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Nutritional and technological potential of whole unripe Bluggoe and Prata-Anã banana flours

Potencial tecnológico e nutricional de farinhas integrais de bananas verde Figo e Prata-Anã

Potencial tecnológico y nutricional de las harinas integrales de plátanos verde Figo y Prata-Anã

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Abstract

The objective of this work was to evaluate the nutritional and technological potential of whole unripe Prata-Anã and Bluggoe flours. Both types of bananas were selected at stage 1 of ripening, including pulp and peel to obtain flour. Determinations of yield, color, chemical composition, resistant starch (RS), antioxidant capacity, total phenolics, tannins, water activity, water absorption, water solubility, oil absorption, and viscosity were carried out. Unripe Prata-Anã and Bluggoe flours presented average yields of 24.2 % and 24.8 %, respectively. The Bluggoe cultivar had a higher pulp content (62.9 %), and Prata-Anã had a higher peel content (41.4 %). A higher RS content and antioxidant capacity for the Prata-Anã cultivar was verified. On the other hand, the Bluggoe cultivar presented a higher fiber content. Prata-Anã WUBF presented higher nutritional and technological application potential. However, both flours require heating during preparation, or pre-cooking, when applied to new food products.

Keywords: Unripe banana; Sustainability; Resistant starch; Bioactive compounds.

Resumo

O objetivo deste trabalho foi avaliar o potencial nutricional e tecnológico das farinhas integrais de bananas verde (FIBV) Figo e Prata-Anã. Os frutos foram selecionados no estágio 1 de maturação, incluindo polpa e casca, para obtenção de farinha. Foram realizadas determinações de rendimento, cor, composição química, amido resistente (AR), capacidade antioxidante, fenólicos totais, taninos, atividade de água, absorção de água, solubilidade em água, absorção de óleo e viscosidade. As FIBV Figo e Prata-Anã apresentaram rendimentos médios de 24,2 % e 24,8 %, respectivamente. A cultivar Figo apresentou maior teor de polpa (62,9 %) e Prata-Anã, maior teor de casca (41,4 %). Verificou-se maior teor de AR e capacidade antioxidante para a cultivar Prata-Anã. Por outro lado, a cultivar Figo apresentou maior teor de fibra alimentar. A FIBV Prata-Anã apresentou maior potencial nutricional e de aplicação tecnológica. No entanto, as farinhas de ambas cultivares requerem aquecimento durante o preparo, ou pré-cozimento, quando aplicadas a novos produtos alimentícios.

Palavras-chave: Banana verde; Sustentabilidade; Amido resistente; Compostos bioativos.

Resumen

El objetivo de este trabajo fue evaluar el potencial nutricional y tecnológico de las harinas integrales de plátano verde (HIPV) Figo y Prata-Anã. Los frutos fueron seleccionados en la etapa 1 de maduración, incluyendo pulpa y piel, para obtención de las harinas. Se realizaron determinaciones de rendimiento, color, composición química, almidón resistente (AR), capacidad antioxidante, fenoles totales, taninos, actividad de agua, absorción de agua, solubilidad en agua, absorción de aceite y viscosidad. HIPV Figo y Prata-Anã tuvieron rendimientos promedio de 24,2 % y 24,8 %, respectivamente. El cultivar Figo tuvo un mayor contenido de pulpa (62,9 %) y Prata-Anã, un mayor contenido de piel (41,4 %). Hubo mayor contenido de AR y capacidad antioxidante para el cultivar Prata-Anã. Por otro lado, el cultivar Figo tuvo un mayor contenido de fibra dietética. HIPV Prata-Anã mostró mayor potencial nutricional y aplicación tecnológica. Sin embargo, las harinas de ambos cultivares requieren calentamiento durante la preparación, o precocción, cuando se aplican a nuevos productos alimenticios.

Palabras clave: Plátano verde; Sustentabilidad; Almidón resistente; Compuestos bioactivos.

1. Introduction

Banana is one of the most commercialized products in the world. Its production reaches about 114 million tons per year, and it is grown in more than 130 countries. Brazil produces about 7 million tons of bananas annually and is classified as the world's fourth largest producer (FAO 2018).

