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PHYSICOCHEMICAL CHARACTERIZATION OF DWARF AMBARELLA (*SPONDIAS DULCIS*) FRUITS

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Resumo

O cajá-manga (*Spondias dulcis*) é uma árvore frutífera tropical da família Anacardiaceae. Recentemente, resultante da mutação natural do cajá-manga, foi criado o cajá-manga anão. No entanto, os frutos da planta anã foram estudados de forma limitada. O objetivo deste estudo foi caracterizar os frutos e a polpa do cajá anão e coletar dados. Foram realizadas análises de peso, diâmetro e comprimento do fruto inteiro. Em seguida, os frutos foram submetidos ao processamento manual para produção da polpa e posterior caracterização quanto a sólidos solúveis (SS), umidade, acidez titulável em ácido cítrico, vitamina C e cor. O cajá-manga anão pesava entre 53,78 e 79,52 g, tinha diâmetro entre 40,31 e 45,35 mm e comprimento entre 53,31 e 60,72 mm. A polpa apresentou teor de sólidos solúveis variando de 10,3 a 13,8 °Brix, umidade entre 84,13 e 86,78%, pH entre 3,14 e 3,31 e a acidez expressa em ácido cítrico variou de 0,80 a 1,03% m/m. O teor máximo de vitamina C foi igual a 1,70 mg.100 g^{-1}. As características de cor foram *L entre 51,53 e 46,72, a* variando de 7,68 a 7,04 e b* de 32,80 a 28,78. O cajá-manga anão possui características físico-químicas semelhantes aos frutos do cajá tradicional.

Palavras-chave: cajá; árvores frutiferas; produção de frutas.

CARACTERIZAÇÃO FÍSICO-QUÍMICA DE FRUTOS DE CAJÁ-MANGA ANÃO (*SPONDIAS DULCIS*)

Abstract

Ambarella (*Spondias dulcis*) is a tropical fruit tree from the Anacardiaceae family. Recently, resulting from the natural mutation of the ambarella, the dwarf ambarella was created. However, the fruits of the dwarf plant have been studied to a limited extent. This study aimed to characterize the fruits and pulp of dwarf ambarella and collect data. The weight, diameter, and length analyses of the entire fruit were carried out. Then, the fruits were subjected to manual processing to produce the pulp and subsequent characterization regarding soluble solids (SS), moisture, titratable acidity in citric acid, vitamin C, and color. Dwarf ambarella weighed between 53.78 and 79.52 g, had a diameter between 40.31 and 45.35 mm, and a length between 53.31 and 60.72 mm. The pulp had a soluble solid content ranging from 10.3 to 13.8 °Brix, moisture between 84.13 and 86.78%, pH between 3.14 and 3.31, and acidity expressed as citric acid ranged from 0.80 to 1.03% m/m. The maximum vitamin C content equals 1.70 mg.100 g^{-1}. The color characteristics are *L between 51.53 and 46.72, a* ranging from 7.68 to 7.04, and b* from 32.80 to 28.78. Dwarf ambarella has physical and chemical characteristics similar to the fruits of traditional cajá trees.

Keywords: cajá tree; fruit tree; fruit production.

Introduction

Fruit growing is one of the most prominent sectors of Brazilian agribusiness. The country is considered one of the leading fruit producers in the world, offering a wide variety of crops produced throughout the territory and in different climates (EMBRAPA, 2023).

The Anacardiaceae family includes economically essential plant species. The genus *Spondias*, comprised of around 18 species, has stood out due to the possibility of cultivating the fruits of these species through family labor. The fruits are distributed in local markets and used for the artisanal production of jams and sweets (Mohammed *et al.*, 2017; Rezende *et al.*, 2018). In this genus, the group of cajás (*Spondias* spp.), also known as golden apple or ambarella, cajarana or cajá-mango, red mombin or siriguela e umbu, among other names, recognized in the different regions of the world in which they are cultivated, show great importance in the fresh fruit trade (Yahia; Elhadi, 2011; Santos *et al.*, 2023).

