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Jabuticaba-açu peel flour: effects of drying on proximate and bioactive compounds

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Abstract

The jabuticaba (*Plinia cauliflora)* is a tropical fruit valued for its sensory and nutritional benefits; however, its use is limited due to its susceptibility to spoilage during transport and storage. This study aims to identify the drying conditions for jabuticaba peel to produce flour high in anthocyanins and antioxidant activity, while also examining its physicochemical characteristics. Fruits were collected from properties in Guaraciaba and São Miguel do Oeste in the western region of Santa Catarina, Brazil. The peels were dried using a forced air circulation oven at three different temperatures (40°C, 50°C, and 60°C) and freeze-drying. Both the resulting flours and *in natura* peels were analyzed for centesimal composition, pH, water activity, anthocyanin content, antioxidant activity, and total polyphenols. Results showed that the 60°C and freeze-dried samples exhibited higher antioxidant capacities, indicating their potential for food industry applications.

Keywords: *Plinia cauliflora*, by-product, antioxidant activity

Introduction

The jabuticaba tree (*Plinia* sp.) is a significant native species in Brazil, found from the states of Pará to Rio Grande do Sul. The jabuticaba-açu (*Plinia cauliflora*) and Sabará (*Plinia jaboticaba* (Vell)) are the most produced varieties in Brazil, with jabuticaba-açu more common in the southern region (Danner *et al*., 2006; Danner *et al*., 2010).

The fruits offer significant sensory and nutritional benefits with a high sugar content of 48.33 g per 100 g of dry mass (DM) and fiber at 33.23 g per 100 g of DM. They also contain vital minerals like calcium (60 mg per 100 g DM) and phosphorus (73.33 mg per 100 g DM). Rich in phenolic compounds, including anthocyanins with potent antioxidant properties (MOURA, 2009), most of these compounds are found in the peel, which can represent up to 43% of the fruit (Lima *et al*., 2008).

One application of jabuticaba byproducts is using the peel as flour (FARIA *et al*., 2016). Anthocyanins make jabuticaba flour a functional food and natural colorant (VIDAL *et al*., 2012); therefore, efforts should focus on preserving these compounds during processing. Exposure to temperature variations is a key factor in anthocyanin degradation (Delgado-Vargas, Jimenez, Paredes-Lopez, 2000).

This study aims to identify the best method for drying jabuticaba-açu peel (*Plinia cauliflora*) through oven drying at 40°C, 50°C, and 60°C and freeze-drying, to minimize the degradation of bioactive compounds for improved nutritional quality.

Materials and Methods

Sampling

The experiment was conducted at the Federal Institute of Santa Catarina (IFSC) in São Miguel do Oeste, using jabuticaba-açu fruits (*Plinia cauliflora*) collected from Guaraciaba (Sample C1) and São Miguel do Oeste

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(Sample C2) in the western region of Santa Catarina State, Brazil.

After harvesting, the fruits were taken to the laboratory, washed in running water, sorted, and left to dry on paper towels. The peels were manually separated and divided into two portions that were frozen at approximately -18°C for later dehydration. One portion was subjected to the dry matter (DM) analysis, while the other underwent drying at various times and temperatures until reaching a final moisture content of 15%, in compliance with the threshold established by the National Health Surveillance Agency in Brazil (BRASIL, 2005).

Obtaining jabuticaba-açu peel flour (JPF)

The peels were thawed at room temperature (25°C ± 2°C) and then partially dehydrated in a forced-air circulation oven at 40°C, 50°C, and 60°C. Moisture content was monitored by weighing the samples every two hours, with 30-minute intervals starting when they reached 30% moisture content. The peels used in the weighing were discarded, and only the peels remaining in the oven were used for further analyses. The drying process was completed when the peels reached 15% moisture content.

Freeze-drying of the frozen shells was done in a Liotop® L101 lyophilizer at -50°C and 30 mm Hg of vacuum pressure for about 50 hours.

The dried peels were crushed in an analytical mill to obtain jabuticaba peel flour, identified by drying conditions, and stored in vacuum-sealed plastic packaging, wrapped in aluminum foil, and frozen to preserve sensitive compounds (RIVA, 2012).

