Nutritional composition, chemical profile and antioxidant potential of black puçá fruit (Mouriri pusa) as a strategy for valuing native Brazilian fruits

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Research Article

Keywords: Native fruit, Antioxidant potential, Carbohydrate profile, Amino acids, Phenolic profile, Pigment extraction

Posted Date: April 11th, 2024

DOI: https://doi.org/10.21203/rs.3.rs-4223551/v1

Additional Declarations: No competing interests reported.

Abstract

The black puçá (Mouriri Pusa) is an unconventional fruit from the Cerrado region of Brazil, commonly known as jabuticaba of forest. However, data on its nutritional composition phytochemical composition are limited. In this study, the nutritional composition, physicochemical characteristics, profile of carbohydrates and organic acids, phenolics and flavonoids individual, amino acids composition, bioactive substances, and antioxidant potential were investigated in the pulp, peel, and seed fractions of puçá-preto. The results confirm that puçá-preto is an important nutritional source. The main organic acids were malic acid (187.54 – 290.50 mg g^{-1}) followed by tartaric acid (57.89 – 134.79 mg g^{-1}). 8 of the 9 essential amino acids were determined in black puçá, with arginine acid (0.24 – 2.03 g 100 g^{-1}) being the majority, followed by glutamic acid (0.34 – 1.87 g 100 g^{-1}). It presented satisfactory results for vitamin C, carotenoids, and anthocyanins, demonstrating potential for pigment extraction. The pulp and peel showed good antioxidant activity in relation to the capture of free radicals by the DPPH method and the reduction of ferric ions in the pulp. In regard to individual phenolic compounds, quercetin was the major compound in the pulp fraction (4.69 μg mL^{-1}); on the other hand, kaempferol had greater expression in the peels (20.78 μg mL^{-1}), while myricetin was quantified only in the seeds (10.67 μg mL^{-1}). The results showed that buritirana is rich in nutrients and bioactive products and can be fully utilized. The products resulting from buritirana processing can be applied in the food, and pharmaceutical industries.

Introduction

The biodiversity of the Brazilian Cerrado is represented by the variety of native species that occupy a prominent place in the regional and global food scene due to the growing interest in healthy and nutritious diets. This biome contains around 30% of Brazil's natural resources, presenting an ecosystem suitable for the development of many underexploited native and exotic species [1]. Therefore, in addition to the economic potential, the inclusion of these fruits in the diet can improve the health of the population. Consumption of native Cerrado fruits has been reported to decrease the incidence of chronic non-communicable diseases and has been associated with a lower incidence of cardiovascular and neurodegenerative diseases and also anti-inflammatory and antiviral activity [2–4]. Among the native species of the Cerrado biome, the black puçá (*Mouriri pusa* Gardner) stands out, where data on its chemical profile is scarce or non-existent. Belonging to the Melastomataceae family, the black puçá is popularly known as jaboticaba of Cerrado. The puçazeiro is a small fruit tree, between 4 and 8 m, with a short, tortuous trunk covered with irregular longitudinal fissures. It flowers from March to August, and fruiting occurs from July to December [5, 6]. The fruits are of the berry type with a purplish or yellowish peel with 1 to 4 seeds surrounded by yellow pulp; its pulp has a light and sweet texture. It is a fruit widely used in folk medicine, presenting a cytoprotective and healing effect in the treatment of gastric ulcers. Studies have shown that leaf and peel extracts are efficient in treating gastritis in rats; these results were associated with the high content of tannins and flavonoids present in the samples [7, 8].

The fruits of black puçá are consumed fresh or used in the production of jellies, sweets, juices, and ice creams. The pulp and peels are sources of bioactive compounds such as vitamins, minerals, and phenolic compounds and are a source of tannins [6]. Lima et al. [5] reported a total carotenoid content of 80.79 mg β-carotene 100 g^{-1}, vitamin C of 76.15 mg 100 g^{-1}, and a total phenolic content of 808.26 mg GAE 100 g^{-1}. Guimarães et al. [6] reported the content of individual phenolics for the black puçá pulp, being catechin (6.32 mg 100 g^{-1}), chlorogenic acid (3.99 mg 100 g^{-1}), rutin (0.48 mg 100 g^{-1}) and gallic acid (1.10 mg 100 g^{-1}) the main compounds. The authors also reported antioxidant activity of 2,2-diphenyl-1-picrylhydrazyl radical (DPPH•) and ferric ion reduction (FRAP) and phosphomolybdenum method of 2.79, 8.44, and 30.52 mg BHT g^{-1}, respectively. Although some studies indicate that black puçá is nutritionally rich and has a high content of bioactive compounds, data on its chemical profile are still scarce. Therefore, studies that contribute to increasing scientific knowledge about the chemical composition of black puçá could increase its consumption, production, and processing. Furthermore, knowledge of the composition of black puçá co-products, such as peels and seeds, can encourage the full use and appreciation of this fruit. Thus, this work has as its central objective the complete nutritional characterization of the pulp, peels, and seeds of black puçá, in addition to physical-chemical analyses, content of bioactive compounds, presence of antinutritional substances, antioxidant potential, as well as the extraction of pigments and optimization of the process using the response surface methodology. Data on the profile of carbohydrates, organic acids, and amino acids were reported for the first time in this study.

