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Diversification of Cultivars and Production of Male Inflorescence Flours for More Sustainable Banana Cultivation

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Abstract: Banana inflorescences are usually discarded, but there has been interest in managing this by-product to turn it into a product with added value. Herein, the inflorescences of seven cultivars were processed into flour and evaluated for their physicochemical characteristics. The weight of the inflorescences ranged from 681.3 to 1245.4 g, with bracts accounting for more than 40%. The Prata Anã cultivar had the largest inflorescence. The part of the inflorescence was the main factor differentiating the flours, with the effect of the cultivar dependent on the part processed. All flours had high levels of fiber (27.70–41.91 g/100 g) and carbohydrates (19.30–33.96 g/100 g). The palm flours were differentiated by their higher levels of protein (17.4–19.4 g/100 g), and the flower flours by their higher levels of lipids (5.89–7.97 g/100 g). The bract flours had a higher water holding capacity (5.62–6.78%) and browning index (40.7–42). The bract and flower flours were less dissimilar. Results revealed the high nutritional quality of the flours and the prospect of using them as a non-conventional food source. Understanding the differences between banana inflorescence flours expands their possible uses and promotes sustainable agricultural production in terms of efficient banana by-product management.

Keywords: *Musa* spp.; residue; bracts; flower; palm; nutritional composition

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1. Introduction

Bananas are one of the most widely grown fruits in the world, with 139.28 million tons produced in 2023, with India leading world production (36.6 million tons), followed by China (12.06 million tons), Indonesia (9.33 million tons), Nigeria (7.3 million tons), Ecuador (7.2 million tons), and Brazil (6.82 million tons) [1].

The state of São Paulo is Brazil's largest producer and has the second-highest average productivity. Banana cultivation in the country and the state of São Paulo has undergone major technological transformations in recent years, experiencing a new reality in cultivation areas with the use of optimum agronomic practices, the use of irrigation, and appropriate harvesting and post-harvesting systems. The diversification of cultivars has emerged as a strategy to reduce pests and diseases, as well as to expand markets [2].

Currently, there has been a change in the management of agricultural by-products, with incentives to convert them into products with greater added value in the pursuit of sustainable development. Although bananas are of great importance to food security and their production is increasing, little attention has been paid to the management of crop residues [3].

During harvest, the banana plant produces significant quantities of by-products, such as inflorescences, pseudostems, leaves, and palms, estimated at 220 tons per hectare [3]. Despite the large volume generated, there is no consolidated consumption of banana by-products as food in Brazil.

Banana inflorescence is the assortment of the male flowers of banana plants. It shows a dark purple color and has a heart-shaped structure located at the end of the peduncle. Removing this structure reduces the weight of the bunch (making the plant less likely to topple over), reduces friction between plant parts, and helps prevent diseases caused by insects and fungi. It also speeds up the ripening of the fruit and increases its sweetness, as the inflorescence consumes some of the sap that would otherwise be used to produce the fruit [3,4].

The composition of the inflorescence varies from 90 to 92% for moisture and contents of 16–60% for carbohydrates, 1.5–20% for proteins, 24–52% for fiber, and 6–18% for ash on a dry basis [5–9]. In some countries, inflorescence has been used as an alternative remedy for hypermenorrhea, asthma, diabetes, dysmenorrhea, diarrhea, and gastric spasms. Despite this high health value, the inflorescence is still little used, being discarded or underutilized by most producers [10–13]. Although studies have shown the nutritional importance of the inflorescence, there is a lack of information about variations between cultivars and the correct approach to the parts of the inflorescence studied [3].

Health concerns and consumer awareness of the importance of consuming foods that can have functionalities that reduce the risk of disease have expanded the development of flours, with the market size estimated to reach 82.9 billion dollars by 2027 and growing at a CAGR of 7.3% during the forecast period 2022–2027 [14].

In addition to the agronomic factors that determine the need to expand varietal diversification, valuing the nutritional composition of the inflorescences from different cultivars and the possibility of adding value through the production of flours can be an important factor in producers' decisions. In this study, seven banana cultivars with important productivity features, commercial acceptance of the fruit, and resistance to pests and diseases had their inflorescences used as raw materials for the production of bract, flower, and palm heart flours, with the aim of providing information on their physicochemical characteristics, highlighting similarities and dissimilarities, as a way of increasing the marketing potential of banana inflorescences as food and improving the sustainability and profitability of banana fields.

2. Materials and Methods

2.1. Banana Cultivation

The banana cultivation was set up in the São Manuel Experimental Farm of São Paulo State University, São Manuel City, São Paulo State, Brazil (22°44′28″ S and 48°34′37″ W, 740 m a.s.l.). The climate, according to the Köppen–Geiger classification system, is Cfa, a humid subtropical climate, mesothermic, with rainfall concentrated from November to April (summer), a mean annual rainfall of 1376.70 mm, and an average temperature of the hottest month of >22 °C. The soil in the area was classified as a Dystrophic Red Oxisol with a sandy texture, according to the nomenclature of the Brazilian Soil Classification System, or as Dystrophic Typic Hapludox [15,16].

The experimental field was prepared two months before planting by plowing and harrowing. Forty seedlings of the banana cultivars Prata-Anã, SCS451 Catarina, Galil-18, BRS Japira, BRS Fhia Maravilha, BRS Pacoua, and BRS Vitória, produced by tissue culture at the Biofactory in the municipality of Cruz das Almas, state of Bahia, Brazil, spent three months acclimatizing in the greenhouse. Table 1 shows some of the characteristics of the cultivars planted.

Table 1. Characteristics of banana cultivars [17–24].

Cultivars	Genotype	Plant Height (m)	Number Fruit/Bunch	Fruit Length (cm)	Fruit Mass (g)	Yield (t ha^{-1})
Prata Anã	AAB	2.3	149–190.5	17.3–20	115–119	19.7
SCS451 Catarina	AAB	3.22–3.3	121.3	17	135–145	23.5–36.7
Galil 18	AAAB	2.12–2.5	97.8–118	13.8–16.4	167.9	16.3–21
BRS Japira	AAAB	2.48	80.5	12.8–20.5	122.8–184.78	20
BRS Fhia Maravilha	AAAB	2.6–2.31	145.6–175	24.3–25	243–245	17.8
BRS Pacoua	AAAB	2.4–3.5	120–130	15	150	17.2–30
BRS Vitória	AAAB	3.10	98	18	145	15
			Susceptibility to pests and diseases			
Prata Anã	Susceptible to Yellow Sigatoka (*Mycosphaerella musicola*, Leach) and Black Sigatoka (*Mycosphaerella fijiensis*, Morelet) and Moko (*Ralstonia solanacearum*), moderately susceptible to Panama Disease (*Fusarium oxisporum*. f. sp. cubense), moderately resistant to nematodes and the Rhizome Borer (*Cosmolites sordidus*).					
SCS451 Catarina	Susceptible to Yellow Sigatoka and Black Sigatoka, and moderately susceptible to Panama Disease.					
Galil 18	Resistant to Black Sigatoka, moderately susceptible to Yellow Sigatoka, and tolerant to Panama Disease					
BRS Japira	Resistant to Black Sigatoka, Yellow Sigatoka, Panama Disease, and Anthracnose					
BRS Fhia Maravilha	Resistant to Black Sigatoka and Panama Disease, moderately resistant to Yellow Sigatoka, and moderately susceptible to Rhizome Borer					
BRS Pacoua	Resistant to Yellow Sigatoka and Panama disease and moderately resistant to Black Sigatoka.					
BRS Vitória	Resistant to Black Sigatoka, Yellow Sigatoka, and Panama Disease					

After acclimatizing in the greenhouse, the seedlings were transplanted to the field in November 2020, with a spacing of 3 m between rows and 2.5 m between plants. The experimental field of banana cultivars was performed in a randomized block design with ten plants per banana cultivar, with four replicates, totaling 280 plants.