The use of unripe banana flour has aroused the interest of researchers and the industry due to its composition, including dietary fiber, proteins, essential amino acids, polyunsaturated fatty acids, and potassium (Singh, Singh, Kaur, & Singh, 2016). Furthermore, peels of a variety of fruits and plants are gaining attention as a natural source of polyphenols and bioactive compounds (Sundaram, Anjun, Dwivedi, & Rai, 2011).

Unripe banana starch has attractive characteristics for industrial application due to its significant levels of amylose, high peak viscosity, final viscosity, and expressive levels of RS (Leonel, Carmo, Leonel, Franco, & Campanha, 2011), considered a prebiotic food component (Homayouni et al., 2013).

Banana peel is a major by-product in the pulp industry and represents about 35% of the total fruit mass. In Brazil alone, around 1.2 million tons of banana peel residues are generated annually (Emaga, Andrianaivo, Wathelet, Tchango, & Paquot, 2007).

Thus, the production of WUBF contributes to reducing these losses, increasing the shelf life, adding value to the fruit, and diversifying consumption (Bezerra, Amante, Olivera, Rodrigues, & Silva, 2013).

Prata-Anã is a cultivar commonly consumed *in natura*, but Bluggoe is used mainly cooked and has technological potential since it is recognized for its resistance to drought and diseases (Jones, 1999).

One of the difficulties found is that there is almost no definition of the fruit's ripening stage, in the literature, since the RS content can vary from 4% to 62% throughout its post-harvest period (Liao, & Hung, 2015). It should be noted that, when the information is present, there is no quoted reference that establishes the fruit selection criteria based on the stage of ripeness (Franca et al., 2020). According to Campuzano, Rosell and Cornejo (2018), while in stages 1 and 2 of ripening the levels of RS in bananas do not change, in stages 2 and 3 a reduction of more than 50 % in the RS content is observed. Thus, the objective of this work was to evaluate the nutritional and technological potential of whole unripe Prata-Anã and Bluggoe flours, at stage 1 of ripening.

2. Methodology

This is an experimental quantitative study (Pereira, Shitsuka, Parreira, & Shitsuka, 2018) carried out in the Dietary Technique and Bromatology Laboratories, at Federal University of Espirito Santo, Health Sciences Center – Vitória, ES – Brazil. This research also was carried out in the pilot plant of food extrusion at Embrapa Food Technology – Rio de Janeiro, RJ – Brazil.

2.1 Raw material, preparation, and yield of whole unripe banana flours (WUBF)

Two banana cultivars were used in the study: Prata-Anã (AAB) and Bluggoe (ABB), donated in December 2018 from the same plant, by the Alfredo Chaves Experimental Farm (FEAC) of the Capixaba Institute of Research, Technical Assistance and Rural Extension (INCAPER), located in the state of Espirito Santo, Brazil. Samples of unripe bananas were selected in a non-probabilistic convenience way. Only bananas in stage 1 of ripening (1.2 to 2.1 ºBrix) (Von Loesecke, 1950) were used. The Prata-Anã and Bluggoe bananas were selected, washed in running tap water, and sanitized with sodium hypochlorite (1 mL/L) (Hidrosteril®). Then, they were sliced (with the peel), 4 mm thick. During this process the slices were kept water immersed, at room temperature, to avoid enzymatic browning. The banana slices were boiled for 5 minutes to inactivate endogenous enzymes and drained to eliminate excess water. The material was organized in stainless steel trays and dried in an air circulating oven (Tecnal TE-394/2, Piracicaba-BR) at 60 °C (Farias et al., 2020; Silva Júnior et al., 2020) for 16 hours. The air temperature was controlled to be lower than the starch gelatinization temperature (<68 ºC). The dried material was processed in a blender (Arno LN720011, São Paulo-BR) for 2 minutes and then grounded in a rotor mill (Tecnal TE651-2, Piracicaba-BR) using a sieve with a 0.8-mm opening. The whole flours were weighed and stored in a refrigerator at a maximum temperature of 10 °C in glass jars protected from light. The percentage of flour yield was calculated based on the following equation: Yield (%) = Final flour weight/initial weight of unripe banana x 100 (Eq.1). Five fresh bananas from each cultivar were selected, and the pulp and peel were weighed separately. The values obtained were substituted into equation 2: Pulp/Peel (%) = Weight pulp or peel/weight of unripe banana x 100 (Eq. 2).

