

Influence of drying on bioactive compounds and antioxidant activity of fruits of guabiju (*Myrcianthes pungens*)

Influência da secagem em compostos bioativos e atividade antioxidante de frutos de guabiju (*Myrcianthes pungens*)

Influencia del secado en compuestos bioactivos y actividad antioxidante de frutos de guabiju (*Myrcianthes pungens*)

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Abstract

The objective of this work was to evaluate the influence of temperature on the content of bioactive compounds of fruits of guabiju (*Myrcianthes pungens* (O. Berg) D. Legrand). The peel, pulp and seed of fresh guabiju were analyzed in relation to physical-chemical composition, metals, color, phenolic compounds, flavonoids, anthocyanins, vitamin C and antioxidant activity. On the dehydrated samples at temperature of 60 °C, where also determined the moisture and water activity. The fractions of the fruit showed high amounts of metals. After drying, moisture of 1.3, 1.0 and 0.9% were observed for peel, pulp and seed and water activity of 0.44 to 0.54. All the samples darkened, with less variation in the dehydrated peel (ΔE 9.2). The samples showed high values of bioactive compounds, and in the fresh peel were observed higher levels of phenolic compounds (8459.8 mg EGA/100g dry extract), anthocyanins (152.0 mg/100 dry extract) and vitamin C (222.9 mg/100g) and on the dehydrated seed higher value of flavonoids (7480.7 mg EQ/100g dry extract). There was 86.3% degradation of anthocyanins in the dehydrated peel. The best values of antioxidant activities were obtained for the dehydrated peel (IC_{50} 1.37 mg/mL), seed (IC_{50} 1.49 mg/mL) and in the fresh peel (IC_{50} 1.41 mg/mL).

Keywords: Phenolic compounds; Flavonoids; Anthocyanins; Antioxidant activity; Centesimal composition.

Resumo

O objetivo deste trabalho foi avaliar a influência da temperatura no teor de compostos bioativos de frutos de guabiju (*Myrcianthes pungens* (O. Berg) D. Legrand). A casca, polpa e semente de guabiju in natura foram analisadas quanto à composição físico-química, metais, cor, compostos fenólicos, flavonoides, antocianinas, vitamina C e atividade antioxidante. Sobre as amostras desidratadas a temperatura de 60 °C, onde também foi determinada a umidade e atividade de água. As frações do fruto apresentaram grande quantidade de metais. Após a secagem, foram observadas umidade de 1,3; 1,0 e 0,9% para casca, polpa e semente e atividade de água de 0,44 a 0,54. Todas as amostras escureceram, com menor variação na casca desidratada (ΔE 9,2). As amostras apresentaram elevados valores de compostos bioativos, sendo que na casca fresca foram observados teores mais elevados de compostos fenólicos (8459,8 mg EGA/100g extrato seco), antocianinas (152,0 mg/100 extrato seco) e vitamina C (222,9 mg/100g) e na semente desidratada maior valor de flavonoides (7480,7 mg EQ/100g extrato seco). Houve 86,3% de degradação das antocianinas na casca desidratada. Os melhores valores de atividade antioxidante foram obtidos para a casca desidratada (IC_{50} 1,37 mg/mL), semente (IC_{50} 1,49 mg/mL) e na casca in natura (IC_{50} 1,41 mg/mL).

Palavras-chave: Compostos fenólicos; Flavonoides; Antocianinas; Atividade antioxidante; Composição centesimal.

Resumen

El objetivo de este trabajo fue evaluar la influencia de la temperatura en el contenido de compuestos bioactivos de frutos de guabiju (*Myrcianthes pungens* (O. Berg) D. Legrand). In natura guabiju se analizó la cáscara, pulpa y semilla de la composición fisicoquímica, metales, color, compuestos fenólicos, flavonoides, antocianinas, vitamina C y actividad antioxidante. Sobre muestras deshidratadas a una temperatura de 60 °C, donde también se determinó la humedad y la actividad del agua. Las fracciones de frutas tenían una gran cantidad de metales. Después del secado, humedad de 1,3; 1.0 y 0.9% para cascarilla, pulpa y semilla y actividad de agua de 0.44 a 0.54. Todas las muestras se oscurecieron, con menos variación en la corteza deshidratada (ΔE 9.2). Las muestras mostraron valores altos de compuestos bioactivos, con niveles más altos de compuestos fenólicos (8459,8 mg EGA/100g extracto seco), antocianinas (152,0 mg/100 extracto seco) y vitamina C (222) en corteza fresca, 9 mg/100g) y en la semilla deshidratada el mayor valor de flavonoides (7480,7 mg EQ/100g de extracto seco). Hubo 86,3% de degradación de las antocianinas en la corteza deshidratada. Los mejores valores de actividad antioxidante se obtuvieron para corteza deshidratada (IC_{50} 1,37 mg/mL), semilla (IC_{50} 1,49 mg/mL) y corteza fresca (IC_{50} 1,41 mg/mL).

