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ORIGINAL ARTICLE

Juçara (*Euterpe edulis* Martius) pulp drum drying: An alternative technology for premium fruit ingredients

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Abstract

Juçara is a Brazilian palm tree commonly found in small farming communities in well-preserved Atlantic Rainforest remnants. Although juçara is a highly perishable fruit that requires freezing temperatures for storage, drying presents a viable alternative to avoid the cold chain. This study assessed the drum drying of juçara pulp under three conditions: (1) without carrier agents, (2) with 5% (dry basis) corn starch, and (3) with 10% (dry basis) organic rice flour. Dried juçara pulp was analyzed for its chemical composition and bioactive properties. Drum drying of juçara pulp seems viable with or without the use of carrier agents (approximately 97% of water removal). While juçara flakes maintained similar total phenolic content as the fresh pulp (p > 0.05), anthocyanin levels and antioxidant capacity were reduced (135.72 mg/100g of anthocyanins in juçara pulp, against 58.71, 75.36 and 79.39 g/100g in juçara flakes with corn starch, organic rice flour and no additives, respectively, p > 0.05). Despite the need for further stability analysis, the product prepared without carrier agents emerged as a promising option for producing 100% juçara flakes.

Keywords: Fruit flakes; Phenolic compounds; Anthocyanins; Antioxidant activity; Thermal processing; Atlantic rainforest fruit.

Resumo

Juçara é uma palmeira nativa da Mata Atlântica brasileira usualmente encontrada em comunidades de pequenos agricultores localizados em conservados remanescentes florestais. Ainda que a juçara seja sazonal e altamente perecível, exigindo temperaturas de congelamento para armazenamento, a secagem é uma boa alternativa para evitar a cadeia do frio. Este estudo avaliou a secagem de polpa de juçara em tambor rotativo, em três diferentes condições: (1) sem coadjuvantes de secagem, (2) 5% (base seca) de amido de milho e (3) 10% (base seca) de farinha de arroz orgânico. Os produtos foram analisados quanto à sua composição química e propriedades bioativas. A secagem de juçara em secador de tambor rotativo mostrou-se viável com e sem o uso de coadjuvantes de secagem, resultando em aproximadamente 97% de remoção da água. Enquanto os flocos de juçara mantiveram teores similares de fenólicos totais em relação à polpa fresca (p>0,05), níveis de antocianinas e capacidade antioxidante foram reduzidos (135,72 mg/100g de antocianinas na polpa de juçara, contra 58,71, 75,36 e 79,39 mg/100g em seus flocos com amido de milho, farinha de arroz orgânica e sem aditivos, respectivamente, p>0.05). Ainda que sejam necessários estudos de estabilidade, o produto elaborado sem aditivos mostrou-se uma opção promissora para a produção de flocos 100% de polpa de juçara.

Palavras-chave: Flocos de fruta; Compostos fenólicos; Antocianinas; Atividade antioxidante; Processamento térmico; Fruta da Mata Atlântica.

Highlights

- Drum drying is a viable technology for producing juçara pulp flakes, both with and without the addition of carriers
- Total Phenolic Compounds are not significantly affected during drum drying of juçara pulp, independently of the use of carriers
- Anthocyanins and antioxidant capacity (DPPH and ABTS) are negatively affected after drum drying juçara pulp, independently of the use of carriers

1 Introduction

The development and strengthening of native biodiversity value chains can be used as a bioeconomy strategy through the valorization of natural resources. This is of special importance for juçara palm species (*Euterpe edulis* Martius), from the Brazilian Atlantic Rainforest, very similar to the Amazonian açaí palm tree (*Euterpe oleraceae* Mart.). Both fruits are black-violet berries due to high anthocyanin contents, and the pulp can be consumed as the Amazonian açaí, in smoothies, mixed with fruits and cereals, or applied to various food products (Barroso et al., 2019).