Materials and Methods

The Materials and methods section is presented in Supplementary Material 1.

Results and discussion

Nutritional composition, physical-chemical characteristics

The nutritional composition and physical-chemical characteristics of the pulp, peel, and seed fractions of the puçá-preto fruit are presented in Table 1. The pulp and peel of puçá-preto presented a high percentage of moisture (75.95 and 78.45 g 100 g^{-1}, respectively), while the seed presented a lower rate (41.60 g 100 g^{-1}) (Table 1). Water content in food is critically linked to production, processing, microbial safety, and chemical stability, while moisture in seeds is related to vigor and germination. For high water contents such as those present in the puçá pulp and peel, it is necessary to adopt preservation techniques to reduce the possibility of fruit deterioration during storage and minimize post-harvest losses [9]. In relation to lipids, the presence of low levels of lipids in the pulp and peel of black puçá (0.35 and 2.91 g 100 g^{-1}, respectively) was observed, a behavior already expected for fruits in general. The seed fraction was the one with the highest lipid content (25.01 g 100 g^{-1}) (Table 1) since, in most plants, the oil is stored mainly in the endosperm of the seeds (Lu et al., 2018). Therefore, the content and composition of oils in the seeds may come from genetic and metabolic factors that must be evaluated in more depth to increase the possibilities of using the Cerrado flora and applying it in industry as a functional product. The pulp had a low protein content (3.61 g 100 g^{-1}); on the other hand, the peel and seed of the puçá can be considered protein sources (6.40 and 16.50 g 100 g^{-1}, respectively).

Pectin is a dietary fiber obtained from a variety of plant sources and is widely used as a gelling agent in the food industry. In the pulp and peel fractions, a content of 31.08 and 14.49 g 100 g^{-1} of pectin was observed (Table 1), higher than the range established for citrus fruit pectin of 10 to 30% [10]; this way, the pectin extracted from puçá pulp and peel can be studied to be used as a substitute for commercial pectin. Therefore, alternative methods for removing this pectin can be proposed in order to maximize the yields obtained. An alternative method for future studies is the extraction of pectin from black puçá with subcritical water and natural deep eutectic solvents. Regarding the results obtained for starch content, low levels can be seen in all fractions (1.17, 1.22, and 1.17 g 100 g^{-1} of starch, for pulp, peel, and seed, respectively), corroborating the high levels of carbohydrates and soluble solids found in the fruit, as during fruit maturation, starch is converted into sugars. Therefore, the starch in the analyzed fruit was almost completely degraded, demonstrating that the fruit was utterly ripe [11].

Table 1. Nutritional composition, physicochemical characteristics, and profile of carbohydrates and organic acids of black puçá (*Mouriri pusa*) pulp, peels, and seeds.

Analysis (dry basis)	Pulp	Peel	Seeds
Composition (g 100 g^{-1})			
Moisture	75.95 ± 0.14	78.45 ± 0.06	41.60 ± 0.03
Ash	0.71 ± 0.01	0.71 ± 0.01	1.83 ± 0.01
Lipids	0.35 ± 0.08	2.91 ± 0.09	25.01 ± 0.10
Proteins	3.61 ± 0.03	6.40 ± 0.01	16.50 ± 0.01
Pectin	31.08 ± 0.01	14.49 ± 0.05	nd.
Starch	1.17 ± 0.02	1.22 ± 0.02	1.17 ± 0.01
Total carbohydrates *	19.38 ± 0.12	11.53 ± 0.27	15.06 ± 0.31
Energetic value (kcal 100 g^{-1})	95.11± 0.33	83.41 ± 0.38	351.33 ± 0.47
pH	5.44 ± 0.07	5.77 ± 0.11	5.81 ± 0.06
Soluble solids (ºBrix)	15.5 ± 0.17	16.5 ± 0.03	nd.
*L**	44.22 ± 2.34	19.24 ± 1.85	-
Chroma (*C**)	35.41 ± 2.59	5.77 ± 0.64	-
ºHue (*h*)	76.00 ± 0.49	42.67 ± 0.80	-
Carbohydrates (mg g^{-1})			
Sucrose	nd.	nd.	nd.
Fructose	10.94 ± 0.05	6.58 ± 0.07	3.81± 0.01
Glucose	nd.	nd.	nd.
Xylose	8.79 ± 0.12	4.66 ± 0.09	3.23 ± 0.04
Cellobiose	nd.	nd.	nd.
Arabinose	nd.	nd.	nd.
Organic acids (mg g^{-1})			
Ascorbic acid	81.36 ± 0.33	58.93 ± 0.12	71.95 ± 0.34
Tartaric acid	57.89 ± 0.07	134.79 ± 0.08	134.68 ± 0.06
Malic acid	290.50 ± 0.14	187.54 ± 0.05	247.34 ± 0.19
Citric acid	234.74 ± 0.03	nd.	nd.