Palabras clave: Compuestos fenólicos; Flavonoides; Antocianinas; Actividad antioxidante; Composición centesimal.

1. Introduction

Brazil has great plant biodiversity (Castuera-Oliveira et al., 2020; Moreira-Araújo et al., 2019), including high number of fruit trees (Schiassi et al., 2018; Vergara et al., 2018; Verruck et al., 2018), with a great variety of antioxidant compounds in its fruits and large number of species with potential of use in the food industry (Neri-Numa et al., 2018).

The family Myrtaceae stands out (Chrystal et al., 2020; Gatto et al., 2020), found mainly in the southern region of Brazil, which demonstrates the importance of developing research with native fruits (Neri-Numa et al., 2018; Rodrigues et al., 2020), many still little explored (Moreira-Araújo et al., 2019) and with great potential for economic exploration (Lattuada et al., 2019; Neri-Numa et al., 2018). In this family, the *Myrcianthes pungens* (O. Berg) D. Legrand, popularly known as guabiju, it is a medium to large tree with around 20 m, present simple leaves and considered ornamental plant, its fruits are appreciated due to the pleasant sweet flavor (Assumpção et al., 2017).

The consumption of fruits that have bioactive compounds with antioxidant properties (Guiné et al., 2020; Moreira-Araújo et al., 2019; Guiné et al., 2018; Arend et al., 2017; Mazzoni et al., 2017;) as phenolic compounds, provide several biological functions: anti-inflammatory, antimicrobial, antifungal, antiviral and antioxidant (Selamoglu et al., 2020), promoting several health benefits (Salgado-Chávez et al., 2020; Nascimento et al., 2019; Neri-Numa et al., 2018; Habibi and Ramezani, 2017; Seleem et al., 2017). Among them, the anthocyanins are natural pigments, water-soluble, responsible for pigmentation of many fruits and vegetables, with a color spectrum that can range from red to blue, or purple (Apáez Barrios et al., 2018; Hurtado & Charfuelan, 2019; Vetö et al., 2020), are widely studied and used as natural coloring agents in foods (Nascimento et al., 2019; Oliveira & Antelo, 2020; Sharma et al., 2016) and because its antioxidant capacity, they prevent the formation of free radicals (Jiao et al., 2018; Miguel & Álvarez-López, 2020; Moreira-Araújo et al., 2019; Verruck et al., 2018), responsible for aging and increased risk of developing chronic non-communicable diseases (Miguel & Álvarez-López, 2020; Moreira-Araújo et al., 2019).

The drying of vegetable foods promotes a reduction of the moisture content, decreasing the water activity, preventing the deterioration caused by microorganisms (Mahayothee et al., 2020), providing greater product diversity, reducing volume and increasing product life (Araujo et al., 2020; Salimi and Hoseinnia, 2020; Landim et al., 2016; Nunes et al., 2020). However, it can compromise the taste and nutritional quality of the food, due to the thermal sensitivity of the bioactive compounds (Kwiatkowski et al., 2016), besides promoting browning reactions depending on the temperature and time used in the drying process (Kwiatkowski et al., 2016; Salimi & Hoseinnia, 2020).

Therefore, as well as the pulp, the peels and seeds of fruit also have a good amount of bioactive compounds, and generally are not consumed or used, generating waste (Paludo et al., 2019; Teles et al., 2018), both can be subjected to the extraction of these compounds and used in foods (Banerjee et al., 2017; Paludo et al., 2019).

Guabiju (*Myrcianthes pungens*) is still little explored commercially, and there are few studies in the literature, and no work has been found comparing the fractions of the peel, pulp and seed of fruits, before and after drying. In this context, this work aimed to evaluate the influence of drying on the content of bioactive compounds and antioxidant activity of peel, pulp and seed extracts of guabiju (*Myrcianthes pungens* (O. Berg) D. Legrand).

2. Material and Methods

2.1 Harvesting, selection, washing, sanitization and storage of fruits

The fruits of guabiju (*Myrcianthes pungens* (O. Berg) D. Legrand) were harvested between January and February 2018, in the coordinate 27° 56 '12 "S and 52° 25' 35" W. A sample of branch with leaves and fruits was saved in the Herbário Pr. Balduino Rambo (HPBR), at URI Erechim, under the registration number of exsiccate 12156.