Despite being historically exploited for its heart of palm, which threatens the natural occurrence of the species (Martinelli & Moraes, 2013), focusing on the juçara fruit consumption can promote its conservation (Schulz et al., 2016). Juçara fruit pulp is still not yet well-explored on an industrial scale (Pereira et al., 2020), but many small farmer communities have already implemented juçara pulp production and marketing, even on an artisanal scale, representing a potential income. Juçara fruit has a great nutritional potential, but since the pulping process involves the addition of water (Santana et al., 2016), its chemical properties are highly dependent on fruit processing practices. As a result, juçara pulp moisture can vary from 76% to 93% and lipid content from 2.2% to 19% (Silva et al., 2013; Bicudo et al., 2014; Santana et al., 2016; Paim et al., 2016). Most of its nutritional interest are focused on antioxidant properties, especially anthocyanin contents, which can appear from 10.4 to 290 mg/100 g of pulp (Paim et al., 2016; Bicudo et al., 2014; Silva et al., 2013, 2018; Brito et al., 2007), with many studies dedicated to develop and understand anthocyanins-rich extracts from juçara fruit and pulp (Passos et al., 2015; Carvalho et al., 2017; Madalão et al., 2021 and others). The main anthocyanin compounds found in the juçara fruit were cyanidin 3-glucoside and cyanidin 3-rutinoside (Brito et al., 2007).

Drying is an alternative for fruit pulp preservation, since it overcomes the main bottleneck of scaling up juçara pulp production by smallholder communities (F.P.C, personal communication). It has many advantages, such as higher nutrient concentrations and easier transportation, storage, and commercialization. Drum drying is a method used to dehydrate materials and involves passing the material over heated drums, which evaporate the water content. It is an alternative for pasty materials, presenting several benefits, such as energy efficiency, high profitability, and flexibility for different products. It is very convenient for purees, like juçara pulp, with a large capacity in a continuous process (Antoniolli et al., 2023).

Stickiness occurs when drying fruit juices, due to the presence of low molecular weight compounds like sugars and organic acids, which tend to decrease glass transition temperatures and stick to surfaces under high drying temperatures (Ahmad & Nguyen, 2017). They are difficult to remove, resulting in impaired product quality, low yields, and dryer damage (Yamato et al., 2020). To mitigate stickiness, the use of high molecular weight carriers, such as starches, maltodextrins, pectins, and gums, is usually required, in a concentration ranging from 3 to 20% d.b. These additives benefit the formation and detachment of the film from the cylinder, enhancing product yields (Antoniolli et al., 2023), increasing the glass transition temperatures, and protecting the nutrients of the material to be dried, improving final product stability (Yamato et al., 2020; Antoniolli et al., 2023).

However, the clean label trend has driven the food industry to communicate whether a certain ingredient or carrier is not present in the final product or if the food has been produced using a more "natural" production method (Asioli et al., 2017). Clean label refers to what is seen as little processed and "natural" or "free from" negatively associated ingredients (Aschemann-Witzel et al., 2019).

The most usual process to meet the clean label demand is freeze-drying, which has been reported as a no-carrier drying method, resulting in 100% powder fruits. The main concern when applying this process comprises energy costs. Despite the development of more efficient equipment, which makes the freeze-drying process a viable alternative, the costs of drying some materials with high water content, like fruit pulps, are still considered too high (Asioli et al., 2017).

Açaí pulp powder is widely consumed globally, especially in the United States of America (USA), as a superfood or dietary supplement, with capsules or the actual powder used as a concentrated juice ingredient and incorporated in foods (Earling et al., 2019). Many açaí powder product variations concerning biochemical quality have been noted, including adulteration reports on the use of commercial açaí powders with very low or no açaí pulp content (Earling et al., 2019; Benatrehina et al., 2018).

Therefore, research on drying solutions for the production of fruit powders with no carriers can meet food ingredient demands and support cleaner formulations. Concerning the low sugar and acid contents of juçara pulp and its cold chain barrier, this study aims to evaluate juçara pulp powder obtained by drum drying, regarding three different carrier regimes: (1) no carrier agents, (2) 5% (dry basis, d.b.) corn starch and (3) 10% (d.b.) organic rice flour.

