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Green Banana Flour Technology: from Raw Material to Sensory Acceptance of Products Made with Green Banana Flour in the Brazilian Scenario

Hebert Teixeira Cândido[1*]
https://orcid.org/0000-0002-3040-6488

Yasmine Ohanna Toledo Marzullo[2]
https://orcid.org/0000-0002-2317-9811

Magali Leonel[1]
https://orcid.org/0000-0001-7896-2398

[1]Universidade Estadual Paulista (UNESP), Centro de Raízes e Amidos Tropicais (CERAT), Botucatu, São Paulo, Brasil;
[2]Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agronômicas (FCA), Botucatu, São Paulo, Brasil.

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*Correspondence: hebert.candido@unesp.br; Tel.: +55-14-38807158 (F.L.)

HIGHLIGHTS

- In Brazil, many banana cultivars can be used in the making of flour.
- Flours can be prepared from the pulp, peel, or whole (pulp and peel).
- Staged I and II of maturation should be prioritized due to starch content.
- The sensory analysis supports the possibility of industrial use of flours.

Abstract: Brazil is a major producer of bananas, being the world's fourth-largest producer. The fruit is a source of minerals and vitamins and, when green, has a high content of resistant starch. Among the possibilities of processing, green banana flour has gained prominence due to its physical, nutritional, and functional characteristics, which can be used for the making of different food products. However, the raw material and the processing steps can influence these characteristics. Thus, this study aimed to provide information ranging from the choice of raw material to the sensory acceptance of consumers. The present work discussed the influence of ripening on fruit characteristics, processing stages and flour characteristics as a result of the different used fruits part or cultivar/variety of banana, and the possibilities of products with good technological quality and sensory acceptance of products made with green bananas flours by Brazilian consumers. One of the main differences provided by the cultivar is the flour yield, which is higher in banana cultivars with lower moisture content and selected for frying. There is little information regarding the whole green banana flour, which could reduce waste and contribute nutritionally to preparations. New products having green banana flours as an ingredient show wide possibilities for a partial or total replacement to other flours, as well as good sensory acceptance, which has led to a growing interest in banana processing and its growing market.

Keywords: banana processing; functional food; green banana flour.

INTRODUCTION

Brazil is a major producer of bananas, being the world's fourth-largest producer, with an over 6.9 million tons production [1]. The distribution of production occurs in all states [2], however, each region produces different cultivars. In general, banana cultivars Prata, Nanica, Terra and Maçã are predominant [3].

From a nutritional point of view, bananas are a source of vitamins and minerals. The main minerals found in these fruits are potassium, phosphorus, magnesium, iron, and zinc. These nutrients stand out for their importance for health and fighting hidden hunger, defined by insufficient intake of essential vitamins and minerals [4].

Besides the presence of minerals, bioactive compounds are also present, such as vitamin C, carotenoids, phenolic acids, and flavonoids, with high antioxidant potential [5,6]. Banana consumption has been associated with a reduced risk of major chronic-degenerative diseases. The consumption of fruits with antioxidant compounds reduces the risk of neurodegenerative diseases, delays the aging process, and helps to reduce the incidence of degenerative diseases, heart disease, arteriosclerosis, arthritis, cancer, and brain dysfunction [7].

The high resistant starch (AR) content of unripe banana fruits shows health benefits through their prebiotic function. AR is not absorbed in the intestine, but it is metabolized by the bacteria of the intestinal flora, producing chain fatty acids, resulting in a decrease in colonic pH, leading to beneficial effects on glucose and lipid metabolism [8,9].

The fruit can be processed for the manufacture of beverages, sweets, raisins, flour, and chips [10]. Among these products, green banana flour has stood out for its technological, nutritional, and functional characteristics and can be used in a wide range of food products [11]. The banana flour can be made from different cultivars or varieties of bananas [12], parts of the fruit (peel, pulp or peel and pulp) [13,14], and different stages of maturation [15], that along with the used methods in the manufacturing process, it can influence the characteristics of the product.

Thus, due to the importance of the fruit in the world scenario and the different types of bananas existing in Brazil, this study aims to provide information ranging from the choice of raw material to the sensory acceptance of products made with green bananas flours. In this sense, the following themes will be addressed: the influence of ripening on the characteristics of the fruit, which is important for the manufacture of flour; processing steps; characteristics of the flour as a result of the chosen raw material (cultivar/variety and pulp or peel) and possibilities of baking preparations with good technological quality and sensory acceptance, mainly by Brazilian consumers. It is hoped that this information will help those who wish to start producing green banana flour or products made from it.

Main transformations during banana ripening and its importance for the production of flours: visual, nutritional, and technological

After harvest, the bananas undergo a maturation process, which from a sensory point of view occurs mainly from the color change <u>in/of</u> their peel, from green to yellow, decreasing firmness and increasingly characteristic odor, aroma, and flavor, due to increased acidity and soluble solids content [17]. From a visual point of view, the change in peel color is currently the most used way to classify the fruit, to which Von Loesecke proposed a maturation scale (Figure 1), which is divided into seven stages [18].

Figure 1. Banana ripening stages. Photo: First author. Stages of maturation from left to right: 1° (completely green), 2° (green with yellow streaks), 3° (greener than yellow), 4° (more yellow than green), 5° (yellow with green tips), 6° (yellow) and 7° (yellow with brown spots).

From the point of view of flours production, maturation will mainly influence the processes of transforming starch into sugars and flour yield. The flour yield is mainly related to the pulp to peel ratio, accumulation of dry matter in the material, cultivars, and its moisture content.

The starch and the resistant starch contents decrease as the fruit matures, which is important, as it gives adequate characteristics to the flour [15,20,21], while the sugar, sucrose, glucose, and fructose contents increase [19]. On the other hand, protein and lipid contents increase at more advanced stages of maturation. Thus, due to the higher starch and resistant starch contents, the first stages of maturation (1st and 2nd) are preferable for the production flours intended to replace wheat in baking preparations, pasta, and food flours [15].

The pulp/peel ratio increases as the fruit mature, however, this increase is due to the transfer of water from the peel to the pulp, promoted by an osmotic gradient [17,22]. Thus, it is expected that the flour yield decreases in the pulp throughout maturation and increases in the peel, which can present gains up to 19% in dry matter mass [22]. In this way, by opting for bananas at more advanced stages of maturation, the flour processor will be investing more financial resources, when actually the water will be lost in the drying process.

To avoid ripening, it was found a study, in which the fruits were frozen after harvest, for subsequent drying and production of green banana flour [23]. Another way to delay ripening is to store the fruit in a cold room at a temperature of 12-13 ºC, where it can remain for up to 40 days in green stages (first, second and third stages), as shown in Figure 1. In addition to these methods, control of the atmosphere (humidity, temperature, O_2, CO_2, and ethylene) and the use of modified atmosphere through active packaging are other methods to increase the green life of bananas [24]. For more information on ripening control methods, we recommend reading the review article published by Brat, Bugaund, Guillermet, and Salmon [24].

Choice of raw material: characteristics of green bananas

To know the moisture of the raw material is important to estimate the flour yield, which can be adequate from the initial moisture of the raw material in natura and the expected final moisture of the flour since the removal of water during the drying process is the biggest influencing factor in yield [23]. Table 1 presents expected moisture contents for peel and pulp of green banana genotypes. In addition to these values, a study with 15 banana cultivars revealed that pulp moisture ranged from 66-74 g 100 g^{-1}[5].

Table 1. Characteristics of raw material for the production of green banana flour.

Ref	Banana	MS	Moisture (%)
	Pulp (*in natura*)		
[25]	*Cavendish*	2	71
[26]	São Domingos	ns	75
[27]	Prata-Zulu¹	1	64
[27]	FHIA-18	1	76
[27]	Caipira¹	1	73
[28]	Prata	2	70
	Peel (*in natura*)		
[25]	*Cavendish*	2	88
[26]	São Domingos	ns	89
[29]	Maçã	ns	87
[29]	Nanica	ns	87
[29]	Terra	ns	86
[29]	Prata	ns	91

MS: maturation stages. ¹Adapted name [30]; ns: not specified.