After harvest, the fruits were manually selected and washed in drinking water. Then they were immersed in NaClO solution at 200 ppm for 15 min. Afterwards, the fruits were washed again and dried on paper towels, packed in polyethylene packaging and subjected to freezing at -20 °C. For the analysis, the fruits were separated into peel, pulp and seed. All processes took place in the absence of light.

2.2 Characterization of the fresh guabiju fractions

The peel, pulp and seed of fresh guabiju were analyzed in relation to moisture, fixed mineral residue, soluble solids, lipids, protein, carbohydrates, crude fiber, pH, metal content, color parameter, content of compounds phenolic, flavonoids, vitamin C and antioxidant activity. The anthocyanin content was analyzed only in the peel, due to the absence of characteristic pigmentation in the pulp and seed.

2.3 Drying of guabiju fractions

The drying of peel, pulp and seed of guabiju was carried out individually in an oven with air circulation (Marconi, MA 037, Brazil). Approximately 5 g of each sample were used, placed separately and dried at 60 °C until constant weight.

After drying, were determined the water activity, moisture, color, phenolic compounds, flavonoids, vitamin C and antioxidant activity of peel, pulp and seed, and anthocyanin content, determined only from the peel.

2.4 Analytical determinations

2.4.1 Physical-chemical characterization

The analyzes of moisture, fixed mineral residue, soluble solids, lipids, protein, carbohydrates, crude dietary fiber, pH and metals were carried out according to the methodology of the Manual of Analytical Standards of Adolfo Lutz Institute (Zenebon et al., 2008). Water activity of peel, pulp and seed of guabiju were determined using AquaLab (AquaLab model 4TE, USA). The moisture content was performed using the infrared moisture analyzer (Mars / ID-200 - Brazil), at 105 ° C, using approximately 3 g of samples.

To evaluate the color parameters a Minolta colorimeter (CR-400, Osaka, Japan) was used, where the coordinate L* represents sample brightness ranging from 0 (dark) to 100 (light), a* indicates chromaticity tending from green (-80) to red (+100) and b* shows chromaticity ranging from blue (-50) to yellow (+ 70). To calculate the total color difference (ΔE) the Eq. (1) was used:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0,5} \quad (1)$$

2.4.2 Determination of bioactive compounds

The antioxidant activity, phenolic compounds and flavonoids, were determined on fresh and dried extracts of peel, pulp and seed of guabiju. The fresh and dehydrated peel and seed were crushed with the aid of a Mixer (Britânia), protected from light. The fresh and dehydrated pulp were macerated in order to increase the contact area.

The extraction of bioactive components was carried out by means of successive extractions using ethyl alcohol (99%). The sample was left in contact with 50 mL of solvent for 12 h followed by filtration. The filtrate was kept away from light, and the sample retained in the filter was subjected to further extraction 2 more times and the filtrate (150 mL) was passed to a 250 mL round bottom flask, previously covered with aluminum foil. Subsequently, the extracts were rotated in a rotary vacuum evaporator (Marconi MA 120) at 60 °C. The concentrated product was lyophilized, weighed and stored at 4 °C until use.

The content of total phenolic compounds was carried out by the Folin-Ciocalteu method with modifications (Singleton et al., 1999). In a test tube 0.5 ml of sample of ethanol extracts were added in the concentration of 5 mg/mL, 2.5 ml of the reagent Folin-Ciocalteu (diluted 1:10 v/v) and 2 mL of 4% of sodium carbonate (w/v). The tubes were shaken and stored for 2 h at room temperature protected from light. After, the absorbance was read on a spectrophotometer (Logen Scientific UV/VIS -LS7052) at 760 nm. The content of phenolic compounds was obtained by linear regression analysis, from a standard curve using gallic acid with concentrations of 1 to 100 µg/mL. The results were expressed in milligrams equivalent of gallic acid per 100 grams of extract (mg EGA/100g).

The flavonoid content was obtained according to the method described by Garrido et al. (2013), with adaptations. In a test tube 0.5 mL of sample of ethanol extracts on the concentration of 5 mg/mL, were added 4.3 ml of 70% ethanol (v/v), 0.1 mL of 10% aluminum nitrate (w/v) and 0.1 mL of 10% potassium acetate (w/v). The tubes were shaken and stored at room temperature, protected from light, for 40 min. Then the absorbance was read on a spectrophotometer (Logen Scientific UV/VIS -LS7052) at 415 nm. The content of flavonoid compounds was obtained by linear regression analysis, from a standard curve

using quercetin with concentrations of 1 to 100 µg/mL. The results were expressed in milligrams equivalent of quercetin per 100 grams of extract (mg EQ/100g).