The cajá tree is a tropical fruit originating from the Polynesian Islands and is now cultivated in Asia, Central and South America, and Africa to a lesser extent (Souza *et al.*, 2021). The fruit originating from this plant is climacteric, has an ellipsoidal shape, and, when ripe, its pulp is juicy, aromatic, and has a bittersweet, slightly acidic flavor, and its peel has high nutritional value. There are two distinct types: the large or traditional type and the miniature or dwarf type (Yahia; Elhadi, 2011). The first grows in trees, whose height varies from 9 to 25 m, and the second varies from 1.5 to 3 m. The dwarf variety is of great interest in fruit growing. The plants have advantages such as ease of management due to the difference in height from traditional plants, availability of fruits throughout the year, and greater yield per unit area (Mohammed *et al.*, 2017).

The fruits from the dwarf plant have been little studied to date. Despite their appearance similar to traditional ambarella, whether they have a different physical-chemical composition is unknown. It is known that, like all fruits, they are rich in nutrients and bioactive compounds, which can contribute to the maintenance and improvement of human health and their potential for use in various food products (Santos *et al.*, 2023; Freitas *et al.*, 2024).

Given the above, it is necessary to characterize the fruits and pulp of the dwarf plant in terms of their physical and chemical characteristics. Due to the ease of production and cultivation, the dwarf plant may have the potential for fresh consumption and industrialization if the fruits have a physical-chemical composition similar to those produced in the traditional plant.

Material and methods

The ambarella fruits used were harvested manually, at random, from each of the five dwarf plants cultivated in the experimental area of the Federal University of Espírito Santo (UFES), located in Rive – ES. Harvesting occurred when the fruits had approximately 80% of their skin yellowed.

Physical analyzes

The fruits were transferred to the Department of Food Engineering, Federal University of Espírito Santo (UFES) laboratories, washed in running water, and sanitized by immersion in a 150 $mg.L^{-1}$ sodium hypochlorite solution for 15 minutes. After sanitization, weight (g), diameter (mm), and length (mm) analyses were carried out. The measurements were done with a Mitutoyo digital caliper and an Even digital analytical scale (Souza *et al.*, 2021).

Production of ambarella pulp from the dwarf plant

The fruits were peeled manually using stainless steel knives and subjected to crushing with the skin in a Walita brand blender. The pulp was filtered using a heavy plastic sieve, packed in polyethylene (PE) plastic packaging, identified, and stored at -18 °C in a Consul brand horizontal freezer until analysis (Souza *et al.*, 2022).

Physicochemical analysis

The physicochemical analyses included pH, soluble solids (SS), humidity, total titratable acidity, vitamin C, and color (Zenebon; Pascuet; Tiglea, 2008; Nascimento *et al.*, 2020).

The pH analysis was done by directly immersing the previously calibrated ATRA digital pH meter electrode into the sample. Soluble solids were determined using a Milwaukee brand digital refractometer, previously calibrated with distilled water. The moisture content was determined by the direct oven drying method from the SPLabor brand at 105 °C, with the result expressed in (%) m/m (Zenebon; Pascuet; Tiglea, 2008).

The total titratable acidity analysis was carried out by titrating approximately 5 g of the sample diluted in 100 mL of water with 0.1 M sodium hydroxide solution, using phenolphthalein as the indicator. The result was expressed in citric acid (%) (Zenebon; Pascuet; Tiglea, 2008).

The vitamin C content was determined by the Tillmans' method, which is based on reducing the dye sodium salt of 2,6 dichlorophenol indophenol by an acid solution of vitamin C. The result was expressed in ascorbic acid mg.100 mL^{-1} (Zenebon; Pascuet; Tiglea, 2008).

Color analysis was performed using a Nova Instruments colorimeter, measuring the parameters luminosity (L*), red intensity (+a*), and yellow intensity (+b*) (Nascimento *et al.*, 2020).

Statistical analysis

The experimental scheme was a Completely Randomized Design, with five dwarf ambarella plants in three replications. The physical and chemical characterization data of the fruits were subjected to Analysis of Variance (ANOVA) using the statistica software version 12.0 (Statsoft, USA), and the means were compared using the Tukey test at 5% probability.

Results and Discussion

Physical characterization of the fruits of the dwarf plant

The fruits from the different dwarf plants differed statistically in weight (Table 1). Matrices 2, 4, and 5 produced the heaviest fruits, weighing 79.52 g, not statistically different from each other. In matrices 1 and 3, fruits of smaller weights, which were not statistically different from each other, were found and varied from 53.78 to 62.16 g.