The genotype is a factor of great influence on the flours yield. It is expected that fried plantains have higher yields since these cultivars have a greater accumulation of dry matter in comparison to dessert banana cultivars. This can be confirmed in a study in Brazil, where the plantains presented an average dry matter accumulation of 40% (*in natura* pulp), while, for dessert bananas, the average was 28.5 % (*in natura* pulp), which resulted in a flour yield of 19.6%-27.2% (plantains) and 14.7%-20.3% (dessert bananas) [12]. Similar results were found in a study with 19 banana cultivars, where cooking and frying banana cultivars had higher accumulated dry matter content [17], on average, and among other 14 genotypes, the 'Terrinha' plantain presented the highest percentage of pulp dry matter [22].

The lowest yield of the peels (Table 2) is related to the characteristic of the fruit, where the green and fresh ones present_values of 60%-70% of pulp [22], with a pulp/peel ratio of 1.18 up to 2.82 [11,22,27]. Moreover, it is expected the yield of fresh green banana pulp to be higher, not only because of its higher proportion in the fruit but also because of its water content, approximately between 10 and 20% lower than that presented by the peel [12,25,26].

Table 2. Flour yield (wet basis) is based on the weight of the whole fruit (*in natura*) or about the initial weight (*in natura*) of the used material (peel or pulp)¹.

Ref	Banana	Material	MS	Yield %
[23]	ns	GBPeF	ns	13
[31]	Pacovan	GBPuF	1	20,9¹
[31]	Prata	GBPuF	1	25,2¹
[31]	Williams	GBPuF	1	19,3¹
[32]	ns	GBPuF	ns	26¹
[32]	ns	GBPuF	ns	24¹
[33]	Terra Maranhão	GBPuF	1	25
[27]	Prata-Zulu²	GBPuF	1	36
[27]	FHIA-18	GBPuF	1	27
[27]	Caipira²	GBPuF	1	27
[34]	Nanica	GBPuF	1	19¹
[34]	Prata	GBPuF	1	26¹
[35]	Prata	GBPuF	1	18
[35]	Prata	GBPeF	1	4
[28]	Prata	GBPuF	2	30
[13]	Nanicão	GBPuF	1	28¹
[13]	Nanicão	GBPuF	1	30¹
[13]	Nanicão	GBPeF	1	12¹
[13]	Nanicão	GBPeF	1	14¹
[36]	Nanica	GBPuF	ns	34¹

¹Weight/weight ratio of the material (peel or pulp) *in natura*; ²Adapted name [30]; GBPuF: Green banana pulp flour; GBPeF: Green banana peel flour; ns: not specified; MS: Maturation stages.

The processing of green banana flours

For the preparation of the flour, the fruits must be sanitized first/initially. The process consists of three steps: washing it in running water, immersion it in chlorinated water, and final rinsing it. The second stage, immersion in chlorinated water, presents variations in the immersion time and the chlorine concentration of the solution, according to studies [33,34,35,37]. However, a simple way to do it is by immersing the fruits in a solution with a concentration of 20 drops L^{-1} of sodium hypochlorite for 15 minutes [38].

After cleaning the fruits and cutting them into slices, the treatment against enzymatic browning can be carried out (Table 3), which will provide lighter flours [39]. At this stage, to prepare the solution, citric acid, ascorbic acid, or both can be used [12,39]. However, there is a large number of studies in which the treatment has not been cited [29,32,40,41,42]. The most recent works published by researchers from the Brazilian Agricultural Research Corporation (Embrapa) use the two acids for the treatment, ascorbic and citric acids, (Table 3).

Other studies also mention the use of bleaching in the treatment of raw material [15,28,32,38,43]. Research that used bleaching after peeling and slicing the fruits, placing them for 1 min in boiling water, followed by cold-water immersion (4 ºC), obtained a lighter flour without the need to use organic acids [32]. Thus, as shown, the acid and thermal treatments provide lighter flours, however, flours of good nutritional and technological quality can be prepared without the need to use these treatments [29,32,40,41,42].

Table 3. Acid concentration and time used in the treatment against enzymatic browning of sliced fruits.

Ref	Ascorbic acid	Citric acid	Time
	g L^{-1}		min
[12]	0,1	0,3	15
[33]	0,1	0,3	10-15
[43]	1,0	1,0	30
[34]	0,35	5,0	15
[14]	nu	5,0	10
[20]	nu	1,0	ns
[28]	nu	10	5

nu: not used; ns: not specified.

Most researchers utilize forced air drying ovens (Table 4). In addition to the methods shown in Table 4, green banana flour can also be obtained by drying in a rotary dryer and spray drying. However, there is a large loss (greater than 90%) in the resistant starch content of the flour, when it is obtained in a rotary dryer in comparison to other drying methods. In this same study, the drying methods influenced the water activity of the food, but in all cases, the water activity was within the limit considered safe about the growth of microorganisms [44], which is below 0.6 [45]. The water activity will be explained in more detail in the topic: Physicochemical and Technological Characteristics of Flours.

There is also dehydration by freeze-drying, which provides better physical and physicochemical characteristics, and less loss of resistant starch, however, due to the high acquisition and operating costs [46], it was not included in this study.

Despite the range of temperature for drying the material (Table 4), for starch preservation, it is recommended temperatures below its gelatinization temperature, 68 ºC [20]. Other studies suggest different gelatinization temperatures, which may be influenced by the cultivar, part of the fruit, drying method and time used [16]. In a spouted bed, for example, the temperature of 80 ºC did not interfere with the gelatinization of the starch, in which the banana flour had the same resistant starch content as the fresh fruit [14]. Another study showed that oven drying with forced air at 50 °C provides a better quality green banana flour with a higher resistant starch content compared to other drying temperatures (80 °C and 110 °C), and a scenario that most came close to the characteristics of the freeze-dried flour [46].

The grinding of dehydrated material can be performed in knife mills [12,33], hammer mills [28,37] and knives/hammer [40], or in a blender [14,29,32,34,41].

After milling, the flour can be sieved in a 30 mash mesh (595 µm) [33]. In roll-knife mills, for example, a set of sieves with different mesh sizes is already included with the equipment.

The particle size can interfere with the physical, physicochemical, and biochemical characteristics of the flour. Green banana flours with smaller particles are lighter and present a higher whiteness index. However, particle size appears to have little influence on pH and does not influence moisture content. A study with four granulometries of green banana flour, from 212 µm - 700 µm, showed that the water activity (from 0.41-0.45) was influenced by the particle size, however, in all cases, the values were within safe limits for storage [47].

Ordinance nº 354, July 18, 1996, determines that 98% of wheat flour must pass through a 250 µm mesh sieve [48]. A study that evaluated the granulometry of banana flour showed all fractions below 149 µm [49], which shows that banana flour could be used in future studies to determine the percentage of green banana flour that can be added in wheat flour for a mixture that fits within the specificity of the legislation.

Table 4. Drying methods to obtain green banana flour.

Ref	Material	Drying	MT (mm)	T ºC	Time (h)
[38]	WGBF	Forced air drying ovens	4	60	16
[12]	GBPuF	Forced air drying ovens	4-5	50	-
[41]	GBPuF	Oven	5	180	1,5
[32]	GBPuF	Forced air drying ovens	10	50	12
[29]	GBPeF	Room temperature	ns	35	72
[33]	GBPuF	Forced air drying ovens	2-3	50	-
[27]	GBPuF	Tray dryer	3-4	60	18
[34]	GBPuF	Forced air convection ovens	3	50	7
[35]	GBPeF and GBPuF	Ventilated dryer	5	60	20
[50]	SRBPF	Forced air drying ovens	20	60	12
[14]	GBPuF and WGBF	Conical spouted bed	ns	80	-
[20]	GBPuF	Forced air drying ovens	4	55	6
[28]	GBPuF	Tray dryer	5	40	24
[40]	WGBF	Forced air drying ovens	5	70	12
[37]	GBPuF	Forced air drying ovens	5	70	12
[51]	GBPuF	Tray dryer	ns	80	4

GBPeF: green banana peel flour; GBPuF: Green banana pulp flour; WGBF: Whole green banana flour (peel and pulp, without separation); SRBPF: Semi-ripe banana pulp flour; MT: Material thickness; T ºC: Drying temperature in Celsius degrees; ns: not specified.