Values expressed as mean ± standard deviation (*n* = 5); *Carbohydrates calculated by difference; **values expressed in g citric acid 100 g^{-1}; **nd**: not detected.

In nutritional terms, the varied consumption of fruits represents an important source of carbohydrates. The replacement of sugars from industrialized foods can be done by consuming native fruits, such as black puçá [5, 6]. The average value of carbohydrates found in the samples ranged from 11.53 to 19.38 g 100 g^{-1} (Table 1). These differences observed in the nutritional results of carbohydrates are due to intrinsic and extrinsic factors, such as pH, solar incidence, rainfall levels, pollution, and soil, among others (Morais et al., 2024). Therefore, from a nutritional point of view, all fractions (pulp, peel, and seeds) would fit as a food rich in this constituent since foods with values of up to 5g of sugars 100 g^{-1} of the food are considered low in sugars [2].

Carbohydrate and organic acid profile

The results for the carbohydrate and organic acid profiles are also presented in Table 1. This study quantified the carbohydrates: glucose, sucrose, fructose, arabinose, cellobiose, and xylose. The results of the carbohydrate profile analysis demonstrate that only xylose and fructose were detected in all fractions of puçá-preto, with fructose being the majority carbohydrate (10.94, 6.58, and 3.81 mg g^{-1} for pulp, peel, and seed, respectively). Fructose is a monosaccharide from the ketose family and an isomer of glucose. It is naturally found in honey and fruits and is associated with glucose and sucrose in smaller quantities. Fructose is also considered sweeter than galactose and glucose and even more so than disaccharide sucrose [12], which explains the sweet flavor of the black puçá pulp. As for the xylose content, it was most abundant in the pulp fraction with 8.79 mg g^{-1}, followed by the peel (4.66 mg g^{-1}) and the seed (3.23 mg g^{-1}). Xylose is a pentose that can be extracted from the cell walls of cereal hemicellulose, for example. It has a sweet taste and is an alternative to several sugars consumed on a large scale, mainly due to its low impact on the glycemic response. Xylose has a functionality that is the inhibition of sucrose hydrolysis by competitive inhibition of the sucrase enzyme in the intestine; that is, the ingestion of xylose together with sucrose can slow down the digestion of sucrose, and glucose absorption will be further delayed. Therefore, the consumption of puçá-preto pulp can potentially reduce the glycemic response post-digestion. Sucrose and glucose were not detected in the black puçá parts, characterizing it as a fruit with a low glycemic content recommended for consumption by people with diabetes [3].

The results on individual organic acids are also presented in Table 1. The quantitative analysis of organic acids detected ascorbic acid (58.93 – 81.36 mg g^{-1}), tartaric (57.89 – 134.79 mg g^{-1}), and malic (187.54 – 290.50 mg g^{-1}) in all portions of puçá-preto, citric acid was detected only in the pulp fraction (234.74 mg g^{-1}). Among the four organic acids identified, malic acid was the majority in all fractions, followed by citric acid in the pulp. In this sense, malic and citric acid are the two most abundant acids in fruits. They have significant protective effects on the myocardium and act on ischemic injuries, and together with their salts, they contribute to the absorption of iron. They are also used in the food and beverage industry as acidulants and flavor enhancers and to mask the aftertaste of artificial sweeteners [13]. Regarding the results for tartaric acid, Table 1 shows that this compound was predominant in the peel fraction (134.79 mg g^{-1}) and the seed (134.68 mg g^{-1}). Like citric acid, tartaric acid is a weak organic acid that occurs naturally in fruits such as grapes, jabuticaba, and juçara and plays an essential role in the sensory quality of drinks, providing a characteristic flavor. Furthermore, tartaric acid has a broad spectrum of applications and can be used as an acidifier, antioxidant, and flavor enhancer in beverages and the food industry [14]. On the other hand, ascorbic acid was predominant in the pulp (81.36 mg g^{-1}) and seed (71.95 mg g^{-1}) of puçá-preto. Fruits are one of the main natural sources of ascorbic acid, also known as vitamin C, and they play an important role as antioxidants and strengthen the immune system. A deficiency in this vitamin can cause a disease called scurvy, which can cause symptoms such as muscle weakness and joint pain [15].