Similarly, concerning fruit diameter, matrices 2, 4, and 5 presented larger diameter fruits, measuring 45.18 mm, 44.79 mm, and 45.35 mm, respectively, showing no significant difference between them. The lowest values were observed in fruits from matrices 1 and 3, which did not present significant differences for the analyzed parameter.

Concerning length, the largest fruits came from matrices 2, 4, and 5 with 58.44, 60.44, and 60.72 mm, respectively, with no significant difference. The smallest fruits belonged to matrices 1 and 3, ranging from 50.17 to 53.31 mm.

Given the data obtained, it is observed that matrices 2, 4, and 5 give rise to the largest fruits, while matrices 1 and 3 are the smallest.

Table 1. Physical characterization of the dwarf plant's ambarella fruits.

Matrix	Weight (g)	Diameter (mm)	Length (mm)
1	53.78 b	40.31 c	50.17 b
2	79.52 a	45.18 b	58.44 a
3	62.16 b	41.84 ac	53.31 b
4	79.52 a	44.79 ab	60.44 a
5	79.52 a	45.35 ab	60.72 a

Means followed by the same letter in the same column do not differ using the Tukey test ($p > 0.05$).

Smaller fruits, in some matrices, may be related to the rootstock and how the dwarf plant is produced. If the plant were produced sexually, the fruits would be larger. Some examples include hybrid jabuticaba (*Myrciaria cauliflora*), pitanga (*Eugenia uniflora*), cerrado pear (*E. klostzchiana*), and dwarf cashew tree (*Anacardium occidentale* L. var. *nanum*) (Donadio *et al.*, 2019).

Despite this possibility, measurements carried out on traditional ambarella fruits (*S. dulcis* Parkinson) found, on average, 59.36 mm in length, 45.97 mm in diameter, and 71.80 g in weight (Guimarães *et al.*, 2020), which is very similar to the fruits of some dwarf matrices in the present study. In other studies, with the traditional plant ambarella (*S. dulcis* Parkinson), the length varied in the range of 64.91 to 76.59 mm and the diameter in the range of 47.53 to 54.91 mm (Souza *et al.*, 2021) higher than those in the present study. According to Chaves Neto and Silva (2019), the fruits of *S. dulcis* Parkinson can reach a weight of 450 g, with a diameter ranging from 30 to 80 mm and a length of 40 to 120 mm. Conversely, the size of umbu (*S. tuberosa*) fruits during ripening can vary from 28.90 to 33.50 mm in length and 26.62 to 27.79 mm in diameter (Menezes *et al.*, 2017).

Analyzing these data, it is worth highlighting that differences can influence such variations in measurements in the location where the plants were grown due to temperature, humidity, light, and wind, as well as internal factors such as physiological factors, which can impact the composition of the fruits, size, and productivity (Bastos *et al.*, 2021). Therefore, the fruits in the present study do not vary, on average, considering the physical characteristics of those found in studies with traditional plants.

This is advantageous since dwarf plants are small, between 1.5 and 3 meters, and thus are easier to manage and require less space for their reproduction, enabling greater yield per area compared to traditional plants. Furthermore, the plant begins to produce fruits early and abundantly, making harvesting possible throughout the year (Chen *et al.*, 2016; Finzi *et al.*, 2020).

Physicochemical characterization of ambarella pulp from the dwarf plant

No significant differences were found in the moisture content of ambarella pulps (Table 2) coming from different dwarf matrices. The moisture contents varied from 84.13 to 86.78% m/m, corresponding to matrices 4 and 2, respectively. Regarding the physical-chemical composition of traditional ambarella, the literature presents an average humidity (%) equal to 85.10 for *S. dulcis* Parkinson (Guimarães *et al.*, 2020), close to that found in this study for dwarf plant fruits. Furthermore, Rodrigues *et al.* (2022) and Nascimento *et al.* (2020) also showed humidity values close to the results of this study when studying cajá (*S. mombin* L.) from traditional plants, being 86.26% and 84,87%, respectively. However, Silva *et al.* (2021) reported a higher moisture content (88.05%) for umbu (*S. tuberosa*). Moisture content is the main factor for determining biological processes, being related to the stability and quality of the fruit (Zenebon; Pascuet; Tiglea, 2008) and influencing the yield for consumption and commercialization (Khakimov *et al.*, 2016).