The planting and management of the crop followed the technical recommendations for the region [25]. Fertilization was carried out based on the results of soil analyses.

The banana plants were grown under a rainfed system. Weed control was carried out whenever necessary, using manual weeding and a brush cutter. The recommended cultural management for the crop was carried out, such as top dressing, weed control, thinning of tillers, removal of old leaves, supporting the plants, bagging the bunches, phytosanitary control, and thinning. The thinning of the banana plants began in the fifth month after planting (April 2021), following the traditional crop management system, leaving three plants per clump [25,26].

2.2. Treatments and Experimental Design

The experimental design was in randomized blocks with four replications, 10 plants per experimental plot, in a 7 × 3 factorial. With a view to the uniformity of the plants, two inflorescences were sampled per experimental plot, obtaining the average values of the variables evaluated for the statistical analyses (n = 4). Thus, the seven levels of the cultivar factor were Prata-Anã, SCS451 Catarina, Galil-18, BRS Japira, BRS Fhia Maravilha, BRS Pacoua, and BRS Vitória (n = 4 inflorescences/cultivar), and the three levels of the inflorescence factor were bracts, flower, and pulp, totaling 84 samples.

2.3. Harvesting the Inflorescences

Inflorescences were harvested from healthy plants in the morning, when the space between the last hand and the inflorescence reached 15 cm [26]. The inflorescences were harvested from plants in the second cycle of the crop (736 to 790 days after planting). After harvesting, the inflorescences were weighed, and their parts were manually separated using sanitized knives. The bracts and male flowers were separated down to the inner core (the inner yellow part, considered the edible part of the inflorescence and popularly known as the palm of the blossom). After separating the parts of the inflorescence, they were weighed, and the percentage of each part in relation to the total mass was calculated.

2.4. Production and Analysis of Flours

The inflorescence parts were washed in water to remove contaminating residues, sanitized (hypochlorite solution 200 ppm/15 min), and rinsed in drinking water to remove residual chlorine. The samples were cut into pieces using sanitized knives. The samples were dried in an oven with air circulation (airflow rate of 2.3 m^3/min) at 50 °C for 8–24 h (until the samples had a moisture content close to 10%). The dried materials were ground in a knife mill, sieved (40 mesh), stored in sealed high-density polyethylene packages, and kept at 5 °C for future analysis.

Flours were analyzed for proximate composition, mineral elements, color parameters, water absorption index, and water solubility index. All analyses were carried out in triplicate. Figure 1 summarizes the steps of the experiment.

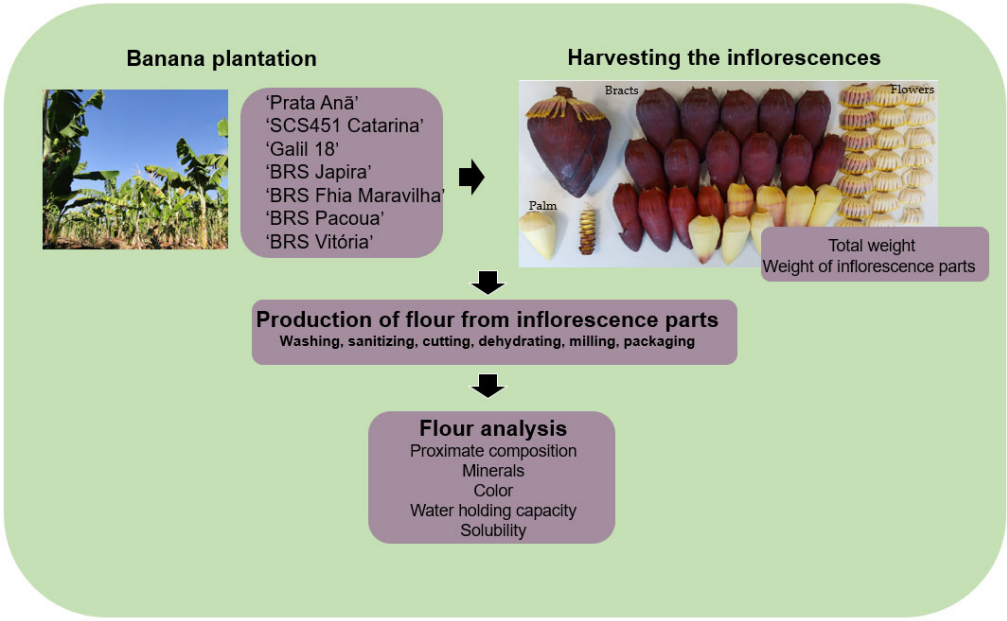

Figure 1. Graphical overview of the experiment.

2.4.1. Proximate Composition and Mineral Elements Contents

The proximate composition of the flours was analyzed according to the AOAC methods [27]. Moisture content (method 925.40) was determined using the oven-drying method at 105 °C until constant weight. To determine the lipid content (method 920.39), the Soxhlet apparatus was used, using hexane as the extracting solvent for 6 h. Proteins were determined by the Kjeldahl method, and the protein conversion factor adopted was 6.25. The ash content was determined by the gravimetric method in a muffle furnace at 550 °C. Total carbohydrates were expressed as residual percent weight by the formula, [100 − (moisture + ash + lipids + fiber + protein)].

For analysis of mineral elements, extracts of inflorescence flours were prepared and subjected to determination of the mineral element contents (P, K, Ca, Mg, S, Cu, Al, Na, B). Samples (500 mg) were weighed and placed in a digestion tube, followed by the addition of 6 mL of HNO_3 and $HClO_4$ (2:1 v/v). The nitric-perchloric digestion was conducted in a digestor block by gradually increasing the temperature to 160 °C and incubating at this final temperature for 40 min. Subsequently, the temperature was raised to 210 °C for 20 min until the extract became colorless. The extract was then transferred to a 50 mL volumetric flask, and the volume was adjusted with deionized water. The samples for boron analysis were prepared by incineration. Dry digestion was carried out in a furnace in the presence of hydrochloric acid, gradually heating the temperature to 550 °C and maintaining this temperature for 3 h. Standard solutions were prepared, and the levels of elements were determined using an atomic absorption spectrophotometer (AAnalyst 800, Perkin Elmer, Waltham, MA, USA) based on the displacement of electrons to higher energy levels [28,29]. Samples were analyzed in triplicate.

2.4.2. Flour Color

The color characterization of the flours was carried out using a chromometer (Minolta CR-400, Osaka, Japan). Measurements were taken through direct readings of the samples under illuminant D65 (daylight, 6500 K) with an observation angle of 10°. A white calibration plate was used to standardize the equipment prior to color measurements (Y = 93.69, x = 0.3170, y = 0.3335). The values of L* (CIE lightness coordinate), a* (CIE red (+)/green (−) color attribute), and b* (CIE yellow (+)/blue (−) color attribute) were recorded. The whiteness index (WI) and browning index (BI) were calculated [30,31] (Equations (1) and (2)).

$$WI = 100 - \sqrt{(100 - L^*) + a^{*2} + b^{*2}} \quad (1)$$

$$BI = \frac{100(X - 0.31)}{0.172} \quad (2)$$

2.4.3. Water Holding Capacity

Water holding capacity (WHC) of flours was determined following the centrifuge technique [32]. For analysis, 0.5 g of the sample and 10 mL of distilled water at 28 °C were added to a centrifuge tube. After stirring for 1 min with a vortex stirrer was then centrifuged at 3000 rpm for 30 min. After centrifugation, the supernatant was discarded, and the tube was turned upside down for 1 min. The residue was weighed, and the WHC was expressed as g of water held per g of sample (Equation (3)).

$$WHC = \frac{WRC}{WS} \quad (3)$$

where WRC: weight of residue of centrifugation (g); WS = weight of sample (g).

2.4.4. Solubility

For determination of solubility (SS) of inflorescence flours, 1 g of flour was carefully added to 50 mL of distilled water in a plastic tube and stirred for 5 min. The solution was centrifuged at 3000× g for 5 min. An aliquot of 20 mL of the supernatant was transferred to pre-weighed Petri dishes and immediately oven-dried at 105 °C for 5 h. Then, the solubility (%) was calculated by weight difference [33].