Physicochemical and technological characteristics of flours

The water activity represents the free water present in the food for the action of enzymes, microorganisms, and chemical changes. Thus, it is related to food degradation. Its value ranges from 0 to 1.0. The closer to 1.0, the greater the amount of free water, therefore, the more perishable the food is going to be, where foods with Aw values below 0.6 are considered safe [45]. Thus, as shown by different studies (Table 5), green banana flours can be considered safe.

The water activity found in the studies is mostly in the range of 0.2 to 0.4 (Table 5), which provides less oxidation. Furthermore, these values provide low enzymatic activity and browning [45].

There is a study that shows the influence of cultivars on Aw values in green banana flours obtained from the cultivars Pacovan, Prata, and Williams, however, all of them are considered safe [31]. Another study showed higher water activity (Aw) in flour obtained from ripe bananas (0.350) than in green banana flour (0.276) [32]. The storage conditions can also affect the water activity of the flour, where the storage of green banana flour in polyethylene terephthalate packaging at room temperature of 26ºC for 90 days, provided an increase in water activity from 0.14 to 0.34 [28]. But still below 0.6.

Peeled or unpeeled green banana flours have a pH equal or above to 5.0 and less than 6.0 (Table 5). Other studies corroborate these values, ranging pH values from 5.14 to 5.46 in four flours obtained from Prata banana in the first stage of maturation [39], and from 5.6 to 5.7 in four flours obtained from Nanicão banana in the first stage of maturation [47]. Although the cultivars can influence the pH of the flours [11.31], researches show that the values are in the same range (5.0-6.0), such as, for example, pH of 5.0 – 5.78 in green banana flours obtained from five different cultivars [11] and another work with flours obtained from three cultivars, Pacovan (pH 5.6), Prata (pH 5.9) and Williams (pH 6.0) [31].

Despite the low acidity presented by the flours (Table 5), studies prove its microbiological stability for three months [28], and four months when used in replacement of 60% in premix for cake [52].

Table 5. pH and water activity (Aw) in green banana flours (wet basis).

Ref	Banana	Material	MS	pH	Aw
[38]	Prata	WGBF	1	5,4	ne
[38]	Nanica	WGBF	1	5,8	ne
[32]	ns	GBPuF	ns	5,7	0,28
[32]	ns	GBPuF	ns	5,7	0,37
[53]	Nanicão	GBPuF	1-2	5,0	ne
[53]	Prata	GBPuF	1-2	5,3	ne
[50]	Nanicão	SRBPF	4	na	0,29
[28]	Prata	GBPuF	2	5,2	0,14
[37]	Prata	GBPuF	ns	5,3	ne
[44]	Nanicão	GBPuF	1	-	0,38
[44]	Nanicão	GBPuF	1	-	0,39
[44]	Nanicão	GBPuF	1	-	0,43

GBPuF: Green banana pulp flour; WGBF: Whole green banana flour (peel and pulp, without separation); SRBPF: Semi-ripe banana pulp flour; MS: Maturation stages; ns: not specified; ne: not evaluated; Aw: water activity.

Also, from a technological point of view, green banana flour has high oil absorption, satisfactory water absorption index (higher than that found in whole and white wheat flours), and emulsifying activity of interest to the food industry, characteristics that can be exploited in the preparation of meat or emulsified products (mayonnaise, cake batters and salad dressings, for example) [54].

The water absorption capacity, 3.38 g water g^{-1} fresh $fiber^{-1}$ and 3.94 g water g^{-1} fresh $fiber^{-1}$, and the oil absorption capacity 1.42 g oil g^{-1} fresh $fiber^{-1}$ and 1.27 g oil g^{-1} fresh $fiber^{-1}$ between the flours obtained from the Prata and Nanica cultivars, respectively, did not differ statistically [38].

As well as, without bleaching influence, results from 2.51 to 2.56 g water g^{-1} fresh $fiber^{-1}$ and from 1.03 to 1.37 g oil g^{-1} fresh $fiber^{-1}$, with and without application of bleaching [32]. In a study with commercial green banana flour, the researchers found 3.02% oil absorption capacity [54]. Other research has shown that the water retention and binding capacities, as well as the water absorption index, show a decrease in flours obtained from bananas at more advanced stages of ripening, unlike oil absorption, which increases in flours obtained from bananas in more advanced stages [15].

These parameters are a representation of the CIELAB color space, which is the most accurate concerning human perception. In this space, L values range from 0 (black) to 100 (white), so foods with higher L values are lighter. The a* coordinates from -60 (green) to 60 (red) and the b* coordinates from -60 (blue) to 60 (yellow), which can be transformed into hue and chroma to facilitate understanding [55]. In a study with 20 banana cultivars, the chroma values ranged from 11.25 to 21.87 and hue from 87.84 to 92.35 (without a statistical difference). These results classified all flours as 'yellow', and the plantain flours as a more intense yellow [12].

Nutritional and functional characteristics of flours

Green banana flour, regardless of the choice of the raw material (cultivar or parts of the fruit: pulp, peel, or whole), has a low moisture content (Table 6), which is below the maximum value allowed 15 g $100g^{-1}$, amount stipulated by RDC nº 263, of January 22, 2005 [56].

Peel flours have higher levels of 'gray' minerals (Table 6), and not removing the peel can contribute to the increase of these levels, in green banana flours [14,57]. There seems to be higher ash content in cultivars from the *Cavendish* subgroup concerning the Prata subgroup [12,31,34]. Only one study, among the others reviewed, did not show this difference [53]. In another study, according to the authors, the means were statistically equal for the cultivars Prata and Nanica, however, the content presented by banana flour Nanica 4.09 g $100g^{-1}$ was about 40% higher than that presented by banana flour Prata, 2.94 g $100g^{-1}$, with no intersections between standard deviations [38]. Another study presented the most elucidating shreds of evidence concerning the influence of cultivars, where the AAA banana flours had the highest ash contents, followed by the flours from the Prata subgroup and, finally, the cultivars from the subgroup Terra. There were no significant differences between cultivars of the same subgroup, in all of these cases [12].

The fiber content showed great variation in the flours obtained from the pulp, ranging from 0.5 g $100g^{-1}$ to 18.8 g $100g^{-1}$ (Table 6), which makes it difficult to establish statements. However, in 61% of them, the flour obtained from the pulp can be characterized as flour with high fiber content, as they present values greater than 5.0 g per 50 g portion [58]. In general, bark flours have higher fiber content (Table 6). Although it is not clear in Table 6, another study showed that not removing the peel provides a higher fiber content flour [14].

Regarding the lipid fraction, green banana pulp flours and green banana whole flours are almost exclusively below 1.0 g $100g^{-1}$, while the peel flours present higher values, on average, 4, 3g $100g^{-1}$ (Table 6). Thus, considering a portion of 50 g, the total fat content of whole banana flours and most pulp flours (Table 6) can be classified as 'zero' or 'does not contain', according to RDC nº 360, December 23, 2003 [59].

Some studies show that peel flour has a higher protein content compared to pulp flour [35,57]. However, this content does not seem to be sufficient to provide a difference in the protein content of the whole flour compared to pulp flour [14]. Unlike other nutrients and functional components, such as ash, fiber, and resistant starch, in which banana flours stand out concerning wheat flour, the protein content is lower [11,60] and presents low biological value [14]. Thus, some studies suggest the insertion of some other raw material for the production of mixed banana flour with higher and better quality protein content [5,14].

The 'total energy value', presented in Table 6, is mainly due to the high levels of carbohydrates present in the flours (Table 6). However, these values would be better represented by 'available carbohydrates', as a large part of the carbohydrates present in green banana flours is resistant starch, which acts as fibers, thus the carbohydrate value substantially decreases, as well as the total energy value, as a consequence [20]. For example, Table 6 shows the carbohydrate content in green banana peel flour for 'Nanicão' banana, calculated as 72 g $100g^{-1}$. However, its authors [57] present as 'available carbohydrates' the content of 32.46 g $100g^{-1}$, as the resistant starch content was deducted from carbohydrates. Thus, the total energy value would be 52% lower than that shown in Table 6, of 320 kcal $100g^{-1}$.