2.2 Instrumental color

The instrumental measurement of the color of WUBF was performed in a colorimeter (Hunterlab Color Quest XE, Virginia-USA). The device was set to illuminating condition D65 (daylight average) and a 10 º (field of view) standard observer. The CIELAB and CIELChe scales were used, and the color coordinates measured were L * = luminosity (0 = 100 = black and white), a * = red-green color (-80 to 0 = green, 0 to 100 = red), and b * = yellow-blue color (-100 to 0 = blue, 0 to + 70 = yellow). The hue (T *) and saturation (C *) were calculated from the values of a * and b *, according to equations 3: h * = arctang (b */a *) (Eq. 3) and 4: C * = [(a *) + (b *)] 1/2 (Eq. 4).

2.3 Chemical composition and antioxidant activity

Moisture (925.45), total protein (960.52), fat (920.39), and ash (923.03) contents were determined according to AOAC methods (2005). The conversion factor used for protein determination was N g/100 g x 6.25. Dietary fiber was determined according to the gravimetric enzymatic method (985.29) (AOAC, 2005). The total carbohydrate content was calculated by difference, as follows: 100 – (moisture + ash + protein + fat). For available carbohydrates, the dietary fiber content was considered. The energy value was defined in kcal according to the following formula: = energy (% of protein x 4) + (% of carbohydrates x 4) + (% of lipids x 9) and the value in kJ, by multiplying the energy value by 4,184. To measure water activity, 10 g of each flour was placed in a glass container and subsequently read on the analyzer (Rotronic Hygro Lab C1 User Manual, New York-USA) following the manufacturer's procedures. The content of RS in WUBF was determined according to the procedure described by Koakuzu, Araújo, Bassinello, Carvalho and Teixeira (2015), with a spectrophotometer reading at 510 nm. The calculations were performed according to equation 5: RS (g/100 g) = (Absorbance RS) x (100/average of the glucose standard absorbance conversion factor) x (Final measured sample volume/Dry Weight) x 0.9 (Eq. 5).

2.4 Bioactive compounds

Sample extraction

Extracts of WUBF were obtained as described by Rufino et al. (2007). For determination of antioxidant capacity, the DPPH Method (2,2-diphenyl-2-picrilhydraz) was used. For total phenolic compound content, 1.5 g of each sample was extracted.

Total phenolic content

Phenolic compounds were determined using Folin–Ciocalteu reagent, according to the methodology described by Singleton, Orthofer and Lamuela-Raventós (1999), using a standard gallic acid curve as a reference (Gallic acid curve: y = 14.984x – 0.065 and R^2 = 0.960).

Antioxidant capacity (DPPH radical-scavenging activity)

Antioxidant capacity was measured using the method described by Blois (1958). Antioxidant capacity was calculated as percent discoloration, according to equation 1.

DPPH scavenging activity (%) = 100% –{(Abs $_{sample}$ – Abs $_{blank/}$Abs $_{control}$) x 100 (eq. 1).

Tannins

Tannins were determined by the spectrophotometric method according to the methodology described by Price, Hagerman and Butler (2010). For the extracts, 1.0 g of each

WUBF was used. A standard catechin curve was used as a reference, and the results were expressed as mg catechin/100 g sample (Line equation: $y = 0.154x + 0.030$ and $R^2 = 0.966$).

2.5 Water absorption, solubility, and oil absorption indexes

The determinations of the water absorption (WAI) and water solubility (WSI) indexes were carried out according to Anderson, Conway, Pfeifer and Griffin (1969) with modifications, using 1 g of each flour for 10 mL of distilled water in the tubes. For the oil absorption index (OAI), the same methodology was used, replacing distilled water with soybean oil. The results were applied in the following equations: WAI (g) or OAI (g) = weight of the centrifuged residue (g)/weight of the sample (g) (Eq. 6) and WSI (%) = (weight of the evaporated residue (g)/weight of the sample in (g)) x 100 (Eq. 7).