Analyses

Physicochemical analysis

Physicochemical analyses were performed in triplicate at the IFSC Bromatology Laboratory. Fresh peels and flours were characterized according to the Adolfo Lutz Institute (2005) methods to measure ash content, moisture, water activity, pH, protein (Kjeldahl method), and lipids (Bligh-Dyer method).

Color parameters of the samples were evaluated using the CIELAB system for flour. A portable colorimeter was used to measure the values for L* (luminosity), C* (chroma), h (hue angle), and the coordinates a* (red-green) and b* (yellow-blue).

Furthermore, the anthocyanin content, antioxidant activity, and total phenolic compounds were determined in these samples.

Quantification of monomeric anthocyanins

Anthocyanin quantification was performed using the differential pH method from Giust & Wrolstad (2001). This involves measuring absorbance at 520 nm and 700 nm using a spectrophotometer with buffers at pH 1.0 and 4.5. Anthocyanins are extracted by mixing sample masses with acidified methanol, followed by overnight extraction under refrigeration at 4–10 °C.

The parameters were used in the Lambert-Beer equation to calculate the concentration of the diluted sample, considering the dilution factor (FD) and the molar extinction coefficient (M). Equation 1 was used for calculations, while Equation 2 was applied to determine the concentration of monomeric anthocyanin pigments (MA).

$$A = \{[(A\lambda 530 - A\lambda 700)pH1.0] - [(A\lambda 530 - A\lambda 700)pH4.5]\} \quad \text{(Eq.1)}$$

$$MA = \frac{(A \times MW \times FD \times 1000)}{\varepsilon} \quad \text{(Eq.2)}$$

Where:

-A is the final absorbance of the diluted sample;

-MW is the molecular weight of the major anthocyanin in the specific solvent;

-FD is the dilution factor;

-ε is the molar absorptivity for the major anthocyanin of the sample in the specific solvent.

The total concentration of monomeric anthocyanins in the original sample was estimated using cyanidin-3-glucoside and expressed as mg/g of dry peel. Sample handling was done in dim light at room temperature.

Quantification of total phenolic compounds

Total phenolic compounds were quantified using a modified method from Bieleski & Turner (1966). First, 1 g samples were extracted with 10 mL of ethanol at 40 °C, followed by centrifugation. Next, following the method outlined by Jennings (1981), an aliquot was mixed with distilled water and Folin-Ciocalteau reagent, incubated for 15 minutes, and treated with an alkaline reagent A (2% sodium carbonate in 0.1 N sodium hydroxide). After standing in the dark for 2 hours, absorbance was measured at 740 nm with a UV-Vis spectrophotometer. Results were expressed as mg total phenols/g^{1} in gallic acid equivalents, based on a gallic acid analytical curve.

Antioxidant activity

Antioxidant activity was measured using the ABTS and DPPH methods with 1 g of sample and 10 mL of ethanol for extraction.

ABTS method

Antioxidant activity was assessed using the ABTS radical capture method based on the technique outlined by RE *et al*. (1999), with modifications. The ABTS• radical was produced by combining 5 mL of a 7 mM ABTS stock solution with 88 µL of 140 mM potassium persulfate.

The mixture was left undisturbed for 16 hours in the dark before analysis. The ABTS radical was diluted in ethanol to achieve an absorbance of 0.700 ± 0.050 at 734 nm. In test tubes, 30 µL of each sample was combined with 3 mL of the diluted ABTS solution, vortexed, and analyzed in a spectrophotometer after 6 minutes. A standard curve was created using different Trolox concentrations (100–2000 µM).

DPPH method

First, a stock solution of 0.6 µmol/L DPPH radical was prepared. For the analytical analysis, a 1/100 dilution with ethanol was used (Brand-Williams *et al*., 1995). To assess the antioxidant capacity of jabuticaba flour, 500 µL of the sample was combined with 3 mL of ethanol and 300 µL of diluted DPPH radical solution. The mixture was shaken for 30 seconds and incubated in the dark at room temperature (25 ± 1°C) for 30 minutes. Absorbance was measured at 517 nm using a UV-Vis spectrophotometer, and a standard curve was created with Trolox concentrations ranging from 100 to 2000 µM.

