reported by Savlak et al. (2016) in green banana flours (1.83–2.23) and by Anyasi, Jideani, and Mchau (2015) in green banana cultivars of different species (2.14–4.64).

The values for parameter b* were different among the three GBBs used in the present study ($p \leq 0.05$) (Table 5), similar to the observations by Anyasi et al. (2015) in green banana flour (9.36–18.80). The GBB of 'BRS Platina' and 'Fhia 18' showed a greater tendency to yellowish color compared to the GBB of 'Fhia 01', where the latter showed a value similar to that found by Savlak et al. (2016) (11.81–13.47) in green banana flours.

The GBB of 'BRS Platina' showed higher saturation (C*) in its matrix, followed by GBB 'Fhia 18' and 'Fhia 01' (Table 5), ($p \leq 0.05$); these values were higher than those reported by Anyasi et al. (2015) and by Savlak et al. (2016) in green banana flours, at 9.61–19.10 and 11.95–13.93, respectively. In contrast, Riquette et al. (2019) obtained values from 12.86 to 19.28 in GBB (*Musa Cavendish*), similar to those obtained in GBB in the present study (Table 5).

3.2 Cooking test of green banana biomasses gnocchi

The cooking time (CT) differed significantly only regarding the gnocchi of 'BRS Platina' cultivar ($p \leq 0.05$) (Table 2), in which was observed a higher CT for the gnocchi from 'Fhia 18' GBB (Table 2). This parameter is associated with the cohesion of pasta product during the cooking process, in which, the CT of GBB gnocchi were lower than that reported by Silva, Rossini, & Carvalho (2016), who obtained 175 seconds for cooking of gnocchi from sweet potato orange-colored pulp.

Table 2. Cooking test of green banana biomass gnocchi.

Parameters*	Green banana biomasses gnocchi		
	'BRS Platina'	'Fhia 01'	'Fhia 18'
Cooking time (seconds)	110 ± 0.04[a]	106 ± 0.03[b]	102 ± 0.02[b]
Weight Increase (%)	6.73 ± 0.04[a]	6.17 ± 0.06[c]	6.53 ± 0.05[b]
Volume Increase (%)	13.33 ± 0.72[a]	10.37 ± 0.64[c]	12.91 ± 0.72[b]
Loss of Soluble Solids (%)	0.636 ± 0.004[c]	0.730 ± 0.006[b]	0.931 ± 0.006[a]

*Values expressed in triplicate average ± standard deviation; Values in the same line followed by different letters differ significantly from each other in the Tukey test ($p \leq 0.05$). Source: Authors (2022).

The shortest cooking times (TC) were obtained for the GBB gnocchi of 'Fhia 18' and 'Fhia 01' in relation to the GBB gnocchi of 'BRS Platina' ($p \leq 0.05$) (Table 2). This parameter is associated with the cohesion of pasta during the cooking process, in which the TC of GBB gnocchi was lower than that reported by Silva, Rossini & Carvalho (2016) as 175 seconds for cooking orange-fleshed sweet potato gnocchi (OFSP), thus demonstrating greater speed and practicality in cooking GBB gnocchi.

The greatest increase in weight (IW) and volume ($p \leq 0.05$) were obtained in the GBB gnocchi of 'BRS Platina' (Table 2), with values similar to those reported by Silva, Rossini & Carvalho (2016) and Cappa et al. (2017) in OFSP gnocchi and commercial gluten-free potato gnocchi as IW from 6.27 to 13.87% and 2.45 to 7.71%, respectively.

The GBB gnocchi of 'BRS Platina' had the lowest loss of soluble solids (LSS) ($p \leq 0.05$) (Table 2), in this study as well as in relation to the LSS obtained by Cappa et al. (2017) in gluten-free potato gnocchi (1.23 to 5.04%), by Alessandrini et al. (2010) in different formulations of potato gnocchi (1.72%), by and Burgos et al. (2019) in Andean potato gnocchi (*Solanum tuberosum ssp. Andigena*) and Huaichas (*Quebrada de Humahuaca*) (0.41%, 0.64%, and 1.45%, respectively).

LSS represents the main attribute of pasta quality, wherein values less than 6% are considered good results, values up to 8% are considered normal, and values greater than 10% are considered low-quality because of the great exudation of starch, generating high turbidity in cooking water (Hummel, 1966).

4. Conclusion

Considering the above results, parameters related to the banana ripening stage (pH, TSS, and reducing sugars), moisture, proteins, total starch, TEV, vitamin C, and total phenolics in green banana biomass were affected by the different green banana cultivars used. Pasta enriched with GBB exhibited good cooking quality (cooking time, weight and volume increase, and loss of soluble solids). Furthermore, the application of green banana biomass as an ingredient can increase the nutritional value and quality of cooking in different pastas, making them healthier and catering to the growing consumer market in search of less processed and healthier products.

In addition, future studies are suggested regarding the application of BBV in other types of food products, their nutritional and functional impacts, as well as their microbiological stability and sensory acceptance, verifying the purchase intention of these new products if they are available for sale in the markets.

Acknowledgments

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