2.6 Paste viscosity

The viscoamilographic properties of WUBF were determined with a Rapid Visco Analyzer (RVA - Perten, Hägersten-Sweden). Three grams of each flour were weighed, and distilled water was added until a final weight of 28 g was reached. The following parameters were used to interpret viscoamilograms: initial viscosity (V25) at 25 ºC, maximum viscosity (V_{Max}) at 95 ºC, and final viscosity (VF) at 25 ºC in the cooling cycle.

2.7 Data analysis

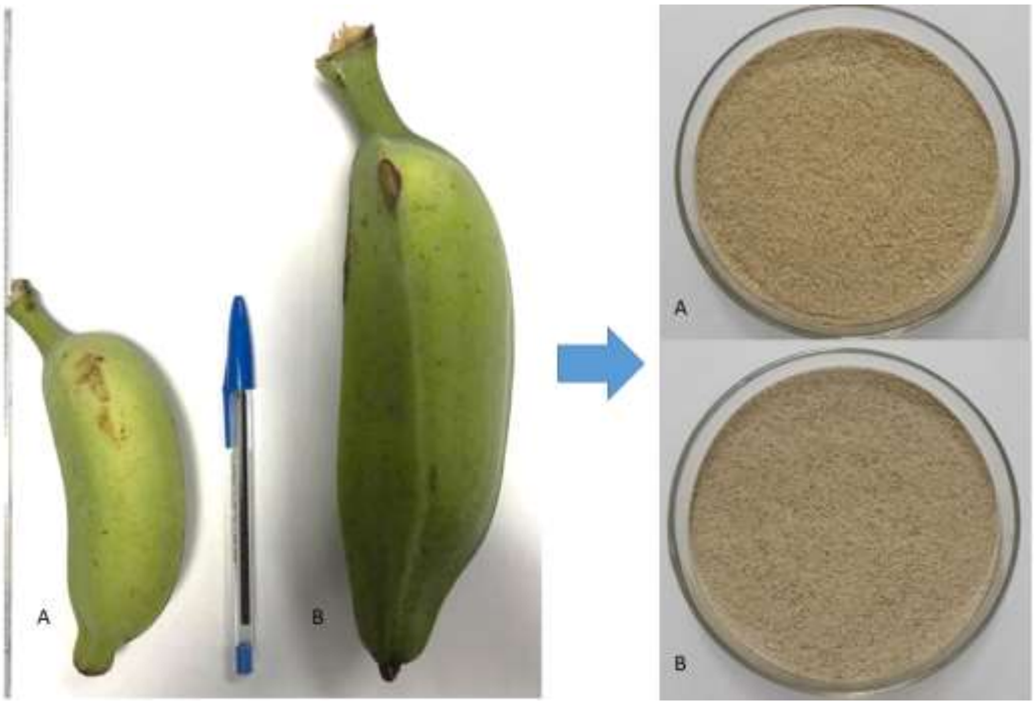
The results were tested for normality using the Shapiro-Wilk test, which showed a normal distribution of the data. The Student’s t-test was used to compare the two WUBF used in this study. All statistical analyses were performed using the Statistical Package for the Social Sciences software version 23.0 (IBM, Armonk, New York, USA), and for all evaluations, a probability of 5% was considered.

3. Results and Discussion

3.1 Yield of fresh bananas and whole unripe banana flours

The two unripe cultivars, Prata-Anã e Bluggoe, as well as their respective whole flours can be seen at Figure 1.

Figure 1 - Prata-Anã (A) and Bluggoe (B) cultivars and their respectively whole flours.



Source: Authors (2020).

It is noteworthy that both flours have a homogeneous appearance (Figure 1). A higher pulp content was observed for the cultivar Bluggoe (62.9 %) and a higher peel content for the cultivar Prata-Anã (41.4 %). These proportions may interfere with the quality, chemical composition, rheological and thermal properties, and bioactive phytochemical content of WUBF (Castelo-Branco et al. 2017).