2.5. Statistical Analysis

The results of the chemical analyses were subjected to analysis of variance (ANOVA), and the means were compared using the Scott–Knott clustering test at a 5% significance level using the SISVAR software, version 5.6 (Lavras, Brazil) [34]. Principal component analysis (PCA) was carried out to correlate and discriminate cultivars and identify the relationships between the different components using XLSTAT software (version 26.4.1, Addinsoft, New York, NY, USA).

3. Results

3.1. Fresh Weight of the Inflorescence Parts

The fresh weight of the inflorescences ranged from 681.26 to 1245.42 g. Analysis of the data showed that there were differences in the weight of the inflorescences for the cultivars studied, with bracts representing the main part of the inflorescence (>40%), followed by the flowers (20–30%) and palm (10–25%) (Table 2, Figure 2).

Table 2. Fresh weight (g) of the inflorescence parts from different banana cultivars.

Cultivars	Inflorescence	Bracts	Flower	Palm
Prata Anã	1245.42 ± 46.45 ^{a}	786.74 ± 37.76 ^{a}	339.02 ± 12.51 ^{a}	119.66 ± 9.33 ^{b}
SCS 451 Catarina	895.44 ± 39.54 ^{c}	539.6 ± 29.9 ^{c}	224.48 ± 8.13 ^{c}	131.36 ± 9.09 ^{b}
Galil 18	874.14 ± 35.54 ^{c}	505.6 ± 19.14 ^{c}	245.3 ± 16.73 ^{c}	123.26 ± 2.92 ^{b}
BRS Japira	808.10 ± 29.93 ^{d}	514.54 ± 17.03 ^{c}	186.32 ± 10.62 ^{d}	107.24 ± 4.56 ^{c}
BRS Fhia Maravilha	1129.4 ± 27.09 ^{b}	677.45 ± 20.84 ^{b}	314.8 ± 14.40 ^{b}	137.15 ± 11.17 ^{b}
BRS Pacoua	777.42 ± 55.60 ^{e}	371.06 ± 13.13 ^{d}	217.8 ± 8.85 ^{c}	188.56 ± 5.74 ^{a}
BRS Vitória	681.26 ± 32.15 ^{f}	360.82 ± 21.85 ^{d}	201.16 ± 10.20 ^{d}	119.28 ± 6.48 ^{b}

Means followed by the same letter in the column do not differ by the Scott–Knott test ($p < 0.05$) (n = 4).

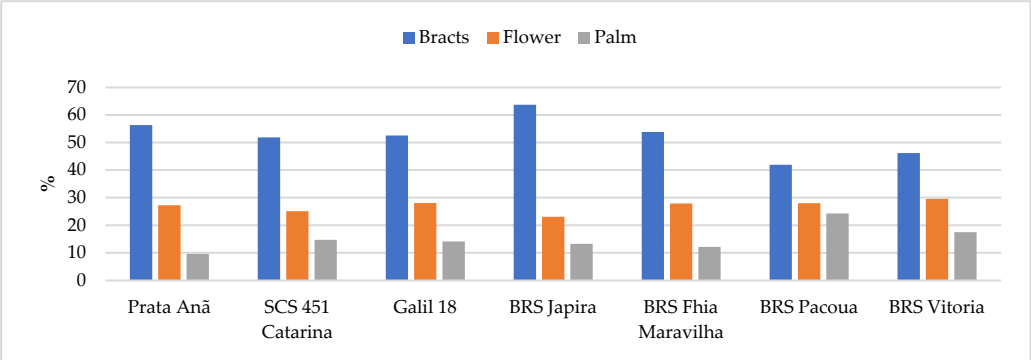

Figure 2. Distribution of the parts of the inflorescence (% of total weight) harvested from the different cultivars.

3.2. Proximate Composition of Flours

Data analysis showed that the interaction between the factors, part of the inflorescence, and cultivar was significant for all the parameters analyzed in the flours. That is, the effect of the cultivar was dependent on the part of the inflorescence processed. Analysis of the proximate composition of the flours showed ranges from 8.4 to 10.1 for moisture, 8.0 to 12.5 for ash, 7.2 to 19.4 for protein, 3.9 to 8.0 for lipids, 27.7 to 41.9 for fiber, and 19.3 to 34.0 for carbohydrates (Table 3).

In human nutrition, mineral elements are classified according to daily intake requirements, with calcium (Ca), phosphorus (P), potassium (K), sodium (Na), and magnesium (Mg) being macrominerals, and iron (Fe), zinc (Zn), boron (B), and manganese (Mn) being microminerals. For all mineral elements, the effect of the interaction of cultivar and inflores-

cence part was observed. The mineral element content of the different banana inflorescence flours is shown in Figure 3. The daily consumption of 20 g of banana inflorescence flour can contribute to the recommended daily intake, as can be seen in Figure 4.