Table 6. Proximate composition (g $100g^{-1}$) and total energy value (TEV) (kcal $100g^{-1}$) in green banana flours (wet basis).

Ref	Banana	MS	Moister	Ash	Fiber	Protein	Fat	Carbohydrate	TEV
						Pulp flour			
[31]	Pacovan	1	4,3	4,1	0,8	4,0	ne	ne	ne
[31]	Prata	1	5,3	3,6	0,7	4,0	ne	ne	ne
[31]	Williams	1	6,0	4,0	0,7	3,9	ne	ne	ne
[12]	BRS SCS Belluna	1	ne	3,3	18,8	4,2	1,1	67,5	296,5
[12]	BRS Platina	1	ne	2,4	7,6	3,5	0,7	76,7	327,1
[12]	Grande Naine	1	ne	3,2	8,4	4,3	0,8	77,6	334,3
[12]	Pacovan	1	ne	2,4	8,1	2,8	0,6	77,3	326,3
[12]	Prata Anã	1	ne	2,5	5,5	3,7	0,7	81,4	346,8
[12]	Terra Maranhão	1	ne	1,9	4,2	3,3	0,8	84,1	356,6
[12]	D'Angola	1	ne	1,5	6,4	2,7	0,7	83,0	349,2
[12]	Terrinha	1	ne	1,8	11,8	3,1	0,5	78,2	329,6
[34]	Nanica	1	6,6	3	0,6	5,2	0,4	91,4	391**
[34]	Prata	1	6,3	2,2	0,6	3,0	0,3	94,5	393**
[33]	Terra Maranhão	1	6,7	1,6	ne	2,7	0,6	88,4	369,9
[53]	Nanicão	1-2	5,8	2,5	3,8	4,9	0,8	61,7	274**
[50]	Nanicão	4	7,8	2,7	ne	3,8	0,6	ne	ne
[53]	Prata	1-2	4,2	2,5	0,5	4,9	0,9	76,5	334**

Cont. Table 6

[35]	Prata	1	3,2	2,5	4,8	4,6	0,5	84,4	361**
[14]	*Cavendish*	2	ne	1,1	8,5	4,1	0,4	86,9	368**
[13]	Nanicão	1	9,5	3,1	ne	0,6	4,1	ne	ne
[13]	Nanicão	1	7,8	3,2	ne	0,6	3,5	ne	ne
[37]	Prata	ns	3,3	2,6	1,0	4,5	0,7	87,9	373
[36]	Nanica	ns	7,6	2,6	ne	4,5	1,9	ne	ne
	Mean		**6,0**	**2,6**	**5,2**	**3,6**	**1,0**	**81,1**	**345,6**
						Peel flour			
[23]	ne	ns	4,6	9,6	38,7	5,9	3,6	76	361
[25]	*Cavendish*	1	5,4	11,7	30,3	6,9	4,7	41*	234**
[25]	*Cavendish*	1	5,7	10,4	29	4,7	3,4	47*	237**
[35]	Prata	1	2,2	2,3	8,9	7,5	9,0	70	391**
[57]	Nanicão	1	7,1	4,3	9,3[1]	5,5	1,2	72*	320**
[13]	Nanicão	1	9,1	9,1	ne	0,9	4,2	ne	ne
[13]	Nanicão	1	8,3	8,3	ne	0,9	3,8	ne	ne
	Mean		**6,1**	**8,0**	**23,2**	**4,6**	**4,3**	**61**	**308,6**
						Whole flour (pulp and peel)			
[38]	Prata	1	6,4	2,9	1,0	8,8	0,8	80	362**
[38]	Nanica	1	6,6	4,1	1,0	4,6	0,7	83	357**
[14]	*Cavendish*	2	ne	2,7	15,5	4,3	0,7	83,9	359**
[40]	Terra	1	ne	2,3	0,5	3,9	0,9	83,3	356,6
	Mean		**6,5**	**3,0**	**4,5**	**5,4**	**0,8**	**82,6**	**358,8**

MS: maturation stages; ne: not evaluated; ns: not specified; *Calculated by this author, Carbohydrates = 100 – (moisture + ash + fiber + fat + protein) [59]; ** Calculated by this author, TEV = 4 x carbohydrates + 4 x protein + 9 x fat [59]; [1]Discounted the resistant starch value presented by the authors [57].

From a functional point of view, the high content of resistant starch presented by green banana flours is perhaps its main characteristic, due to its performance as dietary fiber, which provides a decrease in the glycemic peak and an increase in satiety [20,61]. The content of this starch in green banana flours is much higher than that presented by wheat flour [11,60], and in most studies, *it makes up most* of the total starch presented in flours (Table 7).

The resistant starch content is highly influenced by the cultivar, however, it seems to have little influence over the subgroup/subgenotype [6,12]. The BRS SCS Belluna genotype (registered from the Thai genotype 'Nam') has shown the highest resistant starch level, according to publications [12,62]. Despite the difference in resistant starch content, the total starch content did not show a statistical difference in a study that evaluated flours obtained from 20 different cultivars [12]. In another study with 22 banana cultivars, the total starch content in pulp fluctuated less than the resistant starch content, where for the first (total starch), the means were grouped into 3 (having 15 cultivars belonging to the same group), while for the second variable (resistant starch), the means were grouped into six categories [6].

Despite the increase of other nutrient levels (Table 6), the use of peel in flour has a negative correlation with the total starch content and may decrease its content in whole green banana flour [14,57]. Similar to the total starch content, the resistant starch level is influenced by the part of the fruit used in processing, in which the pulp provides flour with a higher content of it. Thus, the peel flours and the whole meal flours have lower levels of this component [14,42,57].

Table 7. Resistant starch and starch contents ($g100^{-1}g$) in wet base (wb) and dry base (db) of green banana flours.

Ref	Banana	MS	Starch		Resistant starch	
			wb	db	wb	db
					Pulp flour	
[42]	São Domingos	ns	ne	ne	52,3	54,7
[25]	*Cavendish*	1	72,6	ne	54,5	ne
[25]	*Cavendish*	1	67,1	ne	47,8	ne
[12]	BRS SCS Belluna	1	ne	74,6	ne	59,1
[12]	BRS Platina	1	ne	78,5	ne	67,4
[12]	Grande Naine	1	ne	73,8	ne	51,4
[12]	Pacovan	1	ne	84,5	ne	70,1
[12]	Prata Anã	1	ne	79,8	ne	58,3
[12]	Terra Maranhão	1	ne	82,1	ne	62,2
[12]	D'Angola	1	ne	90,1	ne	46,3

Cont. Table 7

[12]	Terrinha	1	ne	83,5	ne	40,1
[34]	Nanica	1	ne	ne	ne	24,1
[34]	Prata	1	ne	ne	ne	13,7
[15]	*Cavendish*	1	ne	96,0	ne	38,3
[33]	Terra Marahão	1	67,5	72,3	56,3	60,3
[50]	Nanicão	4	47,5	ne	ne	ne
[57]	Nanicão	1	ne	80	ne	57,8
[14]	*Cavendish*	2	78,4	ne	40,1	ne
[20]	Nanicão	1	ne	76,8	ne	49,0
[37]	Prata	ns	72,7	75,2	ne	ne
[36]	Nanica	ns	73,3	ne	ne	ne
			Peel flour			
[42]	São Domingos	ns	ne	ne	27,7	28,9
[25]	*Cavendish*	1	26,5	ne	ne	ne
[25]	*Cavendish*	1	25,3	ne	ne	ne
[57]	Nanicão	1	ne	74,5	ne	42,25
			Whole flour (pulp and peel)			
[14]	*Cavendish*	2	68,4	ne	33,9	ne

MS: Maturation stages; ne: not evaluated; ns: not specified.