Amino acid profile

The amino acid contents (expressed in g 100 g^{-1}) of the pulp, peel, and seed fractions of black puçá are presented in Table 2. In the pulp and seed fractions, eight of nine amino acids were determined, these being histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, and valine. The total amino acids in the pulp, peel, and seed amount to 6.65, 3.10, and 10.47 g 100 g^{-1}, respectively; therefore, the consumption of puçá-preto can be an exciting option to provide essential amino acids and contribute to protein intake. Although the amino acid tryptophan has not been identified, black puçá still offers a good variety of essential amino acids, which are necessary for protein synthesis and various functions in the body [16]. Furthermore, the nutritional composition and health benefits go beyond essential amino acids and proteins. It is important to consider other nutrients present in puçá-preto, such as vitamins, minerals, and fiber, which also play an important role in a balanced diet.

Table 2 Total amino acid composition of the pulp, peels, and seeds of black puçá (*Mouriri pusa*) and the standard recommended by FAO/WHO/UNU (2007).

Amino acid (g 100 g^{-1})	Samples			FAO (g protein 100 g^{-1})		
	Pulp	Peel	Seeds	3 – 10 years	11 – 14 years	Adult
Essentials						
Histidine	0.09 ± 0.02	0.09 ± 0.01	0.28 ± 0.07	1.6	1.6	1.5
Threonine	0.12 ± 0.01	0.15 ± 0.02	0.22 ± 0.03	2.5	2.5	2.3
Valine	0.20 ± 0.04	0.20 ± 0.07	0.44 ± 0.07	4.0	4.0	3.9
Isoleucine	0.14 ± 0.01	0.14 ± 0.05	0.33 ± 0.01	3.1	3.0	3.0
Leucine	0.28 ± 0.09	0.25 ± 0.09	0.82 ± 0.03	6.1	6.0	5.9
Lysine	0.15 ± 0.01	0.21 ± 0.01	0.31 ± 0.01	4.8	4.8	5.0
Tyrosine	0.07 ± 0.01	0.08 ± 0.02	0.37 ± 0.06	-	-	-
Methionine	0.02 ± 0.00	< 0.01	0.08 ± 0.00	-	-	-
Phenylalanine	0.16 ± 0.01	0.15 ± 0.01	0.60 ± 0.01	-	-	-
Non-essential						
Aspartic acid	0.39 ± 0.08	0.33 ± 0.01	0.87 ± 0.08			
Glutamic acid	0.62 ± 0.10	0.34 ± 0.01	1.87 ± 0.34			
Serina	0.25 ± 0.02	0.21 ± 0.08	0.33 ± 0.02			
Glycine	0.23 ± 0.03	0.20 ± 0.02	0.81 ± 0.15			
Taurine	< 0.01	< 0.01	< 0.01			
Arginine	0.33 ± 0.02	0.24 ± 0.01	2.03 ± 0.37			
Alanine	0.25 ± 0.01	0.22 ± 0.04	0.39 ± 0.14			
Proline	0.23 ± 0.01	0.21 ± 0.04	0.43 ± 0.12			

Cystine	0.10 ± 0.01	0.05 ± 0.00	0.25 ± 0.02
Hydroxyproline	0.02 ± 0.00	0.03 ± 0.01	0.04 ± 0.00
∑ Amino Acids	6.65 ± 0.12	3.10 ± 0.28	10.47 ± 0.37

Values expressed as mean ± standard deviation (n = 2); * < 0.01 = Below the limit of quantification (LOQ < 0.01).

According to the results, the seed fraction presented a total of 10.47 g 100 g^{-1}, followed by pulp and peel with 6.65 and 3.10 g 100 g^{-1}, respectively. Evaluating individually, it is observed that the seed fraction has a high content of essential amino acids compared to the other fractions. The predominant amino acids in all fractions were glutamic acid and arginine, which constituted approximately 0.62 – 1.87 g 100 g^{-1} and 0.33 – 2.03 g 100 g^{-1} of the total amino acid content, respectively (Table 2). This aligns with previous findings showing that glutamic acid, aspartic acid, and arginine are among the most abundant amino acids in fruits and their derivatives [17]. Although they are not essential amino acids, that is, the body is capable of synthesizing them internally; these amino acids can play important roles in the body and are involved in several biological functions. Glutamic acid, for example, is an excitatory neurotransmitter and plays a fundamental role in transmitting signals between neurons; it is engaged in diverse neurological functions, such as learning, memory, synaptic plasticity, and mood regulation. Arginine plays a crucial role in the synthesis of nitric oxide, which has vasodilatory, antioxidant, and antiplatelet effects, with positive repercussions in reducing the risk of cardiovascular diseases and helping regulate blood flow [18].

Among the essential amino acids and the fractions studied (pulp, peel, and seed), those that showed the highest expression were leucine (0.25 – 0.82 g 100 g^{-1}) and valine (0.20 – 0.44 g 100 g^{-1}), respectively (Table 2). Leucine and valine are essential amino acids with significant benefits for human health, highlighting the importance of their presence in food. Leucine plays a crucial role in the synthesis of muscle proteins, promoting the growth and repair of muscle tissues [19]. Furthermore, valine is a stimulant of the mTOR pathway, which regulates the cell growth process. Both amino acids are considered essential because the body cannot produce them internally, making it necessary to obtain them through food [20]. Therefore, including sources rich in leucine and valine, such as lean meats, eggs, legumes, and fruits, is vital to ensure adequate muscle function, promote tissue regeneration, and maintain the structural integrity of the body.