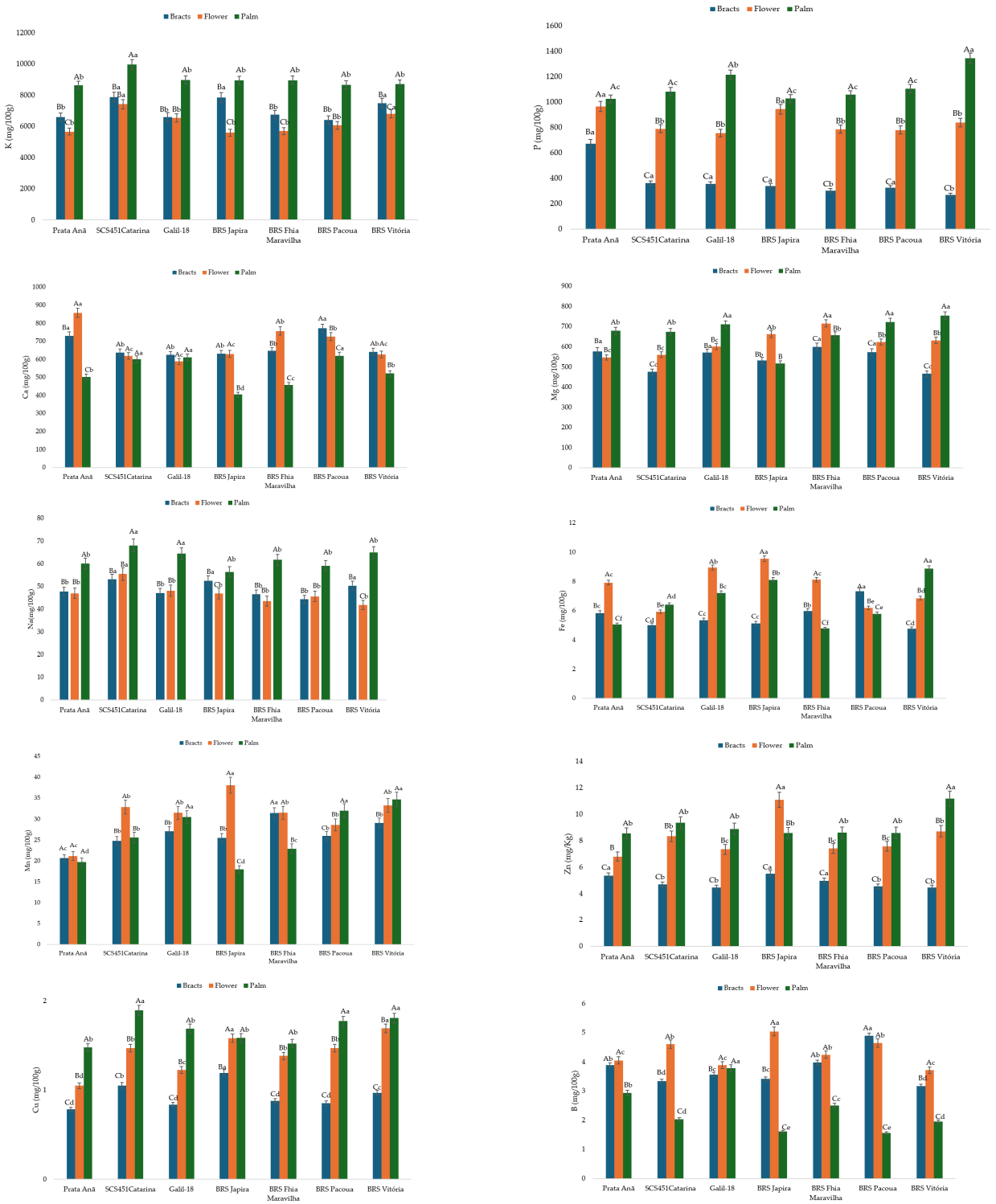

Figure 3. Mineral elements contents of banana inflorescence flours. Two-way ANOVA produced significant effects ($p \leq 0.001$) for all main factors and interactions. Uppercase letters compare the means of the parts of the inflorescence, and lowercase letters compare the means of the cultivars. The same letters do not differ by the Scott–Knott test ($p < 0.05$) (n = 4). The vertical bar in the area of the figure indicates the standard deviation of the means. K = potassium, P = phosphorus, Ca = calcium, Mg = magnesium, Na = sodium, Fe = iron, Mn = manganese, Zn = zinc, Cu = copper, B = boron.

Table 3. Proximate composition of banana inflorescence flours (g/100 g wet basis).

	Moisture			Ash			Protein		
	Bracts	**Flower**	**Palm**	**Bracts**	**Flower**	**Palm**	**Bracts**	**Flower**	**Palm**
Prata Anã	9.9 ± 0.2^{Ab}	9.6 ± 0.2^{Ba}	10.0 ± 0.1^{Aa}	8.8 ± 0.1^{Bc}	8.1 ± 0.2^{Ce}	13.0 ± 0.2^{Aa}	7.8 ± 0.2^{Cd}	13.6 ± 0.2^{Bb}	19.4 ± 0.1^{Aa}
SCS 451 Catarina	9.6 ± 0.2^{Bc}	9.2 ± 0.1^{Cb}	10.1 ± 0.1^{Aa}	9.5 ± 0.2^{Ba}	9.5 ± 0.2^{Ba}	12.5 ± 0.3^{Ab}	8.2 ± 0.1^{Cc}	13.2 ± 0.1^{Bc}	17.4 ± 0.2^{Ad}
Galil 18	9.5 ± 0.1^{Ad}	8.4 ± 0.1^{Cd}	9.0 ± 0.1^{Bc}	8.3 ± 0.1^{Cd}	8.6 ± 0.1^{Bc}	11.6 ± 0.2^{Ad}	7.2 ± 0.2^{Ce}	11.8 ± 0.1^{Be}	17.3 ± 0.3^{Ad}
BRS Japira	9.6 ± 0.2^{Ac}	9.2 ± 0.1^{Bb}	8.8 ± 0.1^{Cd}	9.5 ± 0.2^{Ba}	8.0 ± 0.2^{Ce}	11.0 ± 0.2^{Af}	10.1 ± 0.2^{Cb}	12.1 ± 0.1^{Bd}	18.5 ± 0.2^{Ab}
BRS Fhia Maravilha	9.4 ± 0.2^{Bd}	8.8 ± 0.1^{Cc}	9.8 ± 0.1^{Ab}	8.4 ± 0.1^{Bd}	8.1 ± 0.2^{Ce}	12.3 ± 0.1^{Ac}	7.5 ± 0.2^{Cd}	11.1 ± 0.1^{Bf}	17.8 ± 0.2^{Ac}
BRS Pacoua	10.1 ± 0.1^{Aa}	9.7 ± 0.1^{Ba}	10.0 ± 0.1^{Aa}	8.2 ± 0.1^{Bd}	8.3 ± 0.1^{Bd}	11.2 ± 0.1^{Ae}	7.7 ± 0.2^{Cd}	12.2 ± 0.2^{Bd}	17.4 ± 0.4^{Ad}
BRS Vitória	10.1 ± 0.1^{Aa}	8.9 ± 0.1^{Bc}	9.0 ± 0.1^{Bc}	9.0 ± 0.1^{Bb}	9.0 ± 0.1^{Bb}	12.5 ± 0.1^{Ab}	10.6 ± 0.1^{Ca}	14.4 ± 0.1^{Ba}	19.3 ± 0.3^{Aa}
	Lipids			**Fiber**			**Carbohydrate**		
	Bracts	**Flower**	**Palm**	**Bracts**	**Flower**	**Palm**	**Bracts**	**Flower**	**Palm**
Prata Anã	5.0 ± 0.1^{Ba}	5.9 ± 0.1^{Ad}	4.3 ± 0.1^{Cd}	34.8 ± 0.7^{Bd}	37.2 ± 0.9^{Ac}	27.7 ± 0.6^{Ce}	34.0 ± 0.7^{Aa}	25.6 ± 0.5^{Bd}	25.7 ± 0.5^{Bb}
SCS 451 Catarina	4.4 ± 0.1^{Cb}	6.8 ± 0.1^{Ab}	5.5 ± 0.1^{Bc}	40.0 ± 0.6^{Ab}	36.8 ± 0.9^{Bc}	33.8 ± 0.8^{Cb}	28.3 ± 0.9^{Ad}	24.5 ± 0.9^{Bd}	20.7 ± 0.8^{Ce}
Galil 18	5.0 ± 0.1^{Ca}	8.0 ± 0.1^{Aa}	5.8 ± 0.1^{Bb}	37.6 ± 0.8^{Ac}	35.3 ± 0.7^{Bd}	32.9 ± 0.8^{Cc}	32.4 ± 0.9^{Ab}	27.9 ± 0.8^{Bc}	23.4 ± 1.1^{Cd}
BRS Japira	4.0 ± 0.1^{Cc}	6.4 ± 0.1^{Ac}	4.4 ± 0.2^{Bd}	40.6 ± 0.7^{Ab}	35.0 ± 0.8^{Bd}	30.2 ± 0.43^{Cd}	26.19 ± 0.6^{Be}	29.4 ± 1.0^{Ab}	27.1 ± 0.5^{Ba}
BRS Fhia Maravilha	4.0 ± 0.1^{Cc}	6.4 ± 0.1^{Ac}	4.4 ± 0.10^{Bd}	40.0 ± 0.9^{Ab}	38.6 ± 0.6^{Bb}	30.8 ± 0.4^{Cd}	30.7 ± 1.3^{Ac}	27.0 ± 0.6^{Bc}	25.0 ± 0.4^{Cc}
BRS Pacoua	3.9 ± 0.1^{Bc}	6.7 ± 0.1^{Ab}	6.6 ± 0.1^{Aa}	41.9 ± 0.8^{Aa}	31.1 ± 0.8^{Ce}	35.4 ± 0.8^{Ba}	28.3 ± 1.2^{Bd}	32.1 ± 0.9^{Aa}	19.3 ± 0.5^{Cf}
BRS Vitória	4.3 ± 0.1^{Cb}	6.0 ± 0.1^{Ad}	5.6 ± 0.1^{Bc}	39.9 ± 0.9^{Ab}	40.7 ± 0.9^{Aa}	32.4 ± 0.8^{Bc}	26.1 ± 1.0^{Ae}	21.0 ± 1.0^{Be}	21.2 ± 1.3^{Be}

Two-way ANOVA produced significant effects ($p \leq 0.001$) for all main factors and interactions. Uppercase letters in line compare the means of the different parts of the inflorescence, and lowercase letters in column compare the means of the cultivars. The same letters do not differ statistically by the Scott–Knott test ($p < 0.05$) (n = 4).