Potassium is the mineral with the highest level in green banana flour, regardless of the material used for the flour production, either peel or pulp, or cultivar (Table 8). This can be confirmed in studies with a large number of cultivars [5,6]. In general, it is expected that the peels have higher mineral content [6]. In a study with red banana flour (AAA), the peel flour stood out mainly due to the contents of K, Mg, P, and Zn, concerning the pulp flour [42].

The resolution RDC nº 360, of December 23, 2003, stipulates that when a portion of food contains a mineral content that is equal to or above 5% of its Recommended Daily Intake (IDR), this mineral may have its value shown on the packaging label [59]. A study showed that Cavendish banana peel and pulp flour in maturation stage 1 presented values above 5% of the RDI for almost all macro and micro minerals, except for calcium, in both flours obtained from pulp [25]

Despite the high content of minerals, banana flours have a low sodium content (Table 8). Thus, according to Brazilian legislation, all flours shown in Table 8 could be labeled as 'zero', or 'does not contain' sodium levels, since a mandatory nutrition declaration must be presented in the package [59].

Table 8. Minerals present (mg $100g^{-1}$) in green banana flours (wet basis).

Ref	Banana	MS	k	P	Ca	Mg	Fe	Zn	Cu	Mn	Na
						Pulp flour					
[42]	São Domingos	ns	788	64	37	67	0,7	0,4	0,4	1,5	0,7
[31]	Pacovan	1	1687	127	380	110	1,3	0,9	0,4	0,9	2,4
[31]	Prata	1	1357	85	390	110	0,8	2,5	0,3	0,7	2,2
[31]	Williams	1	1714	85	370	100	0,6	2,1	0,5	0,1	2,2
[25]	*Cavendish*	1	1314	110	25	140	1,7	1,0	1,3	0,5	3,5
[25]	*Cavendish*	1	1389	110	26	120	1,8	1,2	1,6	1,2	2,6
[15]	*Cavendish*	1	1.220	ne	ne	ne	ne	ne	ne	ne	ne
[63]	Williams	2	1086	92	14	115	0,9	0,4	ne	ne	ne
[37]	Prata	ns	1.141	97	126	68	17	515	5,3	4,4	ne
[36]	Nanica	ns	186	190	158	31	3,1	0,5	0,3	0,1	0,8
						Peel flour					
[42]	São Domingos	ns	3150	135	71	153	0,9	1,75	0,4	2,7	1,2
[25]	*Cavendish*	1	4370	170	230	170	2,4	1,96	1,1	1,0	1,4
[25]	*Cavendish*	1	2918	140	250	130	2,3	1,6	1,5	2,8	2,6

MS: Maturation stages; ne: not evaluated; ns: not specified; K: potassium; P: phosphorus; Ca: calcium, Mg: magnesium; Fe: iron; Zn: zinc; Cu: copper; Mn: manganese; Na: sodium.

Bioactive substances, such as carotenoids and vitamins, are influenced by cultivars and parts of the fruit [6,17]. Frying plantains have higher carotenoid contents, while dessert and cooking cultivars may have higher flavonoids [17] and total phenolic compounds contents. Furthermore, to the cultivar, the part of the fruit used in processing also influences the results, whilst/whereas the skins have higher levels of these substances [6].

Studies found 16.54 mg GAE $100g^{-1}$ of total phenols and 195.41 µmol Trolox equivalents of $100g^{-1}$ of antioxidant activity in flour, obtained from Cavendish banana pulp in the first maturation stage [15], 32.9 mg GAE $100g^{-1}$ and 40.3 mg GAE $100g^{-1}$ of total phenolic compound in pulp and peel flours, respectively, obtained from Prata banana in the first stage of maturation, without being able to detect the content in wheat flour [35], total phenols of 19- 31 mg GAE $100g^{-1}$, antioxidant activity (FRAP) of 2315-3683 (FeII) mmol $100g^{-1}$, antioxidant activity (DPPH) of 174-299 mg of Equivalent Trolox $100g^{-1}$, on a dry basis of four green banana flours Nanica (Dwarf Cavendish) [47], 50.65 mg GAE $100g^{-1}$ of total phenols (dry basis) and antioxidant activity of 358.67 µmols of Equivalent Trolox $100g^{-1}$ (dry basis) in green banana flour from cultivar Nanicão in the first maturation stage [20].

Ascorbic acid and vitamin C contents are influenced by the cultivar. Studies show that the presence of the B allele in the genome is related to the higher content of these substances. A recent publication showed that frying plantains (AAB) have the highest levels of ascorbic acid and vitamin C, and among the popular cultivars for fresh consumption in Brazil, Prata-Anã (AAB) has the highest levels of vitamin C, standing out in comparison to the AAA genomic group bananas [17]. Despite the losses that can occur during the drying process [45], these substances can still be found in flours, as found in banana flour Prata during the first stage of maturation, presenting a concentration of 15.12 mg $100g^{-1}$ of vitamin C [37].

Banana flour preparations: technological characteristics, sensory approval, and proximate composition

The researchers are important to show the percentage of green banana flour which can be used to manufacture a product with good technological quality, and this way results in better consumer acceptance. Below (Table 9) is presented some technological results found in products made with green banana flour.

Table 9. Technological results were obtained in products made from the insertion of green banana flour.

Ref	Banana	Preparation	Material	Conclusions
[49]	ns	Biscuit	GBF	For hardness, fracturability, weight, and specific volume, the biscuits made with 7.5% and 15% of GBF in replacement of WF did not differ from those made exclusively with WF.
[50]	Nanicão	Dairy-based product	SRBPF	Made with 33% of SRBF, it showed good reconstitution capacity (69%) and microbiological stability.
[64]	*Cavendish*	Bread	GBF	It replaces WF up to 10% for the production of good quality bread.
[60]	ns	Instant noddle	GBF	It enabled the production of instant noodles when used 10% of GBF in replacement of WF, which was considered functional due to the fiber and resistant starch contents.
[52]	Prata	Premix of GBPUF and WF	GBPuF	The product can be consumed for up to 4 months when stored at room temperature.
[40]	Terra	Mixed flour: green banana and Brazil nut	WGBF	The addition of Brazil nut flour improves the PWRP balance for proteins, fats, ash, and carbohydrates.
[28]	Prata	Banana flour	GBPuF	Little change in flour quality after 90 days of storage, which maintained microbiological stability. So it can be consumed and used in food preparations.

GBF: green banana flour (not specified); WF: Wheat flour; WGBF: Whole green banana flour (peel and pulp, without separation); SRBPF: Semi-ripe banana pulp flour; GBPuF: Green banana pulp flour; ns: not specified.

Despite the focus on the green banana flour, the semi-ripe banana flour can also be used for the production of flours for industrial application/industrial applications of production, such as 'Nanicão' banana flour in stage 4 of maturation, which showed potential to be used in the formulation of dairy-based products [50].

Regarding the main results of the sensory evaluation, the researchers present a great diversity of products that can be elaborated from/with green banana flours in partial wheat flour replacement and presenting a high sensorial approval. Some of these studies formulated products using up to 75% of wheat flour or cassava starch replacement by green banana flour. Products such as brownies, cereal bars, and cookie-type biscuits can be entirely made with green banana flour. Moreover, for one of the main products consumed by Brazilians, the bread, studies showed preparation options with up to 20% of green banana flour (Table 10).

Table 10. Possibilities for the use of green banana flour for the manufacture of products with good sensory acceptance.