Statistical analysis

Data were analyzed using ANOVA and Tukey's test ($p < 0.05$) with Statistica 8.0® software.

Results and Discussion

Physicochemical composition analysis

The physical-chemical composition of jabuticaba-açu peel flour is shown in **Table 1**.

The moisture content of jabuticaba peel flour (JPF) exceeds the 15.00% threshold established by the National Health Surveillance Agency (BRASIL, 2005).

Only sample C1 at 60°C meets the legal moisture standard (5 to 15%) with 14.73% moisture. The freeze-dried sample C2 had the highest moisture level at 24.44% (Table 1).

The high moisture level was likely attributed to uneven heat transfer in the drying oven, causing variations in drying. Additionally, the freeze-drying time may have been insufficient to reach the desired moisture.

The ash content in sample C1 was higher than the 4.26 g/100g reported by Vieites *et al*. (2011) and the 4.23 g/100g found by Lamounier *et al*. (2015). In contrast, sample C2 showed lower ash content than the 3.89% reported by Ferreira *et al*. (2012).

The freeze-dried samples displayed lower ash content than the other treatments for the same sample. This decrease may result from mineral carryover during the sublimation of water. Specifically, ash content was around 4.93% and 4.37% for sample C1, and 3.39% to 3.28% for sample C2. These values can help meet part of the Recommended Daily Intake (RDI) of minerals, following the current legislation in Brazil (BRASIL, 2005).

This result indicates that FCJ is a mineral-rich food that contributes to healthy body maintenance. Lima *et al*. (2008) highlight jabuticaba peel as a source of essential minerals like iron, potassium, magnesium, and calcium, which are vital for cellular metabolism.

The lipid content of jabuticaba peel flour (JPF) for sample C1 ranged from 2.14% to 2.34% and remained consistent across measurements, with drying treatments showing no effect. In contrast, sample C2 exhibited a lipid range of 0.91% to 2%, indicating significant variability. This discrepancy may be due to short-chain fatty acids in sample C2, which volatilize at high temperatures, while the freeze-dried sample preserved these compounds better.

Table 1. Mean and standard deviation of the centesimal composition parameters of jabuticaba peel flour (JPF), expressed on a dry basis.

		Moisture %	Ashes %	Lipids %	Proteins %	Carbohydrates %
Sample C1	40 °C	16.41 ± 0.00 b	4.55 ± 0.34 ab	2.14 ± 0.20 a	10.44 ± 0.51 ab	82.7 ± 0.25 d
	50 °C	22.06 ± 0.53 a	4.58 ± 0.07 ab	2.34 ± 0.07 a	10.71 ± 0.84 a	82.36 ± 0.77 d
	60 °C	23.76 ± 1.17 a	4.93 ± 0.22 a	2.17 ± 0.09 a	9.60 ± 0.96 abc	82.75 ± 0.58 d
	Freeze-dried	21.15 ± 3.11 a	4.37 ± 0.01 b	2.21 ± 0.07 a	8.36 ± 0.57 cd	85.26 ± 0.70 c
Sample C2	40 °C	23.90 ± 0.19 a	3.39 ± 0.21 c	0.91 ± 0.06 d	9.23 ± 0.32 abc	86.47 ± 0.17 b
	50 °C	24.07 ± 0.30 a	3.78 ± 0.06 c	1.68 ± 0.25 bc	9.05 ± 0.06 bc	85.65 ± 0.08 bc
	60 °C	14.73 ± 0.86 b	3.71 ± 0.00 c	1.33 ± 0.07 c	7.07 ± 0.07 d	87.93 ± 0.14 a
	Freeze-dried	24.44 ± 1.57 a	3.28 ± 0.33 c	2.00 ± 0.02 ab	8.77 ± 0.23 c	89.90 ± 0.22 bc

Means followed by the same letter, in the column, do not differ from each other, by the Tukey's test, at the 5% probability level.