The highest soluble solids content, 13.8 °Brix, was found in fruits from matrix 1, which was higher and statistically different from fruits from other matrices. In matrix 4, the fruits presented a content of 11.3 °Brix, which is statistically different from other matrices. The lowest levels found ranged from 10.3 to 10.6 °Brix in matrices 2, 3, and 5, not statistically different from each other. The values found for the soluble solids content in fruits from dwarf plants were similar to those found in fruits from traditional plants. Matrix 1 was the one that presented fruits with the highest soluble solids content among the five matrices, being 13.8 °Brix. Guimarães *et al.* (2020) attested a value of 13.16 °Brix for fresh ambarella pulp from the traditional plant (*S. dulcis* Parkinson). When studying different matrices (*S. dulcis*), Souza *et al.* (2022) observed a variation in soluble solids content ranging from 9.6 to 11.48 °Brix. Similarly, Rodrigues *et al.* (2022) and Silva *et al.* (2020) reported averages of 11.83 and 11.2 °Brix, respectively, for cajá fruits (*S. mombin* L.), values close to those found in this study. In contrast, Chaves Neto and Silva (2019) reported averages of 14.61 °Brix for fruits of the traditional plant (*S. dulcis* Parkinson). This parameter indicates the degree of ripeness of the fruit and represents the concentration of sugars, mainly glucose, fructose, sucrose, organic acids, and other constituents (Zenebon; Pascuet; Tiglea, 2008).

Concerning pH, values between 3.14 and 3.31 were found in the fruit pulps, depending on the different matrices, and in matrices 1, 2, and 4, the values did not differ statistically, and matrix 5 presented a value lower and statistically different from that found in pulps from other matrices. The pH of traditional ambarella fruits (*S. dulcis* Parkinson) ranged from 2,28 to 2.90 (Chaves Neto; Silva, 2019; Guimarães *et al.*, 2020). Mendonça and Vieites (2019) reported a pH value of 3.12 for siriguela (*S. purpurea* L.) fruits, similar to the values found in this study. In monitoring and evaluating *S. mombin* fruits after their development, Silva *et al.* (2018) observed the pH behavior, describing it as decreasing from day 40 to 80 after fruit development, with values ranging from 3.36

to 2.47. Silva *et al.* (2020) and Nascimento *et al.* (2020) reported pH values of 2.93 and 2.49, respectively, in *S. mombin* pulps. Regarding industrialization, lower pH values are preferable, as they hinder the proliferation of microorganisms. However, there is a preference for higher pH values for the consumption of fresh fruits (Guimarães *et al.*, 2020).

Vitamin C content ranged from 1.70 to 0.92 (mg.100 mL^{-1}). Among the matrices, 1 presented fruits with the highest vitamin C content, on average 1.70 (mg.100 mL^{-1}), statistically different from the levels present in the other matrices (Table 2). There was no significant difference between fruits from matrices 2, 3, 4, and 5 regarding vitamin C content. The literature has averaged between 3.41 and 55.71 (mg/100 g) for the fruits of the traditional plant. This value is influenced by storage time, temperature, and processing (Fonseca *et al.*, 2017). Silva *et al.* (2022) reported 2.89 mg/100 g of vitamin C in *S. tuberosa* pulps. Ascorbic acid is an easily degraded vitamin affected by temperature, pH, light, and other parameters. Studies highlight the nutritional potential of ambarella for this vitamin due to its ability to provide antioxidant protection to the human body (Souza *et al.*, 2022; Santos *et al.*, 2023). The values found for the ambarella of the dwarf plant were lower than those found in fruits of the traditional plant, which can be justified by the storage time of the pulp until the moment of analysis, approximately six months at a temperature of -18 °C. Similarly, Silva *et al.* (2018) reported a decrease in vitamin C content, observing values ranging from 54.8 mg/100 mL (40 days after development) to 15.7 mg/100 mL (100 days after development) in ambarella (*S. mombin* L.) fruits. Fresh fruits of traditional ambarella (*S. dulcis* Parkinson) exhibit vitamin C content close to the values reported for 'Pera' orange (62.5 mg of ascorbic acid per 100 mL of pulp) (Yahia; Elhadi, 2011). Souza *et al.* (2022) reported averages ranging from 58.87 to 67.70 when analyzing six matrices in Jataí, Goiás.