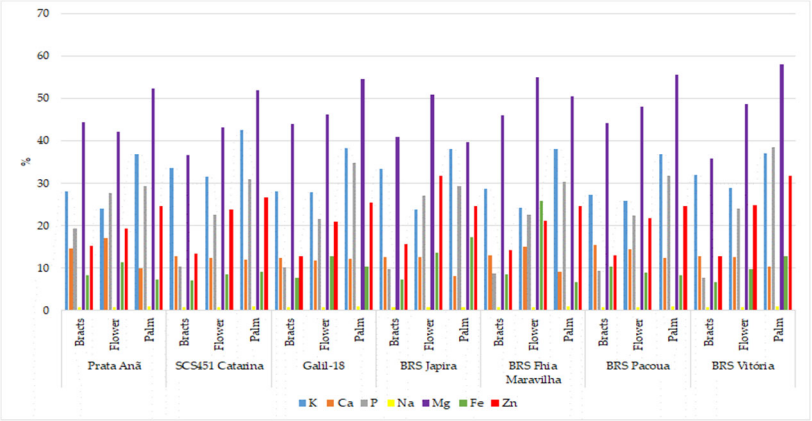

Figure 4. Estimated daily intake (%) considering average daily per capita consumption of 20 g of banana inflorescence flour and the Recommended Dietary Intake (RDI) for mineral elements [35].

The differences in color parameters of inflorescence flours are shown in Table 4. It was observed effects of the interaction of factors, inflorescence part, and cultivar on color parameters. Luminosity (L*) values ranged from 32.9 to 44.2, a* value from 3.1 to 5.8, b* value from 7.7 to 12.9, whiteness index (WI) from 11.7 to 16.0, and browning index (BI) from 33.0 to 48.3.

The water holding capacity (WHC) of flour is a hydration parameter that assesses the powder's ability to absorb water and attain the correct consistency, and solubility (SS) refers to the amount of soluble molecules. Analysis of the data showed that there was a significant effect of the interaction of factors on the water-binding capacity and solubility of banana inflorescence flours (Table 5). The WHC of the inflorescence flour prepared by processing different parts of inflorescence from banana cultivars ranged from 2.2 to 6.8 g water/g dry sample, and SS ranged from 4.9 to 9.2%.

Principal component analysis was carried out to explore possible groupings between the chemical components, mineral elements, color parameters, and water holding capacity of the different banana inflorescence flour samples. The biplot principal component graph and cluster dendrogram are shown in Figure 5.

Table 4. Color parameters of banana inflorescence flours.

	L*			a*			b*		
	Bracts	Flower	Palm	Bracts	Flower	Palm	Bracts	Flower	Palm
Prata Anã	42.9 ± 0.3 ^{Ab}	32.5 ± 0.3 ^{Be}	32.8 ± 0.2 ^{Bc}	5.1 ±0.1 ^{Ac}	3.22 ± 0.1 ^{Bg}	3.1 ± 0.0 ^{Ce}	12.6 ± 0.2 ^{Ab}	8.3 ± 0.2 ^{Bf}	7.7 ± 0.1 ^{Cf}
SCS 451 Catarina	39.1 ± 0.2 ^{Ae}	33.5 ± 0.2 ^{Cc}	33.9 ± 0.1 ^{Bb}	5.0 ± 0.1 ^{Ad}	3.94 ± 0.0 ^{Bf}	3.6 ± 0.0 ^{Cd}	11.7 ± 0.2 ^{Ad}	9.7 ± 0.1 ^{Bc}	8.9 ± 0.1 ^{Cd}
Galil 18	41.1 ± 0.2 ^{Ac}	35.0 ± 0.1 ^{Ba}	33.9 ± 0.2 ^{Cb}	5.6 ± 0.0 ^{Ab}	5.11 ± 0.0 ^{Ba}	4.4 ± 0.1 ^{Cc}	11.9 ± 0.0 ^{Ac}	11.2 ± 0.2 ^{Ba}	9.4 ± 0.1 ^{Cc}
BRS Japira	38.8 ± 0.1 ^{Ae}	32.9 ± 0.2 ^{Cd}	34.1 ± 0.2 ^{Bb}	4.8 ± 0.0 ^{Ae}	4.05 ± 0.0 ^{Ce}	4.4 ± 0.1 ^{Bc}	10.8 ± 0.1 ^{Ae}	8.9 ± 0.1 ^{Be}	8.9 ± 0.1 ^{Bd}
BRS Fhia Maravilha	44.2 ± 0.2 ^{Aa}	33.0 ± 0.1 ^{Cd}	34.0 ± 0.2 ^{Bb}	5.8 ± 0.0 ^{Aa}	4.5 ± 0.0 ^{Bc}	4.4 ± 0.0 ^{Cc}	12.9 ± 0.1 ^{Aa}	9.0 ± 0.1 ^{Be}	8.7 ± 0.1 ^{Ce}
BRS Pacoua	42.9 ± 0.3 ^{Ab}	34.3 ± 0.2 ^{Cb}	35.8 ± 0.2 ^{Ba}	5.0 ± 0.0 ^{Ad}	4.43 ± 0.0 ^{Cd}	4.7 ± 0.0 ^{Bb}	11.8 ± $^{0.2\ Ac}$	9.5 ± 0.0 ^{Bd}	9.7 ± 0.1 ^{Bb}
BRS Vitória	39.8 ± 0.3 ^{Ad}	34.9 ± 0.2 ^{Ca}	35.5 $^{\pm}$ 0.2 ^{Ba}	5.1 ± 0.0 ^{Ac}	4.6 ± 0.0 ^{Cb}	4.8 ± 0.0 ^{Ba}	11.9 ± 0.2 ^{Ac}	10.0 ± 0.1 ^{Bb}	9.9 ± 0.1 ^{Ba}
	WI			BI					
	Bracts	Flower	Palm	Bracts	Flower	Palm			
Prata Anã	15.6 ± 0.2 ^{Ab}	12.1 ± 0.2 ^{Bf}	11.7 ± 0.1 ^{Cf}	42.7 ± 0.3 ^{Ac}	35.9 ± 0.4 ^{Bf}	33.0 ± 0.3 ^{Cf}			
SCS 451 Catarina	14.9 ± 0.2 ^{Ad}	13.3 ± 0.1 ^{Bc}	12.6 ± 0.1 ^{Ce}	43.9 ± 0.4 ^{Aa}	42.0 ± 0.3 ^{Bc}	37.5 ± 0.2 ^{Ce}			
Galil 18	15.2 ± 0.1 ^{Ac}	14.7 ± 0.1 ^{Ba}	13.2 ± 0.1 ^{Cc}	43.3 ± 0.2 ^{Bb}	48.3 ± 0.6 ^{Aa}	41.2 ± 0.2 ^{Ca}			
BRS Japira	14.2 ± 0.1 ^{Ae}	12.7 ± 0.1 ^{Be}	12.9 ± 0.1 ^{Bd}	40.7 ± 0.4 ^{Ad}	39.7 ± 0.3 ^{Be}	39.1 ± 0.3 ^{Cc}			
BRS Fhia Maravilha	16.0 ± 0.1 ^{Aa}	13.0 ± 0.1 ^{Bd}	12.7 ± 0.1 ^{Ce}	43.3 ± 0.3 ^{Ab}	41.0 ± 0.4 ^{Bd}	38.2 ± 0.3 ^{Cd}			
BRS Pacoua	14.9 ± 0.2 ^{Ad}	13.3 ± 0.1 ^{Bc}	13.4 ± 0.1 ^{Bb}	40.0 ± 0.3 ^{Be}	41.2 ± 0.3 ^{Ad}	40.2 ± 0.3 ^{Bb}			
BRS Vitória	15.1 ± 0.2 ^{Ac}	13.7 ± 0.1 ^{Bb}	13.6 ± 0.1 ^{Ba}	44.0 ± 0.6 ^{Aa}	42.7 ± 0.2 ^{Bb}	41.6 ± 0.3 ^{Ca}			

Two-way ANOVA produced significant effects ($p \leq 0.001$) for all main factors and interactions. Uppercase letters in line compare the means of the different parts of inflorescence and lowercase letters in column compare the means of cultivars. The same letters do not differ statistically by the Scott–Knott test ($p < 0.05$) (n = 4). L* = lightness (0 to 100), a* = red-green color axes (−60 to +60), b* = yellow-blue color axes (−60 to +60), WI = whiteness index, BI = browning index.