Phytochemicals, antioxidant potential, and anti-nutritional factors

Phytochemical composition

The results of the phytochemical composition analysis of the pulp, peel, and seed fractions of the puçá-preto fruit are presented in Supplementary material 2. Carotenoids are important natural pigments, giving a yellow, orange, or red color. It was observed that the pulp (23.51 mg β carotene 100 g^{-1}) and peels (24.07 mg β carotene 100 g^{-1}) of black puçá presented considerable carotenoid content; in comparison, the seeds presented low concentrations of the compound (5.47 mg β carotene 100 g^{-1}) (Supplementary material 2). According to Lima et al. [5] and Guimarães et al. [6], the pulp and peel fractions are considered an excellent source of carotenoids with a higher concentration of β-carotene, a precursor of vitamin A. In addition to carotenoids, it is also an important source of vitamin B_2 (riboflavin), but it is more concentrated in its pulp due to its yellow-orange color. However, the results for the black puçá pulp were higher than those reported by Lima et al. [5] at 21.76; these differences in carotenoid content between the fruits may be the result of several factors, such as degree of maturation, environment sample storage, genetic factors, water availability, and temperature, among other factors [21]. These results demonstrate that the pulp, as well as the peels of black puçá, can be considered for carotenoid prospecting and can be used as strategies to add value to these fruits due to their high concentration.

The findings presented in Supplementary material 2 elucidate the levels of vitamin C for pulp, peels, and seeds of black puçá, quantified at 36.03, 15.71, and 14.11 mg AA 100 g^{-1}, respectively. Ascorbic acid is an essential molecule, as it participates in numerous physiological processes in organisms. Within plant physiology, it plays a protective role against reactive oxygen species generated during respiratory and photosynthetic pathways. Therefore, fruits with considerable vitamin C content, such as black puçá, deserve recognition. Vitamin C is the predominant water-soluble antioxidant in plant systems [22]. Consequently, the components of the black puçá fruit have notable reservoirs of this compound. Analogous levels have been observed in several other tropical fruits native to the Brazilian biome, including açaí (84.00 mg AA 100 g^{-1}), murici (148.10 mg AA 100 g^{-1}), and cajá (26.50 mg AA 100 g^{-1}) [23]. Vasco et al. [24] classified fruit phenolic compounds into three different categories according to content: low (< 100 mg GAE 100 g^{-1}), medium (100 – 500 mg GAE 100 g^{-1}), and high (> 500 mg GAE 100 g^{-1}) for samples based on fresh matter. Therefore, the total phenolic contents for the peels and seeds of black puçá (1232.04 and 1788.37 mg GAE 100 g^{-1}) (Supplementary material 2) are classified as fruits with high levels of this bioactive compound, respectively. The pulp was classified as having a medium total phenolic content (282.08 mg GAE 100 g^{-1}), in accordance with the findings of Guimarães et al. [6], who reported total phenolics for the black puçá pulp of 325.47 mg GAE 100 g^{-1}. The presence of phenolic compounds contributes to the antioxidant activity of foods and has antimicrobial, anticancer, antiviral, anti-inflammatory, lipid-lowering, and hypoglycemic effects [25].

A relevant result for the total anthocyanin content was identified in the fruit peel (45.93 mg 100 g^{-1}) when compared to purple fruits such as açaí (22.08 mg 100 g^{-1}) and grapes (30. 9 mg 100 g^{-1}), for example. Anthocyanins are part of a subgroup of secondary metabolites known as flavonoids and are largely responsible for the antioxidant capacity in fruits [26]. Regarding the flavonoid content, they were found in high concentrations in the peel (11.32 mg RU 100 g^{-1}) and seed (53.71 mg RU 100 g^{-1}) of black puçá, which is relevant regarding the use of the fruit, since flavonoids are substances that have free radical capture properties, antioxidant, anti-inflammatory activity, and, therefore, can add value to waste.

Evidence also suggests that the pharmacological effects of flavonoids are correlated with their antioxidant activity [27].