The extraction of total anthocyanins was carried out following the methodology of Medina et al. (2011) with adaptations. 5 g of sample were packed in Falcon tubes of 25 mL, which were covered with aluminum foil. Then, 15 mL of the solvent at 4 °C (containing 0.1% HCl P.A.) was added. The extraction took place light-free, under refrigeration (at 4 ± 1 °C), for 2 h. After the time, the samples (MPW-351R) were centrifuged at 8000 rpm for 15 min under refrigeration (at 4 ± 1 °C). The supernatant was collected and the precipitate was washed with 5 ml of solvent, after centrifugation using the same parameters as the first operation. Then, the extract was subjected to vacuum filtration in Whatmann paper filter number 01 and Buchner funnel, with the standardization of the volume of each sample to 20 mL. Subsequently, the extracts were packed in flasks covered with aluminum foil and sent for the quantification of anthocyanins through colorimetric analysis.

The anthocyanins were quantified according to the method described by Fetter et al. (2010), where the absorbance reading was performed at 535 nm, in a spectrophotometer (Logen Scientific UV/VIS -LS7052), using the solvent as white.

The anthocyanin content (AT) was obtained according to Eq. (2):

$$c = \frac{A}{\epsilon l} \quad (2)$$

Where: ϵ is the molar absorptivity coefficient of the species; A is the absorbance of the sample; c is the molar concentration of the species; l is the length traversed by the radiation beam (optical path).

The extraction and quantification of anthocyanins of pulp and seed were not determined due to the absence of pigmentation.

To determine the vitamin C content of the samples (IAL, 2008), 5 g of sample were weighed, added 50 mL of distilled water and crushed with the aid of a mixer (Britânia), transferred to Erlenmeyer of 250 mL. After, 10 mL of sulfuric acid solution (20% v/v) was added, then the content was homogenized and filtered into another Erlenmeyer, washing the filter with water and then with 10 mL of sulfuric acid solution (20% v/v). After, 1 mL of potassium iodide solution (10%) and 1 mL of starch solution 1% (m/v) were added. Then was titrate with 0.0002 M of potassium iodate solution until blue color.

The vitamin C content was obtained according to Eq. (3):

$$\text{VitaminC} \left(\text{mgpercent} \frac{m}{m} \right) = \frac{100xVxF}{P} \quad (3)$$

Where: V = volume of iodate spent on titration; F = 0.08806 for KIO₃ 0.0002 mol/L; P = g or mL of sample.

The antioxidant activity of ethanol extract was determined by DPPH analysis. This methodology is based on the measurement of the extinction of the absorption of the radical 2,2-diphenyl-1-picryl hydrazil (DPPH) at 515 nm, according to Vanin et al. (2014) with modifications. The technique consisted in incubation of pulp sample for 30 min, and of peel and seed for 6 min, of 1000µL of ethanolic solution of DPPH 0.1 mM with 1000µL of solutions containing increasing concentrations of extracts in ethanol. The solution called "white" was prepared (without sample and without DPPH) and the control solution (mixture of ethanol-DPPH). The absorbance was determined using a UV-Visible spectrophotometer (Logen Scientific UV/ IS -LS7052) at 515 nm. The activity of capturing radicals by extracts was obtained by Eq. (4).

$$AA(\%) = 100 - (|sample|/|control|) * 100 \quad (4)$$

After evaluating the ideal concentration range, the extract concentration needed to capture 50% of the free radical DPPH (IC₅₀) was calculated by linear regression analysis (Silvestri et al., 2010).

2.5 Statistical analysis

All experiments were carried out in triplicate and the results of the analyzes were statistically treated by analysis of variance (ANOVA), followed by comparison of the averages by the Tukey's or student's t test using Statistica software version 5.0, with 95% confidence level.

3. Results and Discussion

3.1 Characterization of guabiju fractions

3.1.1 Physical-chemical composition and metals of fresh guabiju fractions

Table 1 present the values obtained for moisture, fixed mineral residue, carbohydrates, proteins, lipids, crude dietary fiber, soluble solids, pH and metals of fresh guabiju. All parameters, except pH, showed significant differences between the samples. Comparing the guabiju fractions, the peel showed a higher amount of protein, crude dietary fiber and soluble solids, the pulp had a higher moisture content and the seed had a higher content of fixed mineral residue, lipids and carbohydrates.

Table 1. Physical-chemical composition and metals of peel, pulp and seed of fresh guabiju.