The Prata-Anã and Bluggoe WUBFs showed an average yield of 24.2 % and 24.8 %, respectively.

3.2 Instrumental color

The WUBF presented greater luminosity, closer to white (75.56 ± 0.15 for Prata-Anã and 75.18 ± 0.06 for Bluggoe). The Prata-Anã WUBF showed a higher concentration of color (saturation: 9.02 ± 0.01) and a redder tendency (hue: 1.41 ± 0.00) when compared with Bluggoe WUBF (saturation: 7.10 ± 0.00 and hue: 1.39 ± 0.00). Even so, both flours were neutral in color, typical of flours rich in starch (Figure 1). Color has an impact on the evaluation and acquisition of food products, for both consumers and the food industry. In general, whiter flours are met with greater consumer acceptance because, when incorporated as ingredients, they are less likely to alter the appearance of the final product (Castilho, Fontanari, & Batistuti, 2010).

3.3 Chemical composition and antioxidant activity

The chemical composition and antioxidant activity of whole unripe banana flours can be seen at Table 1.

Table 1 – Chemical composition and antioxidant activity of whole unripe banana flours.

	Prata-Anã[a]	Bluggoe[a]	*P value*[b]
Moisture (g/100 g)	9.27 ± 0.15	8.22 ± 0.06	*<0.001*
Water activity	0.55 ±0.10	0.39 ± 0.06	*<0.001*
Ash (g/100 g)	2.83 ± 0.01	2.53 ± 0.02	*<0.001*
Lipids (g/100 g)	1.13 ± 0.05	0.39 ± 0.09	*<0.001*
Proteins (g/100 g)	5.75 ± 0.03	4.75 ± 0.05	*<0.001*
Total carbohydrates (g/100 g)	81.02 ± 0.24	84.11 ± 0.12	*<0.001*
Dietary fiber (g/100 g)	9.60 ± 0.00	10.08 ± 0.02	*<0.001*
Available carbohydrates (g/100 g)	71.42 ± 0.24	74.03 ± 0.11	*<0.001*
Resistant starch (%)	26.29 ± 0.41	23.01± 0.62	*0.002*
Energetic value (kcal)	357.25 ± 0.40	358.99 ± 0.29	*0.040*
Energetic value (kJ)	1494.71 ± 1.66	1502.03 ± 1.21	*0.040*
Antioxidant activity (%)	76.00 ± 1.05	67.21 ± 0.26	*<0.001*
Total phenolics (mg gallic acid/100 g)	24.53 ± 2.69	23.53 ± 2.96	*0.687*
Tannins (mg catechin/100 g)	4.77 ± 0.04	4.71 ± 0.16	*0.586*

[a]medium ± standard deviation from three replicates. [b] Student's *t*-test. Source: Authors (2020).

Prata-Anã whole unripe flour had higher moisture (and water activity), protein, lipid, ash, and RS contents. On the other hand, there was a higher dietary fiber content and lower water activity in Bluggoe whole flour (Table 1). Prata-Anã fresh banana had a higher pulp content, which may be related to a higher amount of starch. In contrast, the cultivar Bluggoe had a higher proportion of peel, contributing to a higher fiber content.

Even though Prata-Anã whole flour had a higher moisture content and water activity, both flours had water levels considered important for the reduction of enzymatic activity, improvement of microbiological quality, and maintenance of their sensory characteristics during storage.

Studies have shown that RS in unripe banana flour can vary from 17.5% to 52.88% (Juarez-garcia, Agama-Acevedo, Sáyago-Ayerdi, Rodríguez-Ambriz, & Bello-Pérez, 2006; Ramli, Alkarkhi, Yong, Min-Tze, & Easa, 2009; Menezes et al. 2011). In these studies, the variation in the RS content is due to two factors, the banana cultivar and the use or omission of the peel in flour processing. For example, in a study by Ramli et al. (2009), the content of RS present in the peels of two varieties of unripe banana was six times lower than that found in the respective pulps. RS can present several benefits to human health, as it is considered a prebiotic. It is also associated with a reduction in LDL cholesterol levels, control of the glycemic index, and increased satiety power, which contributes to weight loss and an increase in the fecal bolus (Homayouni et al., 2013).