Antioxidant potential

The results for DPPH, expressed in Supplementary material 2, demonstrate that extracts from the peels and seeds of black puçá have a high capacity to eliminate free radicals, resulting in 90.54 and 89.12% inhibition of the DPPH radical, respectively. Values similar to those found for the peels and seeds of buritirana (*Mauritiella armata*), another fruit native to the Brazilian Cerrado, of 77.90 and 60.50% inhibition of the DPPH radical, respectively [4]. The antioxidant activity of black puçá peels and seeds may be linked to the high levels of phenolic compounds identified in these fractions. It is important to analyze the profile of phenolic compounds, as it can determine which compounds are generating a high antioxidant capacity. The FRAP method evaluates antioxidant activity through iron reduction, based on the observation of results, so that higher values express more significant antioxidant potential [28]. Therefore, the FRAP protocol presented satisfactory values for the pulp, peels, and seeds of black puçá, obtaining results of 5.42, 11.90, and 10.08 μM of ferrous sulfate g^{-1} (Supplementary material 2). However, despite presenting satisfactory results, they were inferior to the findings reported for açaí 32.1 μM of ferrous sulfate g^{-1}, jambolan 35.5 μM of ferrous sulfate g^{-1}, and mangaba 18.3 μM of ferrous sulfate g^{-1} studied by Rufino et al. [23]. According to the $ABTS^{+}$ method, the value of the antioxidant capacity equivalent to Trolox characterizes the ability of the tested sample to react with ABTS+, as well as to inhibit oxidative processes [4–6]. Therefore, the higher the value expressed, the greater the antioxidant potential. The data obtained by this method were 2.68, 29.21 and 8.81 μM Trolox g^{-1} for the pulp, peels and seeds of black puçá, respectively (Supplementary material 2), demonstrating a low capacity to reduce radical cations in all samples studied.

Individual phenolics

The phenolic compounds identified in the different parts of black puçá (Table 3) were only gallic acid and the flavonoids kaempferol, quercetin, and rutin. Two phenolic compounds were identified in the pulp and seed and four in the peels. However, several compounds evaluated were below the limit of quantification (< LOQ). In the black puçá pulp, only two individual phenolics were quantified, namely gallic acid (0.36 μg mL^{-1}) and quercetin (4.69 μg mL^{-1}). However, Guimarães et al. [6] reported catechin (63.20 μg g^{-1}) and chlorogenic acid (39.90 μg g^{-1}) as being the main compounds of black puçá pulp. These differences between samples are mainly due to factors such as maturation, compound extraction techniques, soil and climate factors, and selectivity of the equipment used. Gallic acid, due to the number and location of hydroxyls in the aromatic ring, has high antioxidant activity and may be directly correlated with the antioxidant capacity to scavenge the DPPH radical [29]. On the other hand, quercetin, the majority component of black puçá pulp, has anti-diabetic, anti-inflammatory, antioxidant, antimicrobial, anti-Alzheimer's, cardiovascular effects, as well as its anticancer activity against different cancer cell lines, has recently been reported [30].

Table 3. Phenolic profile of the pulp, peels, and seeds of black puçá.

Standards (μg mL^{-1})	R^2	Pulp	Peels	Seeds
Phenolic acids				
Caffeic acid	0,9995	< LOQ	nd.	nd.
Ellagic acid	0,9995	< LOQ	nd.	nd.
Gallic acid	0,9998	0.36 ± 0.03	0.12 ± 0.16	nd.
Chlorogenic acid	0,9995	nd.	nd.	nd.
Flavonoids				
Catechin	0,9999	< LOQ	< LOQ	< LOQ
Kaempferol	0,9993	< LOQ	20.78 ± 0.01	nd.
Myricetin	0,9998	< LOQ	< LOQ	10.67 ± 0.01
Quercetin	0,9996	4.69 ± 0.05	1.33 ± 0.08	< LOQ
Naringin	0,9996	nd.	nd.	nd.
Rutin	0,9998	< LOQ	7.56 ± 0.12	9.06 ± 0.21

Values expressed as mean ± standard deviation; nd.: Not detected.; < LOQ: Limit of quantification.

The black puçá peel was part of the fruit that presented the highest amount of identified compounds, which were gallic acid, kaempferol, quercetin, and rutin with 0.12, 20.78, 1.33 and 7.56 μg mL^{-1}, respectively. As far as we know, this is the first work to evaluate individual phenolic compounds in the peels of black puçá, thus demonstrating the novelty of this work. These compounds uniquely act on diverse biological processes and maintain human health; however, when they act in synergism, they exhibit a wide range of therapeutic effects, including high antioxidant, antimicrobial, anticarcinogenic, hepatoprotective, antiviral, anti-inflammatory, antithrombotic potential, and helps to increase sperm viability, in addition to having an antiseptic effect [29]. In relation to the black puçá seed, the only phenolic compounds identified were myricetin (10.67 μg mL^{-1}) and rutin (9.06 μg mL^{-1}) (Table 3), which are also the first findings for this fraction. These two compounds act on a wide range of benefits proven in the literature, such as protection against degenerative diseases, antidiabetic, antibacterial activity against gram-positive bacteria, and help to strengthen the brain sectors responsible for memory [30].