Parameters	Peel	Pulp	Seed
Moisture (%)	77.13 ^b ± 0,21	84.29 ^a ± 0.22	45.70 ^c ± 1.11
Fixed mineral residue (%)	0.98 ^b ± 0.04	0.38 ^c ± 0.05	1.14 ^a ± 0.01
Carbohydrates (%)	10.76 ^c ± 0.23	11.34 ^b ± 0.28	44.97 ^a ± 0.16
Proteins (%)	4.11 ^a ± 0.07	2.14 ^c ± 0.06	2.38 ^b ± 0.10
Lipids (%)	0.73 ^b ± 0.05	0.38 ^b ± 0.04	2.50 ^a ± 0.41
Crude dietary fiber (%)	7.02 ^a ± 0.03	1.46 ^c ± 0.04	3.90 ^b ± 0.39
Soluble solids (%)	6.03 ^a ± 0.01	4.20 ^b ± 0.02	nd
pH	5.17 ^a ± 0.52	5.37 ^a ± 0.53	4.96 ^a ± 0.50
Metals (mg/100g)			
Potassium (K)	218.16 ^b ± 7.89	82.62 ^c ± 3.37	287.31 ^a ± 4.16
Calcium (Ca)	183.19 ^a ± 3.28	47.46 ^c ± 2.21	141.29 ^b ± 7.56
Magnesium (Mg)	32.64 ^b ± 0.99	8.18 ^c ± 0.97	35.83 ^a ± 1.52
Sodium (Na)	20.57 ^a ± 2.14	13.56 ^{ab} ± 0.09	12.59 ^b ± 4.43
Aluminum (Al)	6.82 ^a ± 1.27	4.13 ^a ± 1.58	0.34 ^b ± 0.14
Iron (Fe)	2.73 ^a ± 0.11	0.44 ^b ± 0.16	0.72 ^b ± 0.15
Zinc (Zn)	0.41 ^a ± 0.07	0.23 ^b ± 0.06	0.23 ^b ± 0.05
Manganese (Mn)	0.22 ^a ± 0.02	0.05 ^b ± 0.02	0.13 ^{ab} ± 0.06
Copper (Cu)	0.12 ^b ± 0.01	0.04 ^b ± 0.01	0.23 ^a ± 0.05
Cadmium (Cd)	0.02 ^a ± 0.00	0.01 ^a ± 0.01	0.00 ^b ± 0.00
Chrome (Cr)	0.02 ^a ± 0.00	0.00 ^b ± 0.00	0.00 ^b ± 0.00

Means ± standard deviation followed by different lowercase letters on the same line show a significant difference (p <0.05) by Tukey's test.

nd= not determined

Source: Authors.

It is noteworthy that there are few studies on the physical-chemical of guabiju composition, mainly in relation to the fractions of peel, pulp and seed, so the results were compared with other fruits.

The values obtained in the present study are in agreement with those described by Assumpção et al. (2017) for the moisture of peel (71.66%), pulp (84.06%) and seed (40.81%) of guabiju. Seraglio et al. (2018) describe moisture content between 83.21 to 83.19 g/100g in fresh guabiju fruits. The ash content found in the present study was lower than that described by Assumpção et al. (2017), 3.96, 3.39 and 3.55 for peel, pulp and seed of guabiju, respectively.

The levels of carbohydrates and lipids were higher, and the proteins levels were lower than those described by Assumpção et al. (2017) in guabiju. The guabiju could be compared to other native species, and can be considered a protein fruit, as well as araçá-pitanga, pêssego-do-mato, among others (Kinupp & De Barros, 2008).

The amount of crude dietary fiber found for peel, pulp and seed was lower than the fiber content of peel (11.53%), pulp (7.71%) and seed (16.67%) found by Assumpção et al. (2017). However, it was higher than that observed in fresh blackberry (4.08%) (Casarin et al., 2016), and also fresh jabuticaba (1.84%) and freeze-dried peel jabuticaba (3.89%) (Faria et al., 2016).

The soluble solids content described by Goldmeyer et al. (2014) was 5.23 °Brix for blueberry, for jabuticaba the values ranged from 12.00 to 14.00 °Brix and for guabiju from 11.00 to 14.00 °Brix (Seraglio et al., 2018).

The pH found for peel, pulp and seed (5.17, 5.37 and 4.96) were higher than those observed in jabuticaba (3.68 to 3.80) and red araçá (3.31) and similar to those of fresh guabiju fruit (5.19 to 5.32) and freeze-dried guabiju fruit obtained by Seraglio et al. (2018) and Dalla Nora et al. (2014b).