The antioxidant activity was significantly higher in the cultivar Prata-Anã (Table 1). However, these values are lower than that found in the study by Haslinda, Cheng, Chong and Aziah (2009) made with WUBF from the cultivar Awak (ABB), whose average was 81.2%. Although the results presented here refer to whole samples (peel and pulp), it is observed, through the study of Someya, Yoshiki and Okubo (2002) that the peel can contribute up to 2.2 times more antioxidant activity than the pulp, in Nanicas bananas.

There was no significant difference in the levels of total phenolics between the two cultivars (Table 1). However, the values found are about seven times higher than those described by Moongngarm et al. (2014), who evaluated unripe banana flour produced with banana pulp from the cultivar Prata, also at stage 1 of ripeness. Although these authors evaluated only the pulp, it can be inferred that, in the study presented here, not only did the peel contribute to the increase in the total phenolic content, but the cultivar in question, as well as the planting conditions, may have been responsible for this result.

The degree of maturation is another factor that can affect the phenolic content, as well as the antioxidant activity. In this study, stage 1 was used, since the total phenolic content can decrease from 15% to 45% during ripening (Sundaram et al. 2011; Fatemeh, Saifullah, Abbas, & Azhar, 2012).

There was no significant difference in the tannin content between the two cultivars (Table 1). Maina, Heidi and Shagal (2012) observed tannin values equal to 1.1 g of catechin/100 g in the pulp and 5.86 g of catechin/100 g in the gold banana peel. These data suggest that the skin has 5 times more tannins than the pulp. However, it is noteworthy that in this cited study, fresh bananas were used and the stage of maturation of the fruits used was not specified. The tannin values found were lower than expected for an unripe banana flour. This may have occurred due to processing, since bananas go through the process of boiling, dehydration, and grinding, which can cause this component to degrade. However, this reduction contributes positively to the flour, since tannins are also considered as anti-nutritional factors.

3.4 Water absorption, solubility, and oil absorption indexes

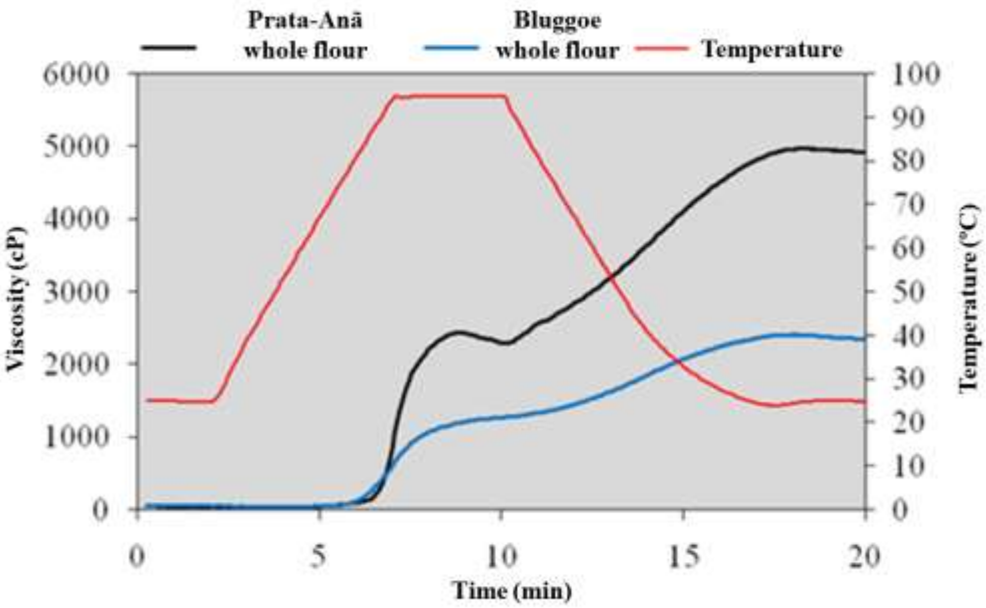
The Bluggoe unripe banana flour had the highest WAI (3.63 g ± 0.05) and the Prata-Anã banana flour the highest WSI (11.43 % ± 0.16). In contrast, the WAI of Prata-Anã whole unripe flour was 3.52 g ± 0.36 and the WSI of Bluggoe flour was 6.11 % ± 0.16. The WAI and WSI values may be related to the pulp and peel content. This is justified due to the natural characteristics of the presence of fibers, in which the soluble ones are commonly found in the fruit pulps and the insoluble ones, mostly in the peels. In the study by Bezerra et al. (2013) made with WUBF of the cultivar Nanicão in the first stage of maturation, the values of WAI and WSI were lower, varying from 2.88 to 3.28 g and from 1.22 to 1.92 %, respectively.
WAI and WSI are suitable parameters for assessing the integrity of the starch granule. WSI is related to the amount of soluble solids in the dry sample. The WAI is related to the cold paste viscosity, because only the damaged starch granule absorbs water at room temperature and swells. These results are extremely important in the destination of the flour for application in new food products.