Table 2. Chemical characteristics of ambarella pulps: moisture, total soluble solids (TSS), pH, and vitamin C.

Matrix	Moisture (%)	Total Soluble Solids (°Brix)	pH	Vitamin C (mg/100 g)
1	84.75 a	13.8 c	3.24 a	1.70 b
2	86.78 a	10.4 a	3.23 a	1.13 a
3	85.47 a	10.6 a	3.31 b	1.04 a
4	84.13 a	11.3 b	3.26 ab	0.94 a
5	85.74 a	10.3 a	3.14 c	0.92 a

Means followed by the same letter in the same column do not differ using the Tukey test ($p > 0.05$).

Regarding the color characteristics of the pulp, values between 51.53 and 46.72 were found for luminosity for the different matrices. Regarding the red intensity parameter, the averages varied from 7.68 to 7.04. A variation from 32.80 to 28.78 was observed for the yellow intensity parameter. Color is an essential attribute for the consumption of fresh fruits and processed products, and from this, the consumer assesses whether the product is suitable for consumption (Castro *et al.*, 2016). Pulps of the traditional ambarella fruit have a solid yellow color, tending to red, at the end of the physiological stage. Souza *et al.* (2022) observed values from 42.86 to 58.49 for the L* coordinate, which concerns the luminosity of the fruits, and a range from 8.27 to 28.40 for the b* coordinate in ambarella fruit pulps (*S. dulcis* Parkinson). Nascimento *et al.* (2020) reported an L* value of 42.60 in cajá (*S. mombin*) fruits, showing a luminosity similar to that mentioned by Souza *et al.* (2022). The study by Silva *et al.* (2020) reveals values of 54.47 for the L* parameter, 24.66 for the a* coordinate, and 54.10 for the b* coordinate in *S. tuberosa* pulps, as well as values of 54.44 for the L* parameter, -6.74 and 30.44 for the a* and b* coordinates, respectively, in *S. mombin* L. pulps. Some of these values are close to those found for ambarella pulp from dwarf plants in the present research. The differences in the luminosity parameters L* and coordinates a* and b* may be due to the maturation stage of the material analyzed, both in the present study and those of traditional plants presented in the literature.

Regarding the acidity parameter, the percentages varied between 0.80 and 1.03% m/m of citric acid (statistical data not shown). The analysis of titratable acidity in organic acid applies to various fruit products. The organic acids in fruits influence the flavor, odor, color, stability, and quality maintenance (Zenebon; Pascuet; Tiglea, 2008). Traditional ambarella (*S. dulcis* Parkinson) fruits express acidity values of 0,61 to 1.14% m/m (Chaves Neto; Silva, 2019) for cajarana fruits (*Spondias mombin* L.), a value of 1.72 g of citric acid per 100 g was observed, according to Rodrigues *et al.* (2022). Souza *et al.* (2022), analyzing six mother plants of ambarella (*S. dulcis* Parkinson), observed variation in titratable acidity between the matrices, with the highest titratable acidity equal to 1.21 g of citric acid/100 mg of fresh fruit (M4). The lowest titratable acidity content was 1.09 g of citric acid/100 mg per fresh fruit (M1). According to Nascimento *et al.* (2020), cajá (*S. mombin*) fruits also showed a value of 1.21 g of citric acid per 100 g. Slightly lower values were found in the present study. On the other hand, Mendonça and Vieites (2019) found 0.74 g of citric acid per 100 g in siriguela (*S. purpurea* L.) fruits, and Guimarães *et al.* (2020) reported 0.86 g of citric acid per 100 g in cajarana (*S. dulcis* Parkinson) pulp, values similar to those in this study.

Conclusion

In summary, the results presented in this study indicate similarities between the fruits of the dwarf ambarella and traditional ambarella in terms of size measurements and chemical composition.

Due to the similarities with traditional fruits, the ability to produce fruits throughout the year, and low management requirements, the fruits of the dwarf plant become an alternative for the consumption of fresh fruits and can be sold in domestic pots due to their small size. Furthermore, it presents itself as an economically attractive fruit for industrialization, requiring less space for its reproduction and generating greater yield per area when compared to fruits from traditional plants.

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