Guabiju has a higher pH which is good for juices, as described by Massaguer et al. (2014). However, due to its high pH, it is not indicated for the formation of gels, since when developing jellies and jams with guabiju, it is necessary to acidify the products.

The metal content of guabiju samples presented in Table 1, K, Ca, Mg, Na, Fe and Al are noteworthy, with the peel showing higher amounts of Ca, Na, Al, Fe, Zn and Mn compared to the pulp and seed. However, the seed showed a higher content of K, Mg and Cu in relation to pulp and peel. Seraglio et al. (2018) observed higher amounts of K, Na, Ca and Mg for guabiju and jabuticaba in relation to the values found in the present study, in fruits with intermediate maturation stage they verified the following values respectively in (mg/100g dry weight), jabuticaba (4922.10; 239.95; 281.83 and 591.82), guabiju (3100.32; 100.43; 932.48 and 585.78). In mature fruits, the results were: jabuticaba (4533.83, 359.80, 330.13 and 455.60), guabiju (9603.64; 309.94; 465.30 and 2276.48). In all samples, potassium was the predominant metal (Seraglio et al., 2018).

Souza et al. (2014) found in blackberry, red raspberry, strawberry, blueberry and cherry P values (7.25; 5.70; 6.59, 8.61 and 12.21 mg/100g), k (79.73; 71.84; 51.24; 70.13 and 90.92 mg/100g), Ca (7.25; 1.14; 2.20; 0.00 and 0.00 mg/100g), Mg (15.70; 15, 96; 8.78; 4.92 and 12.21 mg/100g), Zn (0.20; 0.37; 0.13; 0.13 and 0.69 mg / 100 g) and Fe (1.28; 1.06; 1.00; 1.24 and 1.16 mg/100g), respectively.

Thus, guabiju proved to be a considerable source of K in relation to blackberry, red raspberry, strawberry, cherry and blueberry (Souza et al., 2014). Potassium intake is associated with lower blood pressure, reduced mortality from stroke and heart disease, therefore, encouraging the consumption of fruits and vegetables source of this mineral can be an important action for the control and prevention of diseases chronic non-communicable diseases (Porto et al., 2014).

3.1.2 Water activity, moisture and color parameters of dehydrated guabiju fractions

Table 2 describes the results of water activity, moisture, color parameters Luminosity (L^*), Chromaticity (a^* and b^*) and ΔE of peel, pulp and seed dehydrated at 60°C.

Table 2. Results of water activity, moisture, color parameters Luminosity (L*), Chromaticity (a * and b *) and ΔE of peel, pulp and seed dehydrated at 60°C.

Parameters	Samples		
	Peel	Pulp	Seed
Δ L*	-8.47 ^b ± 0.22	-12.46 ^c ± 0.05	14.56 ^a ± 0.10
Δ a*	-1.91 ^c ± 0.12	8.25 ^a ± 0.07	7.99 ^b ± 0.08
Δ b*	3.04 ^b ± 0.06	1.00 ^c ± 0.09	4.86 ^a ± 0.22
Δ E	9.20 ^c ± 0.24	14.98 ^b ± 0.06	17.30 ^a ± 0.13
Water activity	0.44 ^b ± 0.04	0.54 ^b ± 0.05	0.72 ^a ± 0.07
Moisture (%)	1.30 ^a ± 0.13	1.00 ^b ± 0.10	0.90 ^b ± 0.07

Means ± standard deviation followed by different lowercase letters on the same line show a significant difference (p <0.05) by Tukey's test
Source: Authors.

When the brightness parameter (L*) is positive the sample is lighter (seed), and when negative the sample is darker (skin and pulp). As for the chromaticity a*, it varies between the colors green (-) and red (+), and was possible to verify that the peel had a shade closer to green, while the pulp and the seed had a red shade. The chromaticity b* varies between the colors blue (-) and yellow (+), and was observed that all samples analyzed presented a hue close to yellow. The highest value of ΔE obtained was for the seed, followed by the pulp and peel. According to Alves et al. (2008) the higher the ΔE value, the greater the total color difference of the processed product compared to the original product.

Nemzer et al. (2018) analyzed the color parameter of blueberry, cherry and strawberry after drying in hot air at 70 °C and observed that samples with a dark hue, such as blueberry, maintained their dark tone during drying, therefore, they presented a lower ΔE (2.89). In addition, the blueberry showed a decrease in L*, thus looking slightly darker. On the other hand, the cherry and the strawberry, presented higher values of ΔE 10.72 and 20.90, respectively.

When analyzing the color of the jaboticaba pulp, it presented L* of 24.23, indicating a dark hue. As for chromaticity, red (+ a *) 15.64 and yellow (+ b *) of 17.25, showing a greater tendency to yellow than to red (Lemos et al., 2019), which corroborates with the result found in this study.