Compared to the findings of Silva *et al*. (2015), the values obtained were lower than 3.34% and below those of Ferreira *et al*. (2012) at 4.89%. The low lipid content in JPF may benefit health, especially since many people consume high-fat diets, leading to an increase in chronic non-transmissible diseases linked to excess weight (Russo *et al*., 2012).

The protein concentration in JPF ranged from 10.44 to 8.36% for sample C1 and from 9.23 to 7.07% for sample C2, both higher than the 5.89% reported by Silva *et al*. (2015) and 5.23% by Ferreira *et al*. (2012).

The carbohydrate content was notably high, with freeze-drying yielding 85.26% for sample C1 and 89.90% for sample B. The high carbohydrate level observed in Sample C2 is due to the thicker jabuticaba peel, likely containing more fiber and simple carbohydrates. Silva *et al*. (2015) reported a carbohydrate level of 76.45%.

The differences in the chemical composition of JPF may result from variations in cultural practices, climate, soil, ripening, and growing environments, as well as peel thickness and subspecies differences. Nevertheless, since the jabuticaba peels from samples C1 and C2 were statistically similar, the observed variations likely stem from the treatments used to produce the flours.

The *in natura* peels have a high moisture content, with sample C1 at 85.05% and sample C2 at 84.93% (Table 2). This makes jabuticaba highly perishable after harvest, with a marketing window of about two days (Moura, 2009).

The Student's *t*-test shows that only the pH in *in natura* samples differs statistically with a 5% error probability; other parameters were similar.

The JPF samples showed an increase in ash and protein contents compared to the *in natura* peel. However, both samples showed reduced carbohydrate content, and sample C2 experienced a decrease in lipid content. This decline may result from the treatments applied, which could degrade certain compounds in the peel during drying.

Freeze-dried samples showed lower losses of compounds since this method does not require high temperatures, preserving compounds that are unstable at elevated temperatures.

The pH values of jabuticaba peel flour (JPF) ranged from 2.997 to 2.943 for sample C1 and 3.247 to 3.203 for sample C2, lower than those reported by Lima et al. (2009) for jabuticaba peel (varieties Sabará at pH 3.39 and Paulista at pH 3.47). The pH in JPF samples decreased compared to *in natura* samples. Variations in pH among *Plinia cauliflora* samples may be influenced by genetic and environmental factors, as growing regions affect the physicochemical characteristics of jabuticaba fruits (Almeida, Silva, Gonçalves, 2018).

The pH and total acidity of JPF classify it as an acidic product (**Table 2**). According to the Adolfo Lutz Institute (2005), acidic foods are less prone to microbial growth, aiding in preservation. Their acidity also enhances flavor and odor, contributing to the bitter taste of the peel. Thus, no additional acids are necessary when incorporating JPF into diets or food products.

Table 2. Mean and standard deviation of the chemical composition of *in natura* jabuticaba peel, on a dry basis.

Parameters analyzed	Samples	
	Peel C1	Peel C2
Moisture %	85,05± 0,30	84,93 ± 0,73
Ashes %	3,68 ± 0,37	2,87 ± 1,11
Lipids %	2,09 ± 0,03	3,36 ± 2,23
Proteins %	4,85± 1,93	4,76 ± 1,42
Carbohydrates %	90,34 ± 1,66	89,46 ± 0,56
Water activity	0,98 ± 0,00	0,98 ± 0,00

*Differ statistically with a 5% probability of error.

A study conducted by Arsego *et al*. (2003) found that the pH of *in natura* fruit is crucial for anthocyanin retention, as anthocyanins are more stable at pH < 3.0 than the factors that cause their deterioration (**Table 3**).