Table 5. Water holding capacity and solubility of banana inflorescence flours.

	WHC			SS		
	Bracts	Flower	Palm	Bracts	Flower	Palm
Prata Anã	6.8 ± 0.1^{Aa}	4.4 ± 0.1^{Ba}	2.4 ± 0.1^{Cc}	6.1 ± 0.2^{Ba}	6.6 ± 0.1^{Be}	7.5 ± 0.1^{Ac}
SCS 451 Catarina	6.5 ± 0.1^{Ab}	3.4 ± 0.1^{Be}	2.6 ± 0.1^{Cb}	5.5 ± 0.2^{Cb}	8.2 ± 0.1^{Bc}	8.6 ± 0.1^{Aa}
Galil 18	6.3 ± 0.1^{Ac}	3.9 ± 0.1^{Bc}	2.5 ± 0.1^{Cc}	5.5 ± 0.1^{Cb}	8.9 ± 0.1^{Ab}	7.6 ± 0.1^{Bc}
BRS Japira	5.9 ± 0.1^{Ae}	3.6 ± 0.1^{Bd}	2.2 ± 0.1^{Ce}	5.3 ± 0.1^{Cc}	9.2 ± 0.2^{Aa}	8.0 ± 0.1^{Bb}
BRS Fhia Maravilha	6.3 ± 0.1^{Ac}	3.6 ± 0.1^{Bd}	2.4 ± 0.1^{Cc}	4.9 ± 0.1^{Cd}	6.7 ± 0.2^{Ae}	6.1 ± 0.1^{Bd}
BRS Pacoua	6.2 ± 0.1^{Ad}	3.5 ± 0.2^{Bd}	2.8 ± 0.1^{Ca}	5.1 ± 0.1^{Cc}	8.1 ± 0.2^{Ad}	7.6 ± 0.2^{Bc}
BRS Vitória	5.6 ± 0.1^{Af}	4.1 ± 0.1^{Bb}	2.3 ± 0.1^{Cd}	5.6 ± 0.1^{Cb}	8.3 ± 0.2^{Bc}	8.5 ± 0.4^{Aa}

Two-way ANOVA produced significant effects ($p \leq 0.001$) for all main factors and interactions. Uppercase letters in line compare the means of the different parts of inflorescence, and lowercase letters in column compare the means of cultivars. The same letters do not differ statistically by the Scott–Knott test ($p < 0.05$) (n = 4). WHC = water holding capacity, SS = solubility.

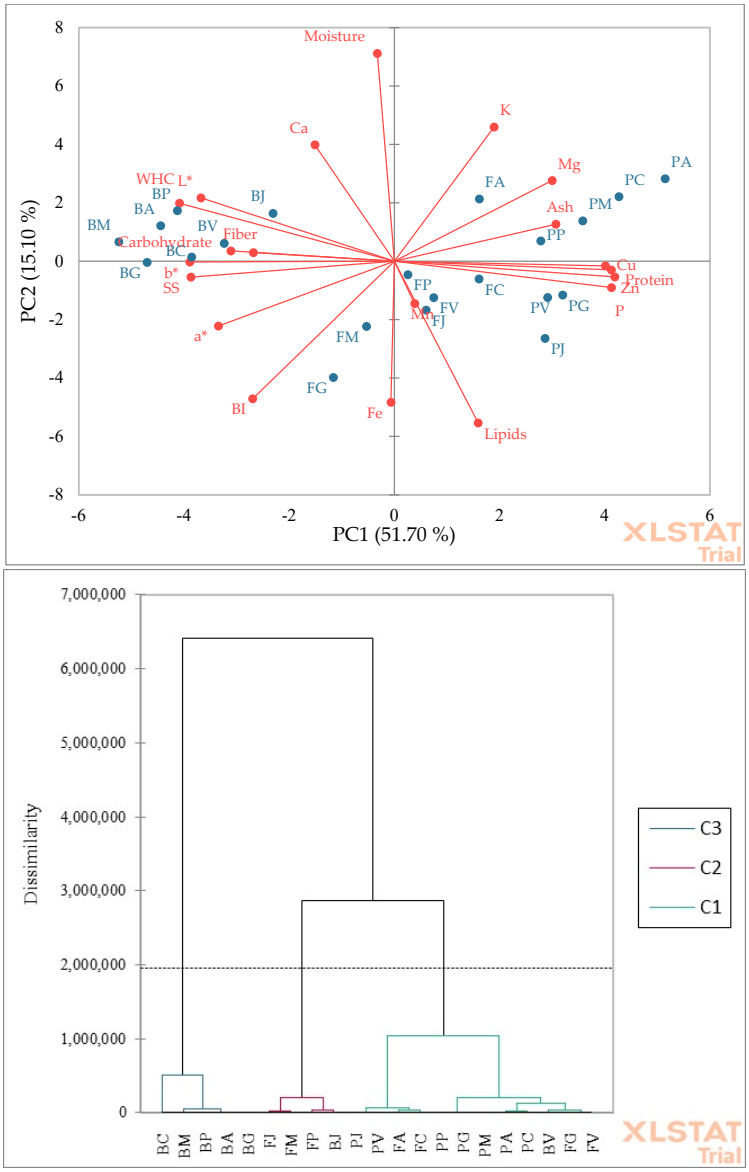

Figure 5. Principal component biplot and cluster dendrogram of banana inflorescence flour. The first letter in the flour abbreviation represents the inflorescence part, with B = bract flour, F = flower flour, and P = palm flour. The second letter represents the banana cultivar with A = Prata Anã; C = SCS451 Catarina, G = Galil 18, J = BRS Japira, M = BRS Fhia Maravilha, P = BRS Pacoua, and V = BRS Vitória. PC1 = principal component 1, PC2 = principal component 2, C1, C2, C3 = clusters 1, 2, and 3.

4. Discussion

The inflorescence consists of three main parts: the bracts, an outer sheath-like structure that is reddish to purple; whitish flowers known as florets; and the palm (edible portion) [36]. The inflorescence harvested from the Prata Anã cultivar was differentiated by its greater weight, which is due to the greater mass of bracts and flowers (Table 2). The 'BRS Vitória' had inflorescence of lower weight, similar to the weight of 558.48 g reported by Silva Neto et al. [37] as the average of 23 samples of inflorescences harvested from banana (*Musa* sp. cv. Pacovan). With the aim of obtaining flours, it is interesting to look at cultivars whose inflorescences have a higher fresh weight and a higher dry matter content, given the yield of the process. For all cultivars, the fraction with the highest fresh weight was the bracts, followed by flowers and the palm (Figure 2).

The banana inflorescence has a very high moisture content, which results in a short shelf life, justifying the production of flours to expand the possibilities of use. The flours were dehydrated until they reached values close to 10 g/100 g. The low moisture content of the inflorescence flours in this study means that they are more stable and can have a longer shelf life. All samples analyzed showed moisture values within the limit allowed in Resolution No. 711/2022, which establishes a maximum of 15% moisture in flours [38]. Moisture content is considered to be one of the main factors accelerating chemical and enzymatic reactions and can influence the quality of the product [39].

The potential applications of banana inflorescence flours depend on their chemical composition as well as physicochemical properties. The proximate composition of the banana inflorescence flours (Table 3) showed that the order of the nutrients present in the bract flours was fiber > carbohydrate > ash > protein > lipid. The order for the flower and palm flours was fiber > carbohydrate > protein > ash > lipid. Senevirathna and Karim [3] also reported variations in the proximate composition of the whole inflorescence (dry weight basis): 16.09 to 59.68% of carbohydrates, 1.53 to 19.60% of protein, 23.71 to 52.16% of fiber, and 6.51 to 18.30% of ashes.