Ref	Banana	Material	Preparation	Sensory evaluation
[23]	ns	GBPeF	Snack	Made with 75% of GBPeF in replacement of WF and approved by 85% of the tasters.
[65]	Belluna	GBF	Gluten free pizza dough	Made with 31% of GBF in place of WF, it presented the best assessment for global acceptance, with an index above 90%. However, all other preparations, using 25%, 38%, and 45% GBF had global acceptance rates above 70%.
[66]	Belluna	GBF	Oatmeal Cake	Cakes made with GBF in replacement of OF had acceptance rates above 80% for color, flavor, aroma, and overall impression.
[41]	Prata	GBPuF	Cake	Made with 30%, 40%, and 50% of GBPuF in replacement of WF, they did not differ in flavor, aroma, texture, overall impression, and purchase intent. Furthermore, all formulations presented an acceptability index above 70% for all evaluated attributes.
[34]	Prata	GBPuF	Whole grain bread	Made with 15% of GBPuF, it had an acceptance rate of 82%. In addition, more than half of the tasters would buy frequently (41.1%) or always (14.4%).
[33]	Terra Maranhão	GBPuF	Loaf bread	High sensory acceptance when used in 15% and 20% of GBPuF in replacement of WF.
[67]	Belluna	GBF	Biscuit	Made with 50% and 75% of GBF in replacement of cassava starch, they presented approval over 85%.
[53]	Prata/Nanicão	GBPuF	Gingerbread	No difference for the standard product when using 30% of GBPuF (Prata or Nanicão), presenting an acceptance rate above 80%.
[35]	Prata	MGBF	Noodles	Made with 30% of MGBF, it tasted better than those made with WF and did not differ in texture. In addition, it presented acceptance rates above 80% for these attributes.
[68]	ns	GBF	Brownie	100% made with GBF, it had higher rates for global acceptance, color, and texture than those made with WF.
[69]	Maçã	GBPuF	Cereal bars	Made with 50% or 100% of GBPuF, it did not differ from that prepared with WF in the parameters evaluated. In addition, the overall rating was between “I liked it a lot” and “I liked it moderately”.
[70]	ns	GBF	Cookie	It presented an acceptability index higher than 80% for appearance, flavor, and global acceptance and 77% for texture when prepared with 100% of GBF.
[70]	ns	GBF	Cookie	When made with 75% of GBF and 25% of RF, it did not differ from the product made with WF for the evaluated parameters (appearance, texture, flavor, and global acceptance). In addition, it presented an acceptability index higher than 84% for these parameters.
[36]	Nanica	GBPuF	Cookie	Same acceptance as the standard when prepared with 30% and 20% GBPuF.
[51]	Banana-da-terra	GBPuF	Loaf bread	When GBPuF was used up to 7%, it did not differ from bread made only with WF for color and odor parameters and presented better evaluations for flavor and texture. Furthermore, the use of up to 10% of GBPuF showed adequate rheological properties for the manufacture of loaf loaves of bread.

GBF: green banana flour (not specified); GBPeF: Green banana peel flour; GBPuF: Green banana pulp flour; RF: Rice flour; WF: Wheat flour; OF: Oatmeal flour; MGBF: Mixed green banana flour (50% peel and 50% pulp); ns: not specified.

The addition of green banana flour replacing wheat flour normally provides an increase in mineral content (ash), fibers, and resistant starch, such as fibers and minerals in the preparation of instant noodles [60]; resistant starch in loaf bread [33]; resistant starch and fiber in cake [66], resistant starch and ash in wholemeal bread [34] and resistant starch, fiber and ash in pizza dough [65]. Resistant fiber and starch contents increase as the percentage of green banana flour in the preparation increases as well [65,66]. Similar results, but without protein losses, were found in preparations where green banana flour replaced cassava starch, in which green banana flour provided higher ash, fiber, protein, and resistant starch contents [67].

Nutritional losses resulting from the replacement of wheat flour by banana flour can occur from the decrease in the levels of lipids and protein in instant noodles and cake [60,66] and protein levels in sliced bread and pizza [33,65]. The lower lipid content shown in most recipes is because green banana pulp flour has lower levels of this nutrient than wheat flour [35,60], unlike green banana peel flour [35]. However, the lipid content can be increased depending on the type of preparation, since in some recipes a higher oil content can be added to give more elasticity to the dough [65]. One way to reduce protein loss in the preparation was to make the bread from the mix of flour of peel (50%) and pulp (50%) of green banana, in which there was no loss in protein content, furthermore, it provided gains in ash and fiber contents [35].

Table 9 presents examples of proximate composition in prepared recipes using green banana flours.

Table 11. Proximate composition of preparations with green banana flours that showed good acceptance in sensory analysis (wet basis).

Ref	Product	GBF %	Moisture	Ash	Protein	Fiber	Fat	Carbohydrate	TEV kcal 100^{-1}
			g 100g^{-1}						
[65]	Gluten-free pizza dough	31	22	2	5	5	18	48	376
[66]	Oatmeal Cake	18	33	2	7	11	9	37	252
[66]	Oatmeal Cake	14	32	2	8	10	10	36	273
[34]	Whole grain bread	15	42	2	6	1	1	49	ne
[67]	Biscuit	75	4	2	3	6	16	75	433
[67]	Biscuit	50	3	1	3	4	15	77	442
[33]	Loaf bread	20	34	2	9	ne	2	53	263
[35]	Noodles	30	16	3	12	2	9	57	ne
[70]	Cookie	100	2	1,4	3	3	24	67	580
[70]	Cookie	75	5	1,5	3	3	26	62	515
[36]	Cookie	30	3	1,9	7	ne	20	ne	ne

GBF: Green banana flour; TEV: total energetic value; ne: not evaluated.

CONCLUSION

The choice of raw material (peel or pulp, cultivar, and maturation stage) can influence several characteristics of the flour. However, the flours reviewed here, regardless of the raw material used, fall within the moisture content established by Brazilian legislation. The microbiological stability of the flour seems to be little influenced by the cultivar since the pH shows little variation and the values for water activity are considered safe. Thus, from a technological point of view, one of the main characteristics of the raw material is the flour yield, which is expected to be higher in banana cultivars for frying. Despite the possibility of manufacturing flours from bananas at more advanced stages of maturation, the first stage should be prioritized, as it has the highest levels of starch and resistant starch, in addition to lower water content in the pulp, therefore, higher yield.

Sodium is mandatory for labeling, and banana flours have low levels of this mineral, which, according to the values presented in this review, can be classified on the label as 'zero' or 'does not contain'. All other minerals are present in amounts greater than 5% of the Recommended Daily Intake for an adult in a 50 g serving of flour, except calcium in pulp flour.

Among the processing steps, there is a wide variety of drying and treatment methods against enzymatic browning. However, drying with forced air circulation at 50°C maintains a better technological and functional quality of the flour. Regarding the treatment against enzymatic browning, solutions prepared from ascorbic and citric acids have been used. However, some studies used other methods without the use of acids, and others did not carry out any enzymatic or thermal treatment and, even so, they obtained flours of good nutritional and technological quality.

Sensory studies over more than 15 years support the possibility of using green banana flour for the preparation of different products. In addition, other technological studies support the possibility of industrial use so that green banana flour will become increasingly common in the Brazilian market.

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REFERENCES

1. Food and Agriculture Organization of the United Nations [Internet]. Roma: FAOSTAT. – c2021 [cited 2021 Jul 11]. Available from: http://www.fao.org/faostat/es/#data/QC
2. IBGE [Internet]. Rio de Janeiro: [Agricultural Census 2017 - Final Results]. - c2019 [cited 2021 Jul 11]. Available from: encurtador.com.br/jnyAF
3. Silva SO, Amorim EP, Santos-Serejo JA, Borges AL. [Cultivars]. In: Ferreira CF, Oliveira e Silva S, Amorim EP, Santos-Serejo JA, editors. O agronegócio da banana. Brasília: Embrapa; 2016. p. 137-170. Portuguese.
4. Valença AW, Bake A, Brouwer ID, Giller KE. Agronomic biofortification of crops to fight hidden hunger in sub-Saharan Africa. Glob. Food Sec. 2017 Mar 17;12: 8-14.