Table 3. The pH content and water activity of jabuticaba peel flour (JPF), expressed as mean ± standard deviation.

		pH	Water activity
Sample C1	40 °C	2.997 ± 0.015 c	0.53 ± 0,00 c
	50 °C	2.970 ± 0.010 cd	0.43 ± 0,02 de
	60 °C	2.980 ± 0.021 cd	0.42 ± 0,01 de
	Freeze-dried	2.943 ± 0.006 d	0.40 ± 0,00 e
Sample C2	40 °C	3.220 ± 0.017 ab	0.71 ± 0,03 a
	50 °C	3.203 ± 0.006 b	0.58 ± 0,03 b
	60 °C	3.210 ± 0.021 ab	0.44 ± 0,01 d
	Freeze-dried	3.247 ± 0.012 a	0.42 ± 0,00 de

Samples with different letters in the same column differ from each other by the Tukey's test at the 5% level of error probability.

Changes in jabuticaba peel flour (JPF) color

A notable increase in luminosity and the a* and b* parameters was observed in the dehydrated samples (**Table 4**) compared to the *in natura* peel. This change may be attributed to the polymerization of some anthocyanins in the JPF, leading to a lighter-colored peel.

A temperature of 60°C produced better results for a* and b* in sample C1, and L*, a*, and b* in sample C2, compared to 40°C. This suggests that higher temperatures

can be used without significant loss of color compounds.

Total polyphenols

Total polyphenol contents for both samples are presented in **Table 5**, expressed in mg of gallic acid equivalents (GAE) per gram of sample.

The freeze-drying treatment effectively preserved total polyphenols, with sample C2 showing the highest concentration at 103.58 ± 2.00. Furthermore, higher temperatures led to less degradation of phenolic compounds, likely because quicker drying at elevated temperatures reduced the time for degradation compared to lower temperatures.

The *in natura* samples had lower than expected values, possibly because the extraction with a mortar and pestle followed by ethanol was insufficient to retrieve the compounds from the cellular vacuoles in jabuticaba peel (Acati *et al*., 2007; Oki *et al*., 2006; Madhavi *et al*., 1995).

Faria *et al*. (2016) reported 62.04 mg GAE/100 g in freeze-dried jabuticaba, lower than the findings of the present study. In contrast, Araújo (2011) found 414.3 mg GAE/100 g of total phenolic compounds in JPF, higher than the results of this study.

According to the classification by Vasco, Ruales, and Kamal-Eldin (2008) and Rufino *et al*. (2010), total phenolic compounds in fruits are categorized as low (< 100 mg GAE/g), medium (100-500 mg GAE/g), and high (> 500 mg GAE/g). Jabuticaba peel flour (JPF) is classified as low in phenolic content, while only the freeze-dried C2 sample exhibited a medium content of phenolic compounds.

Phenolic compounds help plants adapt to their environment, which may explain the variation in polyphenol concentrations among different samples (Rocha *et al*., 2011).

Antioxidant activity

This study confirmed the presence of antioxidant substances in *in natura* peel and JPF, effective against DPPH• and ABTS• radicals. Antioxidant activity results are

Table 4. Color parameters of jabuticaba peel flour (JPF) and *in natura* peel.

		L*	a*	b*	C*	h*
Sample C1	in natura	7.80±0.96 f	-5.14±0.16 g	8.58±1.00 b	10.03±0.89 f	122.44±2.76 b
	40 °C	20.56±1.12 bc	18.24±0.67 d	4.78±0.56 cd	18.85±0.76 e	13.86±1.35 e
	50 °C	16.11±2.53 de	31.38±2.37 b	10.60±3.36 b	33.19±3.25 bc	16.31±4.22 cde
	60 °C	22.55±0.79 b	24.99±0.50 c	6.89±0.19 bc	25.92±0.54 d	15.50±0.17 de
	Freeze-dried	17.73±1.01 cd	37.96±1.53 a	13.79±1.49 a	40.40±1.88 a	19.94±1.47 cd
Sample C2	in natura	2.46±0.50 g	-2.36±0.48 f	2.89±0.59 d	3.74±0.76 g	129.23±0.01 a
	40 °C	13.61±0.19 e	6.88±0.50 e	2.04±0.65 d	7.20±0.50 f	14.20±5.20 e
	50 °C	6.69±2.22 f	18.09±1.92 d	7.81±1.78 b	19.47±1.78 e	21.47±4.18 c
	60 °C	12.22±1.83 e	32.78±0.68 b	7.51±1.53 b	33.79±0.83 b	13.58±1.06 e
	Freeze-dried	39.89±1.77 a	29.75±0.95b	3.07±0.14 d	29.91±0.95 c	5.78±0.24 f

Samples with different letters in the same column differ at the 5% level of error probability.