As observed in Table 2, except for the seed, the samples of peel and pulp showed low values of water activity, less than 0.6. As well as, for the moisture analysis that showed low values for the three guabiju fractions after drying.

The drying process reduced the water activity of the seed and pulp, providing stable microbiological conditions, promoting more safety for conservation of the product (Guiné et al., 2018; Mayor and Sereno, 2004).

3.1.3 Evaluation of bioactive compounds

The values for phenolic compounds, flavonoids, anthocyanins and vitamin C of the samples (peel, pulp and seed) fresh and dehydrated at 60 °C are shown in Table 3.

Table 3. Values of total phenolic compounds, flavonoids, anthocyanins and vitamin C of peel, pulp and seed of guabiju fresh and dehydrated at 60 °C.

	Total phenolic compounds (mgEGA/100g dry extract)	Flavonoids (mg EQ/100g dry extract)	Anthocyanins (mg/100g dry extract)	Vitamin C (mg/100g)
Peel				
Fresh	8459.8 ^a ± 35.0	4936.8 ^c ± 13.2	152.0 ^a ± 8.2	222.9 ^a ± 16.6
60 °C	3511.3 ^d ± 21.9	3436.8 ^d ± 75.0	20.8 ^b ± 36.0	134.9 ^b ± 8.3
Pulp				
Fresh	5934.0 ^b ± 20.2	3384.2 ^d ± 45.0	nd	117.3 ^{bc} ± 8.3
60 °C	2841.2 ^e ± 51.0	2278.9 ^e ± 9.8	nd	88.0 ^d ± 11.3
Seed				
Fresh	5511.3 ^c ± 38.5	5700.0 ^b ± 50.3	nd	93.9 ^{cd} ± 21.5
60 °C	5985.6 ^b ± 37.2	7480.7 ^a ± 87.4	nd	111.5 ^c ± 8.3

Means ± standard deviation followed by different lower-case letters in the same column show a significant difference ($p < 0.05$) by Student's t test. na = Not determined due to absence of pigmentation.

Source: Authors.

The content of phenolic compounds, flavonoids, anthocyanins and vitamin C of the peel and pulp in nature decreased after drying at 60 °C. However, for seed the values of phenolic and flavonoid compounds increased after drying. Santos et al. (2018) evaluated the influence of time and drying temperature on the content of phenolic compounds of native fruit and observed that these parameters alter the final quantity of the analyzed compounds, and that drying at 65 °C led to a longer drying time of the fruits, promoting greater losses of phenolic compounds and less antioxidant capacity.

The levels of total phenolic compounds and flavonoids in dehydrated extracts and, mainly, in fresh extracts were high compared to the levels described in other fruits. Celant et al. (2016), analyzed extracts of blackberry cultivars in 80% ethanol, and observed that the levels of phenolic compounds ranged from 8.23 to 14.98 (mg EGA/g fresh weight), and flavonoids 0.46 to 1.14 (mg EQ/g fresh weight). Casarin et al. (2016) found values of phenolic compounds and flavonoids of fresh blackberry (357.86 mg EGA/100g dry basis and 201.00 mg EC/100g dry basis) and in blackberry flour dehydrated at 55 °C (344.94 mg of EGA/100g dry basis and 182.82 mg EC/100 g dry basis), respectively. The content of phenolic compounds and flavonoids in red araçá peel extracts was 477.53 EGA/100g of peel and 351.80 mg of catechin/100g of seed, as described by Meregalli et al. (2020).

The content of phenolic compounds in the guabiju fruit (without seed) was 219.58 mg/100g and 83.75 mg/100g in the guabiju juice, as described by Reis; Bernardi; Silva, (2016). Paludo et al. (2019) studied varieties of jabuticaba from different harvests and found phenolic compounds between 55.27 to 147.88 mg EGA/g in the lyophilized peel and 72.05 to 131.62 mg EGA/g in lyophilized seed.

In the present study, there is a significant reduction in the anthocyanins content of dehydrated seed at 60 °C with 86.3% of degradation compared to fresh peel. Dalla Nora et al. (2014a) also verified degradation of anthocyanins from guabiju (94%) and red araçá (98%) submitted to drying at 70 °C, which was also observed by Fang (2015), which reported that temperatures above 60 °C, could occur polymerization of the molecule being transformed into chalcone, causing degradation and turning the solution yellow, demonstrating that the thermal processing causes the degradation of anthocyanins.

Because they are sensitive and unstable compounds, during processing, factors such as temperature, heating time, presence of oxygen and light can affect the stability of anthocyanins (Sharif et al., 2020).