5. Dotto J, Matemu AO, Ndakidemi PA. Nutrient composition and selected physicochemical properties of fifteen Mchare cooking bananas: A study conducted in northern Tanzania. Sci Afr. 2019 Nov; 6:e00150.
6. Borges CV, Maraschin M, Coelho DS, Leonel M, Gomez HAG, Belin MAF, Diamante MS, Amorim EP, Gianeti T, Castro GR, Lima GPP. Nutritional value and antioxidant compounds during the ripening and after domestic cooking of bananas and plantains. Food Res. Int. 2020 Jun; 132:109061.
7. Singh B, Singh JP, Kaur A, Singh N. Bioactive compounds in banana and their associated health benefits – A review. Food Chem. 2016 Sep 1;206:1-11.
8. Falcomer AL, Riquette RFR, Lima BR, Ginani VC, Zandonadi RP. Health benefits of green banana consumption: a systematic review. Nutrients. 2019 May 29;11(6):1222.
9. Urrutia MAD, Ramos AG, Menegusso RB, Lenz RD, Ramos MG, Tarone AG, et al. Effects of supplementation with kombucha and green banana flour on wistar rats fed with a cafeteria diet. Heliyon. 2021 May;7(5):e07081.
10. Godoy RCB, Poiani LM, Viana ES, Ortiz AD, Maccari Junior A, Waszczynskj N. [Processing and use]. In: Ferreira CF, Oliveira e Silva S, Amorim EP, Santos-Serejo JA, editors. O agronegócio da banana. Brasília: Embrapa; 2016. p. 695-726. Portuguese.
11. Kumar PS, Saravanan A, Sheeba N, Uma, S. Structural, functional characterization and physicochemical properties of green banana flour from dessert and plantain bananas (*Musa* spp.). LWT. 2019 Dec;116:108524.
12. Reis RC, Viana ES, Assis SLF, Sena LO, Souza AS, Amorim EP. Promising green banana and plantain genotypes for making flour. Pesq. Agropec. Bras. 2019; 54:e01303.
13. Bertolini AC, Bello-Pérez LA, Méndez-Montealvo G, Almeida CAS, Lajolo F. Rheological and functional properties of flours from banana pulp and peel. Starch. 2010 Jun 08;62(6):277-284.
14. Bezerra CV, Rodrigues AMC, Amante ER, Silva LHM. Nutritional potential of green banana flour obtained by drying in a spouted bed. Rev. Bras. Frutic. 2013 Dec;35(4):1140-1146.
15. Campuzano A, Rosell CM, Cornejo F. Physicochemical and nutritional characteristics of banana flour during ripening. Food Chem. 2018 Aug 1;256(1):11-17.
16. Silva AA, Barbosa Junior JL, Barbosa MIMJ. [Green banana flour as a functional ingredient in food products]. Cienc. Rural. 2015 Dec;45(12):2252-2258. Portuguese.
17. Borges CV, Amorim EP, Leonel M, Gomez HAG, Santos TPR, Ledo CAS, Belin MAF, Almeida SL, Minatel IO, Lima GPP. Post-harvest physicochemical profile and bioactive compounds of 19 bananas and plantains genotypes. Bragantia. 2019 Apr-Jun;78(2):284-296.
18. PBMH & PIF. Programa Brasileiro para a Modernização da Horticultura e Produção Integrada de Frutas. Normas de Classificação de Banana [Internet]. São Paulo: CEAGESP; 2006. Portuguese. Available from: http://www.ceagesp.gov.br/wp-content/uploads/2015/07/banana.pdf
19. Rocha KR, Uribe SJ. [Relation of starch and soluble sugars during the maturation process of ‘Prata’ banana]. J. Agr. Tech. Sci. 2018 Jun;12(2):51-56, Jun. 2018. Portuguese.
20. Menezes EW, Tadini CC, Tribess TB, Zuleta A, Binaghi J, Pak N, Vera G, Dan MCT, Bertolini AC, Cordenunsi BR, Lajolo FM. Chemical Composition and nutritional value of unripe banana flour (*Musa acuminata*, var. Nanicão). Plant Foods Hum. Nutr. 2011 Sep;66(3):231-237.
21. Yang J, Bi Y, Liang S, Gu Z, Cheng L, Li C, et al. The *in vivo* digestibility study of banana flour with high content of resistant starch at different ripening stages. Food Funct. 2020 Nov 13;11:10945-10953.
22. Aquino CF, Salomão LCC, Cecon PR, Siqueira DL, Ribeiro SMR. The physical, chemical and morphological characteristics of banana cultivars depend on maturation stages. Rev. Caatinga. 2017 Jan-Mar;30(1):87-96.
23. Acosta-Coello C, Parodi-Redhead A, Medina-Pizzali ML. Design and validation of a nutritional recipe for a snack made of green banana peel flour (*Musa paradisiaca*). Braz. J. Food Technol. 2021;24:e2019349.
24. Brat P, Bugaud C, Guillermet C, Salmon F. Review of banana green life throughout the food chain: from auto-catalytic induction to the optimization of shipping and storage conditions. Scientia Horticulturae. 2020 Feb 27;109054.
25. Cândido HT. [Evaluation of the banana production system in the municipality of Botucatu-SP: characterization of ripening and of the green banana flours] [dissertation]. Botucatu (SP): Universidade Estadual Paulista, Faculdade de Ciências Agronômicas; 2020. Portuguese.
26. Souza APS, Cândido HT, Santos TPR, Leonel M. [Characterization of 'São Domingos' banana ripening]. Anais Sintagro. 2019 Out;11(1):123-132. Portuguese.
27. Espinosa-Moreno J, Centurión-Hidalgo D, Mayo-Mosqueda A, García-Correa C, Martínez-Morales A, García-Alamilla P, et al. Flour quality of three banana cultivars (*Musa* spp.) resistant to black sigatoka disease in tabasco. Agrociencia. 2018 Feb 16;52(2):217-229.
28. Santos JC, Silva GF, Santos JAB, Oliveira Júnior AM. [Processing and evaluation of the stability of the green banana flour]. Exacta. 2010;8(2):219-224. Portuguese.
29. Neris TS, Sousa e Silva S, Loss RA, Carvalho JWP, Guedes SF. [Physicalchemical evaluation of banana peel (*Musa* spp.) *in natura* and dehydrated in different maturation stages]. Rev. Cienc. e Sustent. 2018 Jul 10;4(1):5-21. Portuguese.
30. Lichtemberg LA, Lichtemberg PSF. [Advances on the Brazilian banana crop]. Rev. Bras. Frutic. 2011 Oct;33(E):29-36. Portuguese.
31. Franca LG, Holanda NV, Aguiar RAC, Reges BM, Costa FB, Souza PA, et al. [Elaboration and characterization of green banana flours]. Res., Soc. Dev. 2020 May 12;9(7):e271973798. Portuguese.