Table 5. Polyphenol contents expressed in mg of GAE/g sample, antioxidant activity in µmol Trolox per gram, and anthocyanins in mg/g of dry peel.

		ABTS	**DPPH**	**Total polyphenols**	**Anthocyanins**
Sample C1	in natura	2642.96 ± 105.43 a	316.38 ± 31.83 a	53.04 ± 0.99 d	16.33 ± 0.08 f
	40 °C	765.73 ± 71.60 ef	126.20 ± 1.36 cdef	32.72 ± 0.85 g	573.63 ± 8.76 d
	50 °C	732.24 ± 78.03 f	134.21 ± 2.15 cd	33.96 ± 0.68 g	566.14 ± 17.00 cd
	60 °C	936.05 ± 65.83 e	146.24 ± 1.74 bc	38.07 ± 1.11 f	448.67 ± 6.10 e
	Freeze-dried	957.80 ± 64.04 e	164.64 ± 3.82 b	43.67 ± 0.51 e	568.64 ± 18.63 cd
Sample C2	in natura	643.16 ± 14.54 f	96.79 ± 2.72 f	21.66 ± 0.15 h	22.89 ± 1.10 f
	40 °C	1245.57 ± 50.96 d	97.26 ± 3.74 ef	62.62 ± 1.53 c	536.87 ± 28.28 cd
	50 °C	1274.17 ± 87.23 d	108.05 ± 4.08 def	64.39 ±1.13 c	632.45 ± 35.80 bc
	60 °C	1586.19 ± 72.86 c	127.33 ± 0.78 cde	85.82 ± 1.82 b	634.27 ± 56.85 b
	Freeze-dried	1844.89 ± 52.83 b	134.03 ± 4.93 cd	103.58 ± 2.00 a	914.29 ± 18.14 a

Averages followed by the same letter in the column do not differ from each other, according to Tukey's test, at the 5% probability level.

shown in Table 5, measured in micromoles of Trolox per gram.

The samples exhibited scavenging activity against the DPPH radical, indicating the presence of substances in jabuticaba peel and JPF that act as hydrogen donors.

Antioxidant activity is indicated by the amount of DPPH consumed, with greater consumption reflecting higher activity (Alves *et al*., 2007; Magalhães *et al*., 2008; BARREIRA, 2010; BARROSO *et al*., 2011). This test's results are mainly influenced by total polyphenol content, which is key to scavenging free radicals.

Jabuticaba peel flour (JPF) shows potent activity against DPPH radical, highlighting its high antioxidant compound content compared to other fruits (Rufino et al., 2010).

The antioxidant capacity found in this study exceeds that of Santos et al. (2016), who reported values of 53.24, 52.32, and 58.45 for *in natura*, freeze-dried, and oven-dehydrated jabuticaba peel, respectively.

The highest preservation of antioxidant activity was found in freeze-dried flours, with sample C1 at 164.64 µmol Trolox/g and sample C2 at 134.03 µmol Trolox/g. Increasing the oven drying temperature enhanced antioxidant retention compared to lower temperatures. Notably, there was no significant difference between freeze-dried flours and those dried at 60°C for both samples.

Compared to fruits with known antioxidant properties, such as *Euterpe oleracea* (açaí, 598.0 g dry matter/g of DPPH), *Anacardium occidentale* (cashew, 906.0 g dry matter/g of DPPH), and *Spondias tuberosa* (umbu, 276.0 g dry matter/g of DPPH) (RUFINO *et al*., 2010), JPF demonstrates significant DPPH radical activity, highlighting the abundance of antioxidant compounds in its peel.

The antioxidant performance of fruits and their residues is influenced by factors such as geographic origin, climate, harvest period, storage, drying temperature, extracting solvent, and levels of phenolic compounds, vitamins, and carotenoids (Moure et al., 2001).