The ash level obtained from the flour represents the mineral content, and its level is an indicator of quality. Inflorescence flours had ash contents ranging from 7.96 to 12.97 g/100 g (Table 3). Nogueira et al. [40] analyzed the palm, the yellow central part of the male inflorescence, of two banana cultivars and reported moisture ranging from 92.7 to 93.2 g/100 g and ash from 0.86 to 0.87 g/100 g (around 12.27 g/100 g on a dry basis), similar to those observed in this study for flour from this part of the inflorescence. The differences in the ash content of the inflorescence flours may be due to differences between cultivars in the nutrient uptake and utilization efficiency [41].

Considerable protein contents were observed in banana inflorescence flours (Table 3). It is important to highlight the higher contents observed for the flours obtained by processing the palm (17.3–19.4 g/100 g), with the highest levels observed for the flours from the Prata Anã and BRS Vitória cultivars. High protein contents and amino acid profiles have been highlighted in other studies. Schmidt et al. [42] also observed a high content of protein in banana inflorescence. The authors studied banana inflorescence from *Musa cavendishii* and reported 15.8 g/100 g (dry basis). Tasnim et al. (2020) [43] reported values of 14.2% protein in banana blossom flour content, higher than wheat flour, 12.34%. Analyzing the nutritional aspects of the inflorescences of two banana cultivars, Sheng et al. [44] found that they contained amino acids such as valine, methionine, isoleucine, leucine, tryptophan, phenylalanine, lysine, aspartic acid, serine, glutamic acid, proline, glycine, alanine, cysteine, tyrosine, histidine, and arginine. Inflorescence flours can be classified as a source of protein according to Resolution No. 429/2020, which permits this claim for products with contents higher than 6 g 100 g^{-1} [45].

Flour protein content can be a factor in their valorization as food ingredients. However, it is important to consider that in starchy products, protein interactions with starch interfere with rheological properties and digestibility [46].

The highest levels of lipids were observed in the flower flours, with the highest content in the flour from the cultivar Galil 18. The study by Ramu et al. [13] with banana inflorescence showed that linoleic acid was the main fatty acid (84.8%), suggesting that banana inflorescence is a good source of beneficial unsaturated fatty acids that can reduce the risk of cardiovascular diseases, which was also discussed by Lau et al. [5].

Regardless of the cultivars, the fiber content ranged from 34.8 to 40.6 g/100 g for the bract flours, 31.1 to 40.7 g/100 g for the flower flours, and 27.7 to 35.4 g/100 g for the palm heart flours, showing that the bract flours have the highest fiber content. These differences are explained by the fact that bracts are a protection that usually has a more rigid structure. Begum and Deka [8] reported a high concentration of total dietary fiber (TDF), soluble dietary fiber (SDF), and insoluble dietary fiber (IDF) in banana inflorescence (*Musa* ABB), with values ranging from 61.13 to 66.22 g/100 g for TDF, 4.36 to 7.23 g/100 g for SDF, and 53.9–61.86 g/100 g for IDF.

Fiber consumption is associated with a reduced risk of chronic diseases, including cardiovascular diseases, type 2 diabetes, and various types of cancer, which has led to the recommendation for a daily intake of 25–30 g/day for adults in many countries [47,48].

The inclusion of banana inflorescence flour in food formulations could help to achieve the recommended intake. Additionally, the functional importance of fruit and vegetable flours as sources of fiber was discussed in a review by Santos et al. [48]. The high fiber content generally observed in these flours can be a transporter of bioactive compounds along the gastrointestinal tract, thus allowing their release in the intestine after fermentation of the fiber by the intestinal microbiota.

Flours with a high fiber content have technological properties comparable to those of food additives that act as thickening agents. In addition, they have a high swelling capacity and can increase water retention, properties that are essential for the preparation of creams, sweets, and frozen desserts, among other food products [49].

Inflorescence flours have higher levels of carbohydrates. Bracts showed higher values, with flour from 'Prata Anã' showing greater content. High total carbohydrate content was reported in studies with banana inflorescence. Kavya et al. [50] observed 9.9 g/100 g in inflorescence with 88.75 g/100 g of moisture, and Kraithong and Issara [51] in a review on the composition of banana inflorescences, reported contents above 90 g/100 g of dry matter.

Currently, there are various types of fruit flour on the market, which have different nutritional compositions due to the raw materials, type of fruit, and part processed (pulp, seeds, albedo, peels). Variations in g/100 g of dry matter of 7.5 to 69.7 for fiber, 4.1 to 74.9 for carbohydrates, 2.9 to 12.9 for protein, 1 to 8.1 for lipids and 1 to 7 for ash were reported by Galvão et al. [35] for commercial fruit flours (banana, apple, orange, passion fruit, grape, blackberry, plum), showing that fruit flours are important sources of carbohydrates and fiber.

Mineral elements play a very important role in human health, with an adequate intake contributing to less susceptibility to infectious diseases due to a weakened immune system. Mineral elements are usually classified into two main categories, macrominerals and microminerals, depending on their required daily intake rather than their relative importance or physiological functions. Macromineral elements are those that require a daily intake of more than 100 mg per day, whereas a mineral required in quantities of less than 100 mg per day is considered a micromineral [52]. The main elements observed in all banana inflorescence flours were potassium, followed by phosphorus, calcium, and magnesium (Figures 3 and 4). This result was also observed in other studies on the mineral

element profile of banana inflorescences [46,53]. Regarding sodium, the values observed for all the inflorescence flours were below the levels reported by Adeolu and Enesi [54], who analyzed banana bracts and reported 280 mg/100 g on a dry basis.

Rosa et al. [55], analyzing the macro and minerals elements present in the flowers and bracts of dried banana inflorescence reported that based on the recommended daily intake the inflorescences could be excellent sources of Mg, P, Cr, Cu, Zn, and Fe for females, males, and pregnant women, all age 31–50 yo, as well as children (4–8 yo). Bracts could be a good source of Zn for male and pregnant women, and a good source of Fe for children.

Macromineral elements play several fundamental roles in the maintenance of the basic functions of the human body. Potassium is necessary for the normal functioning of all cells, tissues, and organs in the human body, acting to control blood pressure and playing an important role in cardiac function. Potassium deficiency impairs glucose metabolism, and, in severe cases, it is linked to cardiac arrhythmias. Sodium and potassium play a fundamental role in the distribution of fluids inside and outside cells. Calcium and phosphate are essential mineral elements needed for neuromuscular function and skeletal mineralization. Calcium plays a key role in cell membrane function and intracellular signaling. Phosphate is an important constituent of bone and is an essential component of DNA and RNA, the structure of cell membranes, and is involved in ATP synthesis. It is also necessary for the phosphorylation of many proteins and sugars. Magnesium is the second most abundant cation in the body's cells after potassium and is a cofactor in numerous enzyme systems that regulate biochemical reactions in the body, being essential for energy production (ATP), oxidative phosphorylation, and glycolysis. Magnesium also plays a key role in the active transport of calcium and potassium across cell membranes [56–61].

The order of concentration of the microminerals elements analyzed in the banana inflorescences was Mn > Zn > Fe > Cu. Results observed were similar to those reported by Kraithong and Issara [51] in their review of the nutritional aspects of banana inflorescences, reported variations of 4.8–56.4 mg/100 g for iron, 9.13–28.62 mg/100 g for zinc, and 5.53–79.59 mg/100 g for copper.