The anthocyanin content observed in the present study was higher than that reported by Reis et al. (2016) of 0.8 mg/100g for fresh guabiju (without seed) and 0.29 mg/100 g for guabiju juice, and lower than the values reported by Andrade et al. (2011) for two varieties of guabiju (seedless fruit) ranged from 334 to 531 mg/100 g dry weight.

According to Celant et al. (2016) the total anthocyanin content in blackberry cultivars in 80% ethanol ranged from 6.76 to 9.42 mg of ECG/g fresh weight. However, Casarin et al. (2016) found 89.02 mg ECG/100 g for fresh blackberry and 77.93 mg of ECG/100g for blackberry flour. Goldmeyer et al. (2014) described anthocyanin content in blueberry of 61.67 mg/100 g. The anthocyanins content of jabuticaba varieties was from 273.67 to 2892.15 mg of ECG/100g of lyophilized sample (Paludo et al., 2019). In conventional extraction acidified with ethanol, Meregalli et al. (2020) found 116.81 mg of ECG/100g in peel of red araçá.

Thus, it can be seen that guabiju fresh had higher anthocyanins than blackberry (Casarin et al., 2016; Celant et al., 2016), blueberry (Goldmeyer et al., 2014) and red araçá (Meregalli et al., 2020). This characteristic is relevant, because anthocyanins have antioxidant activity (Sonawane et al., 2021) with the ability to reduce pro-inflammatory factors, showing great potential in reducing the risk of developing atherosclerosis (Cardoso et al., 2011), act as antimicrobial, antiobesity, immunological modulators, antiurolytic, hepatoprotective and hypocholesterolemic (Apáez Barrios et al., 2018).

Although not comparable to fruits rich in vitamin C, its values, especially in the peel of guabiju fresh, are high (222.9 mg/100g). According with Mazzoni et al. (2017) the vitamin C content found in the strawberry was 57.98 mg/100g fresh weight. Two varieties of red orange presented 54.13 mg/100mL and 56.53 mg/100mL of vitamin C (Habibi & Ramezani, 2017). Lemos et al. (2019) analyzed the vitamin C content of pulp of jabuticaba and acerola and found values of 10.80 and 3704.50 mg/100g, respectively.

3.1.4 Evaluation of antioxidant capacity

Table 4 presents the results of IC₅₀, for peel, pulp and seed of guabiju fresh and dehydrated at 60 °C. It is observed that the best IC₅₀ values obtained for antioxidant activity were for fresh peel, as well as for peel and seed dried.

Table 4. Values of IC₅₀, with respective equation/ R² for peel, pulp and seed of guabiju fresh and dehydrated at 60 °C.

	IC ₅₀ (%)	Equation	R ²
Peel			
Fresh	1.41	y = 35.128x + 0.2347	0.99
60 °C	1.37	Y = 34.743x + 3.4037	0.95
Pulp			
Fresh	2,97	y = 12.801x + 11.976	0.97
60 °C	4.85	Y = 7.4897x + 13.647	0.92
Seed			
Fresh	3.34	y = 15.091x + 0.4392	0.94
60 °C	1.49	Y = 27.654x + 8.9016	0.94

Source: Authors.

Among the biological activities attributed to phenolic compounds, its ability to reduce free radicals stands out due to the antioxidant activity (Jiao et al., 2018; Verruck et al., 2018, Sonawane et al., 2021; Amaral et al., 2021). Analyzing the antioxidant activity of dehydrated blueberry, Goldmeyer et al. (2014) showed IC₅₀ values of 3.83 mg/mL. In this way, it was possible to observe that guabiju had an IC₅₀ comparable to blueberries, and can be included in human food because of its antioxidant properties.

4. Final Considerations

In guabiju samples, the content of K, Ca, Mg, Na, Fe and Al stands out, where the peel shown higher amounts of Ca, Na, Al, Fe, Zn, protein, soluble solids and crude dietary fiber in relation to the pulp and seed. With the drying process, it was observed darkening of all fractions of fruit analyzed, with less variation in the drying of the peel. Drying reduced the levels of total phenolic compounds, flavonoids, anthocyanins and vitamin C in the peel and pulp, however not affected the antioxidant capacity of the extracts. The guabiju extracts, mainly fresh, presented high levels of phenolic compounds, flavonoids, anthocyanins and vitamin C, when compared to other fruits, mainly native. In this sense, it is suggested to future research the extraction of anthocyanins using different solvents and methods, the encapsulation of extracted anthocyanins to improve their conservation, as well as applications in food products.

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