The ABTS method was used to validate the DPPH test results, as both assess antioxidant activity similarly. Unlike DPPH results, a higher µmol Trolox/g value indicates a greater concentration of antioxidant substances equivalent to the Trolox® standard in one gram of the sample.

The highest antioxidant activity measured for JPF against the ABTS●⁺ radical was found in the freeze-dried sample C2, with a value of 1844.89 µmol Trolox/g of JPF. Each treatment of sample C2 showed statistically significant differences from one another. In contrast, the JPF samples derived from oven-dried sample C1 exhibited similar results among each other, indicating that temperature has an impact on the concentration of antioxidant compounds.

Sample C2 exhibited higher antioxidant activity than sample C1 across all treatments. This may be due to greater levels of secondary metabolites, such as flavonoids and anthocyanins, in the outer plant tissues, which help protect against UV radiation, attract fruit dispersers, and defend against pathogens and predators.

Compared to the study conducted by Santos et al. (2016), which reported 1017.8 µmol Trolox/g of JPF, this result is higher than sample C1 but lower than sample C2.

Jabuticaba peel flour (JPF) effectively captures ABTS●⁺ radicals, outperforming fruit peels like *Hymenaea courbaril* (jatobá)(428.0 µmol Trolox/g), *Callocarpum mamosum* (coastal sapote) (377.0 µmol Trolox/g), and *Theobroma grandiflorum* (cupuaçu) (65.30 µmol Trolox/g) (Contreras-Calderón et al., 2010).

Anthocyanins

Anthocyanin levels are shown in Table 5 for both samples, expressed in mg/g of dry peel.

Freeze-drying significantly preserved anthocyanin content, with sample C2 showing the highest value at 914.29 ± 18.14. This process, performed at low temperatures and without atmospheric air, maintains the product's chemical and organoleptic properties, allowing it to closely resemble the natural product when reconstituted (Gava, 2009).

Samples C1 and C2 showed distinct behaviors. In sample C1, higher drying temperatures resulted in decreased anthocyanin content, whereas in sample C2, increased temperatures corresponded to improved anthocyanin preservation. This difference may stem from the thicker peels in sample C2, which could aid in retaining the compound.

As previously mentioned, the values from the *in natura* samples were lower than expected. This may be due to the extraction method, as a different solvent was used. The drying process also concentrated the content, leading to a higher total value for analysis.

Research conducted by Moura *et al*. (2009) found that jabuticaba boasts a high anthocyanin content of approximately 432.08 mg/100g, surpassing other fruits such as jambolão (378 to 386 mg/100g), blackberry (261 to 292 mg/100g), and grape (277 to 235 mg/100g). This indicates that the anthocyanin levels in jabuticaba are not only substantial but also higher than those of various other fruit species. When compared to the anthocyanin

content found in red cabbage (175 mg/100g) as reported by Lopes *et al*. (2006), values found for jabuticaba are notably higher.

This result indicates that jabuticaba peel, often considered waste, could be a valuable source of anthocyanins, as it is low-cost and widely available in Brazil.

Macheix *et al*. (1990) reported that climatic factors, such as temperature and light, can influence anthocyanin content, complicating comparisons between different fruit cultivars studied in various regions. The higher levels of anthocyanins in jabuticaba peel are due to its greater exposure to environmental stressors, which enhances the production of these protective secondary metabolites.

Conclusion

The findings indicate that both temperature and dehydration time significantly affect the bioactive compounds present in jabuticaba peel. Freeze-drying resulted in higher levels of anthocyanins and antioxidant activity; however, it did not show a statistically significant difference from the drying method at 60°C, thus both methods are viable options for producing flour with high antioxidant capacity. Consequently, utilizing peels as a byproduct in the food industry emerges as a sustainable and promising alternative, capable of enhancing the nutritional value of foods and benefiting public health. Moreover, jabuticaba peel is recognized as a natural source of pigments and bioactive compounds, warranting further research to optimize its extraction and potential applications in the food, pharmaceutical, and chemical sectors.

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