32. Szeremeta JS, Siguel G, Amaral JG, Nascimento RF, Canteri MHG. [Banana flours: product development and its physical-chemical and functional characterization]. Rev. Tecnol. 2019 Oct 3;27(1):1-10. Portuguese.
33. Viana ES, Souza AS, Reis RC, Oliveira VJS. Application of green banana flour for partial substitution of wheat flour in sliced bread. Semin Cienc Agrar. 2018;39(6):2399-408.
34. Andrade BA, Perius DB, Mattos NV, Luvielmo MM, Mellado MS. [Production of unripe banana flour (*Musa* spp) for application in whole wheat bread]. Braz. J. Food Technol. 2018;21:e2016055. Portuguese.
35. Castelo-Branco VN, Guimarães JN, Souza L, Guedes MR, Silva PM, et al. The use of green banana (*Musa balbisiana*) pulp and peel flour as an ingredient for tagliatelle pasta. Braz. J. Food Technol. 2017;20:e2016119.
36. Fasolin LH, Almeida GC, Castanho PS, Netto-Oliveira ER. [Cookies produced with banana meal: chemical, physical and sensorial evaluation]. Ciênc. Tecnol. Aliment. 2007;27(3):524-529. Portuguese.
37. Borges AM, Pereira J, Lucena EMP. [Green banana flour characterization]. Ciênc. Tecnol. Aliment. 2009;29(3):333-9. Portuguese.
38. Soares MGL, Borsoi LM, Sena GGS, Ascheri JLR, Silva EMM. [Whole green banana flours Prata and Nanica: potential application in human food]. In: Barbosa FC, organization. Nutrição em foco: uma abordagem holística. 3nd ed. Piracanjuba: Editora Conhecimento Livre; 2020. p. 170-182. Portuguese.
39. Carneiro TS, Oliveira GLS, Santos J, Constant PBL, Carnelossi MAG. [Evaluation of green banana flour with antioxidant application]. Braz. J. of Develop. 2020 May;6(5):28634-28643. Portuguese.
40. Medeiros MJ, Oliveira PAAC, Souza JML, Silva RF, Souza ML. [Chemical composition of mixtures with green banana and nut Brazil flours]. Rev. Inst. Adolf Lutz. 2010;69(3):396-402. Portuguese.
41. Carvalho LCC, Ferreira IM, Oliveira e Silva AM, Nunes TP, Carvalho MG. [Cake banana with fructooligosaccharide]. Rev. Verde Agroecologia Desenvolv. Sustent. 2019 Jan 01;14(1):55-61. Portuguese.
42. Cândido HT, Molha NZ, Eburneo JAM, Leonel M. [Minerals and resistant starch in red banana flours ‘São Domingos’ triploid (AAA)]. Res., Soc. Dev. 2021 Mar 28,10(4):1810413860. Portuguese.
43. Pires VCF, Silva FLH, Souza RMS. [Parameters of drying banana pacovan and physicochemical characterization of green banana flour]. Rev. Verde Agroecologia Desenv. Sustent. 2014 Jun 06;9(1):197-209. Portuguese.
44. Ferini JL, Ormenese RCSC, Silva VSN, Almeida CAS, Souza AS, Vitali AA, Collares-Queiroz FP. [Chemical and physical characteristics of green banana flours produced by different processes] [Internet]. 2009 [cited 2021 Jun 29]. Available from: http://www.iac.sp.gov.br/areadoinstituto/pibic/anais/2009/Artigos/RE0901040.pdf. Portuguese.
45. Fellows PJ. [Food processing technology: principles and practices]. 2nd ed. Porto Alegre: Artmed; 2006.
46. Khoozani AA, Bekhit AE-DA, Birch J. Effects of different drying conditions on the starch content, thermal properties and some of the physicochemical parameters of whole green banana flour. Int. J. Biol. Macromol. 2019 Jun 01;30(1):938-946.
47. Savlak N, Türker B, Yeşilkanat N. Effects of particle size distribution on some physical, chemical, and functional properties of unripe banana flour. Food Chem. 2016 dec 15;213:180-6.
48. Secretária de Vigilância Sanitária. Ministério da Saúde. Portaria nº 354, de 18 de julho de 1996 [Ordinance No. 354 of July 18, 1996.]. Diário Oficial [da] República Federativa do Brasil, Brasília (1996 Jul 18).
49. Santana RCS, Ribeiro GO, Camilloto GP, Cruz RS. [Physical and textural characterization of green banana flour biscuits]. Braz. J. of Develop. 2020 Oct;6(10):81311-81319. Portuguese.
50. Pires FCS, Martins MG, Moraes JFC, Borges WRF, Pena RS. [Obtaining, characterizing, and using Nanicão semi-mature banana (*Musa* sp.) flour in the production of a dairy base product]. Rev. Bras. Prod. Agroind. 2017;19(1):61-72. Portuguese.
51. Pacheco-Delahaye E, Testa G. [Nutritional, physical and sensory evaluation of wheat and green banana bread]. Interciencia. 2005 May;30(5):300-304. Spanish.
52. Borges AM, Pereira J, Silva Júnior A, Lucena EMP, Sales JC. [Stability of cake pre-mixture made with 60% of green banana flour]. Cienc. Agrotec. 2010 Jan;34(1):173-181. Portuguese.
53. Freitas MCJ, Silveira GE, Veras LS, Santos GFF. Honey bread made with flour of different varieties of green banana. Demetra. 2017;12(2):465-82.
54. Santana GS, Oliveira Filho JG, Egea MB. [Characteristics technological of commercial vegetable flours]. Rev. Agric. Neotrop. 2017;4(2):88-95. Portuguese.
55. Ferreira MD, Spricigo PC. [Colorimetry: principles and applications in agriculture] [Internet]. São Carlos: Embrapa Instrumentação: 2017 (cited 2021 Jul 03). Available from: https://www.embrapa.br/en/busca-de-publicacoes/-/publicacao/1084379/colorimetria---principios-e-aplicacoes-na-agricultura. Portuguese.
56. ANVISA. Resolução da Diretoria Colegiada - RDC nº 263, de 22 de setembro de 2005. Dispõe sobre o Regulamento Técnico para produtos de cereais, amidos, farinhas e farelos”[Collegiate Board of Directors Resolution - RDC No. 263, of September 22, 2005. Provides on the Technical Regulation for cereal products, starches, flours and bran.]. Diário Oficial [da] República Federativa do Brasil, Brasília (2005 Sep 23).
57. Sardá FAH, Lima FNR, Lopes NTT, Santos AO, Tobaruela EC, Kato ETM, et al. Identification of carbohydrate parameters in commercial unripe banana flour. Food Res. Int. 2016 Mar;81:203-209.
58. ANVISA. Resolução RDC nº 54, de 12 de novembro de 2012. Dispõe sobre o Regulamento Técnico sobre Informação Nutricional Complementar. [Resolution RDC No. 54, of November 12, 2012. Provides on the Technical Regulation on Complementary Nutritional Information] Diário Oficial [da] República Federativa do Brasil, Brasília (2012 Nov 12).

59. ANVISA. Resolução da Diretoria Colegiada - RDC nº 360, de 23 de dezembro de 2003. Aprova regulamento técnico sobre rotulagem nutricional de alimentos embalados, tornando obrigatória a rotulagem nutricional.[Resolution of the Collegiate Directory - RDC nº 360, of December 23rd, 2003. Approves technical regulations on nutrition labeling of packaged foods, making nutrition labeling mandatory.] Diário Oficial [da] República Federativa do Brasil, Brasília (2003 Dec 23).
60. Vernaza MG, Gularte MA, Chang YK. Addition of green banana flour to instant noodles: rheological and technological properties. Ciênc. Agrotec. 2011 Dec;35(6):1157-1165.
61. Sardá FAH, Giuntini EB, Gomez MLPA, Lui MCY, Negrini JAE, Tadini CC, Lajolo FM, Menezes EW. Impact of resistant starch from unripe banana flour on hunger, satiety, and glucose homeostasis in healthy volunteers. J. Funct. Foods. 2016 Jun;24:63-74.
62. Ramos DP, Leonel M, Leonel S. [Resistant starch in green banana flours]. Alim. Nutr. 2009;20(3):479-483. Portuguese.
63. Anyasi TA, Jideani AIO, Mchau GRA. Phenolics and essential mineral profile of organic acid pretreated unripe banana flour. Food Res. Int. 2018 Feb;104:100-9.
64. Oliveira DASB, Müller PS, Franco TS, Kotovicz V, Waszczynskyj N. [Quality assessment of bread with the addition of unripe banana flour and unripe banana puree]. Rev. Bras. Fruit. 2015 Sep;37(3):699-707. Portuguese.
65. Viana ES, Reis RC, Guedes ISA, Santos FD, Jesus JL. [Development and characterization of gluten-free pizza dough added with green banana flour]. Cruz das Almas: Embrapa Mandioca e Fruticultura; 2020. Portuguese.
66. Guedes ISA, Viana ES, Reis RC, Assis JLJ, Santos FD. [Application of green banana flour in the production of cake rich in resistant starch]. Cruz das Almas: Embrapa Mandioca e Fruticultura; 2020. Portuguese.
67. Reis RC, Assis SL, Viana ES, Jesus JL. [Use of green banana flour for biscuit production]. Cruz das Almas: Embrapa Mandioca e Fruticultura; 2018. Portuguese.
68. Matos M, Benincá SC, Zanlourensi CB, Schmitt, V. [Sensory and nutritional analysis of brownie with green banana flour]. Revista RBONE. 2017;11(69):722-730. Portuguese.
69. Silva CEN, Santos VAQ, Costa DPS. [Production and sensory evaluation of cereal bars based on green banana flour]. Reagro. 2016 Dec;5(esp):76-86. Portuguese.
70. Cortat CMG, Glielmo JLAP, Iglesias RA, Peixoto VODS, Fontanive R, Citelli M, et al. [Development of gluten free cookie added unripe banana flour and coconut oil]. Revista HUPE. 2015;14(3):20-6. Portuguese.