There was no difference between cultivars in oil absorption capacity (2.12 g ± 0.02 for Prata-Anã and 2.15 g ± 0.03 for Bluggoe). Good oil absorption capacity is attributed to the combination of fat with non-polar groups of proteins or the availability of lipophilic groups. This implies the ability to absorb oil and contribute to flavor retention, improved palatability, and product shelf life (Poiani, & Montanuci, 2019). Therefore, the use of flours, such as those in this study, is viable in preparations that involve mixing oil, such as in bakery products where oil is an important ingredient.

3.5 Paste viscosity

The viscoamylographic curve of whole unripe Prata-anã and Bluggoe flours can be seen at Figure 2.

Figure 2 - Viscoamylographic curve of whole unripe Prata-anã and Bluggoe flours.



Source: Authors (2020).

Neither cultivar showed a significant peak in cold viscosity (V25) (48.92 cP ± 15.04 for Prata-Anã and 57.28 cP ± 5.50 for Bluggoe – Figure 2), which suggests that the heat treatment used to dry the fruits was not sufficient to transform the starch granule. This also indicates that both WUBF were unable to form a viscous gel at room temperature. There was a significant difference in the V_{Max} (2174.87 cP ± 5.51 for Prata-Anã and 1108.74 cP ± 7.43 for Bluggoe – Figure 2) and FV (4910.19 cP ± 25.13 for Prata-Anã and 2378.95 cP ± 5.04 for Bluggoe – Figure 2), between the two WUBF. The WUBF Prata-Anã showed the highest peak of VMax (at 95 °C), as well as of the FV, in the cooling cycle (Figure 2). Regarding the paste viscosity tests, it must be considered that they were carried out with whole flour. This implies that, in addition to carbohydrates in the form of starch and RS, one must also consider the fibers of the peel and the proteins of the banana, which can influence the values of this test. However, when heated to 95 °C, the Prata-Anã WUBF had the greatest capacity to make connections with water, absorbing it to form a more viscous gel with a high degree of retrogradation. Indirectly, it is noteworthy that it has a significant percentage of amylose, which allows this degree of retrogradation.

Prata-Anã WUBF showed a high degree of viscosity, which indicates the possibility of its use in formulated foods, such as soups and other pre-cooked foods, which are prepared under heating. These products require a high degree of thickening, as well as the preparation of porridges for infant feeding. The WUBF Bluggoe, which had a lower viscosity value, can be pre-cooked and used in beverages. This suggestion is based on the principle that heat treatment, where the sample reaches 95 °C and remains for 5 minutes at this temperature, generates the conditions needed to cook the material sufficiently.

4. Final Considerations

WUBFs present differences in composition according to the cultivars from which they are produced. Prata-Anã WUBF presented higher nutritional and technological application potential. However, both flours require heating during preparation, or pre-cooking, when applied to new food products. In-depth studies are necessary on the applications and analysis of different proportions of WUBF in food products such as soups, bread, cookies, and pasta, as well as its acceptance by consumers.

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