2 Material and methods

2.1 Juçara pulp and carrier agents

The juçara samples were harvested and depulped in the city of Sete Barras, in the state of São Paulo (SP) (24°22'31" S 47°56'00" W). After harvest and fruit detachment, juçara fruits were selected, sanitized, and placed in plastic boxes to transport to the manufacturing place (Figure 1). Then, berries were warmed in a water bath at 60 °C and taken to a pulper containing 5 dm^3 of water for each 8 dm^3 of fruits. On average, three kilograms of sanitized fruits yield one kilogram of juçara pulp. The extracted juçara pulp (JP) was then frozen at -20 °C in plastic 1 kg bags until proximal composition and bioactive compound assessments. Thereafter, 50 kg of frozen juçara pulp was collected and transported in thermal boxes to the Fruthotec/ITAL laboratory for drum drying assay. The carriers comprised regular corn starch (Ingredion, Mogi Guaçu, Brazil) and organic rice flour containing 92% starch obtained in a market in the city of Campinas, SP. Corn starch is one of the traditional carrier agents, and organic rice flour was chosen as an organic substitute.

Figure 1. Harvesting and post-harvest practices of juçara fruits in the city of Sete-Barras - SP. Source: Gilberto Ota.

2.2 Drum drying process of juçara pulp

The three treatments were carried out with approximately 12 kg of fresh juçara pulp each, homogenized in a colloidal mill (Meteor, REX 2-AL, São Paulo, Brazil) and fed into a rotary single cylinder dryer (Richard Simon & Sons, D139, Nottingham, England), as shown in the Figure 2. The conditions parameters were as follows: 0.15 mm clearance between the heating and applicator cylinder, pool level of 400 mL, residence time of 20 seconds, and processing temperature of 135 °C. The process conditions were defined based on a previous study carried out with jabuticaba pulp (Nunes et al., 2020) and preliminary tests. The dried product obtained as a film was then flocculated (Fabbe, S508, São Paulo, Brazil) using a 2.5 mm sieve (*8*). Treatments comprised the following process:

- Raw material – Juçara Pulp - JP
- Treatment 1 - Juçara Flakes - JF
- Treatment 2 - Juçara Flakes + corn starch (5% d.b) - JFC
- Treatment 3 - Juçara Flakes + organic rice flour (10% d.b) - JFR

Immediately after the drying process, the dehydrated samples were frozen at -20 °C and transported to the Horticultural Product Laboratory at ESALQ/USP (Piracicaba-SP) and stored at -20 °C.

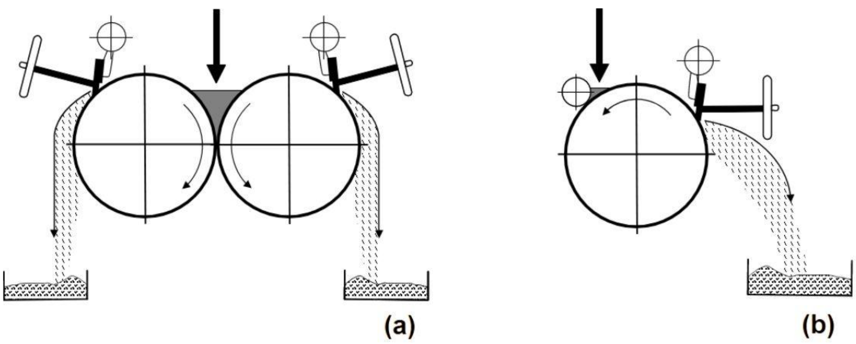

Figure 2. Schematic representation of a drum dryer with a double cylinder (a), and a single cylinder (b). Adapted from Nunes (2019).

2.3 Proximal composition

Proximal composition analyses were carried out according to the Association of Official Analytical Chemists (2016) for all four samples, namely the fresh juçara pulp (JP) and the three dried products (JF, JFC, and JFR). Moisture content was determined by placing the samples in an air circulating oven set at 105 °C until reaching constant weight. Ashes were determined by muffle incineration at 550 °C, protein contents were determined by the micro Kjeldahl method using a 6.25 factor to convert nitrogen values into protein, and soluble and insoluble dietary fibers were determined by the enzymatic-gravimetric method. Non-fiber carbohydrate contents were determined by difference. All analyses were performed for three juçara flakes (JF, JFC, and JFR) and in the JP before drum drying.