Conclusion

The puçá fruit studied is rich in bioactive substances such as phenolics, vitamins, carotenoids, and anthocyanins, which indicates potential for pigment extraction. The high levels of flavonoids in the peel and vitamin C in the peel and seed explain the pronounced antioxidant capacity in these fractions to capture free radicals, which adds value to the use of the fruit due to the related pharmacological effects. Ascorbic acid, malic, tartaric, and citric acid were detected and participated in the fruit's characteristic flavor, in addition to possible technological applications in the food industry. Regarding the presence of flavonoids, kaempferol, myricetin, rutin, and quercetin were detected, demonstrating that the inclusion of puçá in the diet as a source of bioactive can become an effective tool in protecting the body against oxidative stress. Furthermore, fully utilizing the fruit can reduce waste and preserve the environment. The knowledge generated in this study can stimulate the demand, consumption and cultivation of this fruit. The nutritional and chemical composition results of buritirana showed its potential to be incorporated into food, cosmetic and pharmaceutical formulations.

Declarations

Supplementary Information The online version contains supplementary material available.

Autor contribution: Conceptualization: RMS, CMSS, and GASM; Investigation: RMS, GFL, CCG, and JEBO; Writing – original draft: RMS, CMSS, and RAM; Writing – review and editing: RAM, and GASM; Supervising: RAM, and GASM.

Funding and Acknowledgments

G.A.S. Martins received a grant and thanks the CAPES/Brazil nº: 88881.200497/2018-01, PROCAD-AM 1707/2018. G.A.S. Martins received funding and thanks to the CNPq Edital de Produtividade em Desenvolvimento Tecnológico e Extensão Inovadora nº: 304505/2022-6, and CAPES - Process nº: 23038.000878/2021-56, Edital CAPES nº 018/2020 – Programa de Desenvolvimento da Pós-Graduação-Parcerias Estratégicas nos Estados.

Data Availability Data and material may be provided on request by the corresponding authors.

Ethical Approval: Not applicable.

Conflict of Interest: The authors declare no conflict of interest.

References

1. Morais RA, Teixeira GL, Ferreira SRS, et al (2022) Nutritional Composition and Bioactive Compounds of Native Brazilian Fruits of the Arecaceae Family and Its Potential Applications for Health Promotion. Nutrients 14:4009. https://doi.org/10.3390/nu14194009
2. Siqueira APS, Oliveira J de M, Machado Junior DR, Lourenço MF de C (2017) Chemical characterization and antioxidant capacity of guapeva. Rev Bras Frutic 39. https://doi.org/10.1590/0100-29452017584
3. da Silva Sousa HM, Leal GF, da Silva Gualberto L, et al (2023) Exploration of the chemical characteristics and bioactive and antioxidant potential of tucumã (*Astrocaryum vulgare*), peach

palm (*Bactris gasipaes*), and bacupari (*Garcinia gardneriana*) native Brazilian fruits. Biomass Convers Biorefin. https://doi.org/10.1007/s13399-023-05145-1

4. Alves Morais R, Lopes Teixeira G, Aparecida de Souza Martins G, et al (2024) Comprehensive evaluation of the chemical profile and antioxidant potential of buritirana (*Mauritiella armata*) an underexplored fruit from Brazilian Cerrado. Food Research International 179:113945. https://doi.org/10.1016/j.foodres.2024.113945
5. Lima JP de, Nunes EE, Borges LA, et al (2022) Physicochemical characteristics and bioactive compounds of three puçá (*Mouriri pusa* Gardner) varieties, an underexploited fruit from the Brazilian Cerrado. Acta Scientiarum Technology 45: e61765. https://doi.org/10.4025/actascitechnol.v45i1.61765
6. Guimarães ACG, de Souza Gomes M, Zacaroni Lima LM, et al (2023) Application of Chemometric Techniques in The Evaluation of Bioactive Compounds and Antioxidant Activity of Fruit from Brazilian Cerrado. Journal of Food Measurement and Characterization 17:2095–2106. https://doi.org/10.1007/s11694-022-01736-0
7. Mesa K, Serra S, Masia A, et al (2016) Seasonal trends of starch and soluble carbohydrates in fruits and leaves of ‘Abbé Fétel’ pear trees and their relationship to fruit quality parameters. Sci Hortic 211:60–69. https://doi.org/10.1016/j.scienta.2016.08.008
8. Munteanu IG, Apetrei C (2021) Analytical Methods Used in Determining Antioxidant Activity: A Review. Int J Mol Sci 22:3380. https://doi.org/10.3390/ijms22073380
9. Schmidt SJ (2020) Water Mobility in Foods. In: Water Activity in Foods. Wiley, pp 61–122
10. Methacanon P, Krongsin J, Gamonpilas C (2014) Pomelo (*Citrus maxima*) pectin: Effects of extraction parameters and its properties. Food Hydrocoll 35:383–391. https://doi.org/10.1016/j.foodhyd.2013.06.018
11. Mesa K, Serra S, Masia A, et al (2016) Seasonal trends of starch and soluble carbohydrates in fruits and leaves of ‘Abbé Fétel’ pear trees and their relationship to fruit quality parameters. Sci Hortic 211:60–69. https://doi.org/10.1016/j.scienta.2016.08.008
12. Qi X, Tester RF (2019) Fructose, galactose and glucose – In health and disease. Clin Nutr ESPEN 33:18–28. https://doi.org/10.1016/j.clnesp.2019.07.004
13. Kövilein A, Kubisch C, Cai L, Ochsenreither K (2020) Malic acid production from renewables: a review. Journal of Chemical Technology & Biotechnology 95:513–526. https://doi.org/10.1002/jctb.6269
14. Inić S, Ljepović M, Domijan A-M, et al (2020) HPLC Analysis of Citric and Tartaric Acids in Fruit Nectars and Juices. Croatica Chemica Acta 93. https://doi.org/10.5562/cca3662
15. Porto ISA, Santos Neto JH, dos Santos LO, et al (2019) Determination of ascorbic acid in natural fruit juices using digital image colorimetry. Microchemical Journal 149:104031. https://doi.org/10.1016/j.microc.2019.104031
16. Lieu EL, Nguyen T, Rhyne S, Kim J (2020) Amino acids in cancer. Exp Mol Med 52:15–30. https://doi.org/10.1038/s12276-020-0375-3