Micromineral elements have important functions for health, and inadequate intake can cause various problems. Iron is an essential component for the formation of the heme molecule and participates in the formation of various proteins, being essential for the transportation of oxygen, the production of cellular energy, and the maintenance of a healthy immune system. Manganese is involved in the metabolism of carbohydrates, cholesterol, and amino acids and in bone formation. Zinc is necessary for the normal functioning of the immune system and the regulation of blood pressure. Copper is important for metabolism and cell growth and is a component of many enzymes, including those involved in neurotransmitter synthesis, energy metabolism, and the cross-linking of collagen and elastin. Boron is a bioactive element in nutritional amounts that beneficially affects bone growth and central nervous system function, alleviates arthritic symptoms, facilitates hormone action, and is associated with a reduced risk for some types of cancer [53,60].

Ferreira and Tarley [61] evaluated commercial samples of green banana flour and observed great differences in their chemical and mineral elements composition, as well as in the bioaccessibility of mineral nutrients. They found that the presence of proteins and phytic acid had a negative influence on the bioaccessibility of elements and that Mg and Mn were the most bioaccessible elements in the gastrointestinal tract, followed by Zn and Cu. The lowest bioaccessible fractions were observed for Ca and Fe. Thus, based on the knowledge generated in our study, the bioaccessibility of nutrients in banana inflorescence flours should be explored in future research to increase their potential as foods and raw materials for the food and pharmaceutical industries.

Color and appearance attract a consumer to a product and can help with impulse purchases. Analysis of color parameters of inflorescence flours showed that, regardless of the cultivars, bract flour was less luminous than flower and palm flour. All the inflorescence flours had positive a* and positive b*, showing a high browning index (BI) (Table 4). The red-green coordinate, redness (a*), and yellow–blue coordinate, yellowness (b*) are affect the structural integrity of the fiber, the pigment content and disposition, with b* related to carotenoids present in flours [62,63].

Pigments give different colors to flour, with carotenoids providing yellow, orange, and red colors, and anthocyanins providing red, purple, and blue colors. The polyphenols that are oxidized can turn a brownish color to flour [49].

Nogueira et al. [40], after removing the purplish outer bracts and flowers from the male inflorescence of the 'Prata Anã' and 'Grand Naine' banana plants, produced flour from the yellow inner bracts (edible part). Authors reported that inner fresh bracts had a higher L* value (65.6), indicating a lighter color, however, flours showed lower brightness, with L* values close to 40.

The low values of luminosity (L*) added to the high values of browning index (BI) observed in our study can be due to the chemical composition of flours, which may have led to the Maillard reaction. The Maillard reaction occurs during thermal treatment, where amino acids and reducing sugars induce non-enzymatic reactions that produce melanoidin, a high-molecular-weight compound resulting in a brownish color [64].

Differences in fiber composition, protein and lipid content, and their varying proportions and interactions with polar and non-polar molecules influence the functional and technological properties of flours [65–68].

The water holding capacity (WHC) represents the amount of water that remains bound to the hydrated material following the application of an external force (centrifugation). The water retention capacity of banana inflorescence flours followed the order of bracts > flowers > palm. The higher WHC observed in bract flours suggests their potential usefulness in various food formulations, such as sausages, pasta, processed cheese, and bakery products; nevertheless, future studies should be carried out to determine the concentrations in the formulations. An indication of the quantity of soluble solids that are present in flour is its solubility (SS). Higher solubility was observed for palm and flower flours. Flours from the bracts of 'Prata Anã' showed the higher WHC (Table 5). The WHC of inflorescence flours was lower than that of other flours rich in dietary fiber, such as bambangan peel (11.6 g/g) and apple pomace (8.4 g/g), but similar to pomegranate juice whole fruit pomace (4.9 g/g) and mango peel (4.47–4.96 g/g) and pulp (3.2–3.62 g/g) flours [53,56–58]. The water retention capacity of flour defines its quality and its ability to form a viscoelastic dough. Flours that are higher in insoluble fibers are more likely to reduce the product's water absorption, since cellulose fibers have a lower water retention capacity. The higher level of protein in palm flours can be related to higher WHC, as the presence of polar amino acids in protein facilitates hydrogen bonding with water molecules, leading to increased water adsorption. High water-holding capacity improved food quality by reducing dehydration shrinkage, which is generally required for functional foods [51,64,68].

In the PCA loading plot, parameters that are close to each other in pairs or groups are positively correlated, while those in opposite directions are negatively correlated, and those in orthogonal directions are independent of each other (Figure 5). The flours clustered in the biplot have similar characteristics. The results for the inflorescence flour showed that the first and second principal components (PC1 and PC2) accounted for a total variation of 66.8%. In PC1, potassium, calcium, magnesium, and ash contributed to the differentiation of the palm flour of the cultivars Prata Anã, SCS451 Catarina, BRS Fhia Maravilha, and BRS Pacoua. Copper, zinc, and phosphorus contributed to differentiating the palm flour of the

cultivars Galil 18, BRS Vitória, and BRS Fhia Maravilha. The lipid content differentiated the flower flours. In PC2, carbohydrates, fibers, water retention capacity, and luminosity were the main parameters that played a role in differentiating the bract flours of all the cultivars.

The cluster separation method showed three distinct groups (Figure 5). C1 contains the bract flour of most banana cultivars, which shows less dissimilarity with C2, which contains the flower flour. The palm flour showed greater dissimilarity with these two groups, with protein, ash, and mineral element content (except iron and calcium) contributing to this separation.

The dissimilarities pointed out in our findings on the nutritional composition of the inflorescence flour will contribute to future advances. The existing literature on nutrients in banana inflorescences does not cover different cultivars and their portions, and there is a lack of information on the main commercial cultivars [3].

Banana inflorescence flours are therefore a viable, low-cost solution for improving and incorporating nutrients into food products. Future perspectives, however, should include studies analyzing the nutritional efficiency of the components of these flours and the effects of processing conditions on nutrients and technological properties in order to extend their use as a food ingredient. Furthermore, the impact of cultural practices such as fertilization and pest and disease control may interfere with the physical and nutritional characteristics of banana inflorescences, and future studies will need to integrate knowledge of these with the quality aspects of the flours.

5. Conclusions

The search for foods that combine nutritional aspects and contribute to sustainable development is a global priority. In this context, flour produced from fruit by-products has emerged as a promising source of food enrichment, contributing not only to nutrition but also to reducing losses.

The present study demonstrates that the part of the inflorescence was the main factor differentiating the flours, with the effect of the cultivar dependent on the part used to produce the flours. All the flours were high in fiber and carbohydrates. The considerable fiber content of these flours can be valued as a functional food but also enhances use by non-food industries. Palm flour showed higher levels of protein, which can be valued in protein-rich food supplements. The palm flours also stood out for their higher levels of mineral elements, especially potassium and phosphorus, which may contribute to an adequate intake. Flower flour should be investigated for the supply of lipids.

The Prata Anã cultivar had the largest inflorescence, with the highest percentage of bracts, and the flour from this portion stood out for its lower fiber content compared to the other flours. The cultivar SCS 451 Catarina is a cultivar that shows palm flour that can be valued for its higher fiber content and mineral elements such as K, P, Mg, Cu, and Zn. The Galil 18 cultivar had flower flour with higher levels of lipids. The BRS Japira cultivar had inflorescences with a high percentage of bracts, and, similarly to the Prata Anã cultivar, this flour had a high fiber content. The flower and palm flours from this cultivar showed higher levels of carbohydrates, with greater solubility and lower whiteness indices, technological characteristics that are crucial for their applicability. The BRS Fhia Maravilha cultivar had the largest inflorescences, with a high percentage of flowers. Its flower flours had higher levels of carbohydrates and fiber. 'BRS Pacoua' and 'BRS Vitória' had inflorescences of lower weight, which could compromise the flour yield. However, it was highlighted that for the BRS Vitória cultivar, the part of the inflorescence did not cause dissimilarities in the flours, unlike the others, which may favor the use of the whole inflorescence for flour production.

The differences between cultivars can contribute to varietal diversification in different regions, as they add value to an important agricultural by-product. Blends with proportions different from those found in inflorescences, as well as those from different cultivars, can promote the use of banana inflorescence flour in the preparation of nutrient-rich, high-value, flour-based food products.

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