17. Simón MA, Grao SS, Gonzalez EAZ, et al (2021) Physiological, Nutritional and Metabolomic Responses of Tomato Plants After the Foliar Application of Amino Acids Aspartic Acid, Glutamic Acid and Alanine. Front Plant Sci 11. https://doi.org/10.3389/fpls.2020.581234
18. Gawrys J, Gajecki D, Szahidewicz-Krupska E, Doroszko A (2020) Intraplatelet L-Arginine-Nitric Oxide Metabolic Pathway: From Discovery to Clinical Implications in Prevention and Treatment of Cardiovascular Disorders. Oxid Med Cell Longev 2020:1–11. https://doi.org/10.1155/2020/1015908
19. Columbus DA, Fiorotto ML, Davis TA (2015) Leucine is a major regulator of muscle protein synthesis in neonates. Amino Acids 47:259–270. https://doi.org/10.1007/s00726-014-1866-0
20. Dodd KM, Tee AR (2012) Leucine and mTORC1: a complex relationship. American Journal of Physiology-Endocrinology and Metabolism 302: E1329–E1342. https://doi.org/10.1152/ajpendo.00525.2011
21. Carvalho DU de, Cruz MA da, Colombo RC, et al (2020) Determination of organic acids and carbohydrates in 'Salustiana' orange fruit from different rootstocks. Brazilian Journal of Food Technology 23. https://doi.org/10.1590/1981-6723.32918
22. Caritá AC, Fonseca-Santos B, Shultz JD, et al (2020) Vitamin C: One compound, several uses. Advances for delivery, efficiency and stability. Nanomedicine 24:102117. https://doi.org/10.1016/j.nano.2019.102117
23. Rufino M do SM, Alves RE, de Brito ES, et al (2010) Bioactive compounds and antioxidant capacities of 18 non-traditional tropical fruits from Brazil. Food Chem 121:996–1002. https://doi.org/10.1016/j.foodchem.2010.01.037
24. Vasco C, Ruales J, Kamal-Eldin A (2008) Total phenolic compounds and antioxidant capacities of major fruits from Ecuador. Food Chem 111:816–823. https://doi.org/10.1016/j.foodchem.2008.04.054
25. Alu'datt MH, Rababah T, Alhamad MN, et al (2017) A review of phenolic compounds in oil-bearing plants: Distribution, identification and occurrence of phenolic compounds. Food Chem 218:99–106. https://doi.org/10.1016/j.foodchem.2016.09.057
26. Kuskoski EM, Asuero AG, Morales MT, Fett R (2006) Frutos tropicais silvestres e polpas de frutas congeladas: atividade antioxidante, polifenóis e antocianinas. Ciência Rural 36:1283–1287. https://doi.org/10.1590/S0103-84782006000400037
27. Shen N, Wang T, Gan Q, et al (2022) Plant flavonoids: Classification, distribution, biosynthesis, and antioxidant activity. Food Chem 383:132531. https://doi.org/10.1016/j.foodchem.2022.132531
28. Munteanu IG, Apetrei C (2021) Analytical Methods Used in Determining Antioxidant Activity: A Review. Int J Mol Sci 22:3380. https://doi.org/10.3390/ijms22073380
29. Rajan VK, Muraleedharan K (2017) A computational investigation on the structure, global parameters and antioxidant capacity of a polyphenol, Gallic acid. Food Chem 220:93–99. https://doi.org/10.1016/j.foodchem.2016.09.178
30. Salehi B, Machin L, Monzote L, et al (2020) Therapeutic Potential of Quercetin: New Insights and Perspectives for Human Health. ACS Omega 5:11849–11872.

https://doi.org/10.1021/acsomega.0c01818

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