2.4 Bioactive compounds

2.4.1 Total phenolic compounds

Total phenolic compounds (TPC) were determined by the Folin-Ciocalteu method as described by Woisky & Salatino (1998). Samples (1 g) were extracted with methanol (80% v/v), filtered through filter paper and subsequently mixed with 2.5 mL of Folin-Ciocalteu's reagent (1:10) and 2 mL of a 4% sodium carbonate solution (w/v) and maintained in the dark for 2 h. Absorbance measurements were determined at 740 nm using a Biochrom Libra S22 spectrophotometer, and the results were expressed as mg gallic acid equivalents.

2.4.2 Anthocyanins

Anthocyanin contents were estimated spectrophotometrically according to Francis (1982). A total of 1 g of samples was used for the extraction of anthocyanin compounds, mixed with 50 mL of an ethanol: 1.5 M HCl solution (85:15, v/v) and incubated for 1 h at room temperature. After this procedure, a spectrophotometer (Biochrom Libra S22) at 535 nm wavelength, which represents the absorption spectrum of the anthocyanins, was used to determine the absorbance values of the blank containing the ethanol: 1.5 M HCl solution. Total anthocyanins (TA) were calculated using Equation 1. The results were expressed as milligrams of total anthocyanins per 100 grams of sample.

$$TA = \frac{ABS * F}{98.2} \tag{1}$$

where TA comprises total anthocyanins; ABS is the determined absorbance, and F is the dilution factor. The 98.2 factor is the acid-ethanol solvent value.

2.4.3 Antioxidant activity (ABTS and DPPH)

The antioxidant activity by the ABTS ((2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)) radical sequestration method was carried out according to Al-Duais et al. (2009). Briefly, 2 mL of an $ABTS^{+}$ solution and 20 µL of Trolox or crude extract were added to the test tube, which was homogenized using a tube shaker in the dark for 6 minutes. Absorptions were determined on a Biochrom Libra S22 spectrophotometer at 734 nm. Each sample was analyzed in triplicate, and the results were expressed as µmol Trolox equivalent (TE) per gram (d.b.).

The free radical 1,1-diphenyl-2-picrylhydrazyl (DPPH) sequestration test was measured using a method adapted by Brand-Williams et al. (1995). In brief, 500 µL of the crude extract at different concentrations were mixed with 3 mL of ethanol and 300 µL of DPPH (0.004% w/v). After 45 minutes of the reaction, the absorbance of the remaining DPPH was measured at 517 nm against the blanks. The antioxidant capacity of the pulp to eliminate DPPH radicals was calculated as the percentage of inhibition and expressed as µmol Trolox (TE) per gram (d.b.).

2.5 Statistical analyses

The data were expressed as means ± standard deviation (M ± SD) and statistical comparisons among groups were carried out using a One-way Analysis of Variance (ANOVA) followed by Tukey's post-hoc test at $p < 0.05$.

3 Results and discussion

Drum drying of juçara pulp was successfully performed both with and without carriers (corn starch and rice flour). Yields, calculated considering a dried product with 5% moisture content, were 19.25 kg/100 kg fresh pulp for no carrier treatment (JF); 20.22 and 24.52 kg/100 kg fresh pulp for treatments containing 5% (d.b.) corn starch (JFC) and 10% (d. b.) rice flour (JFR), respectively.

Table 1 presents fruit pulp composition before and after the drying process, which resulted in approximately 97% of water loss. Other components, protein, insoluble dietary fiber, and soluble dietary fiber, calculated on a dry basis, were not substantially affected during the drying process. Results indicate JP with almost 13% less moisture content than that reported by Silva & Santos (2020), which could be a result of the applied depulping methods, which incorporate warm water into the fresh fruit. Moisture seems to be significantly affected by the addition of carrier agents, although it shows a slight difference.

Table 1. Chemical composition of fresh (JP) and drum-dried juçara pulp, with and without carriers (JF, JFC, and JFR).

	Moisture %	Ashes %	Lipids g/100 g	Protein^{ns} g/100 g	Soluble Fiber g/100g	Insoluble Fiber g/100 g	Total Carbohydrate g/100 g
JP	76.6 ± 0.01 a	2.99 ± 0.02 c	29.3 ± 0.03 c	7.2 ± 0.3	3.7 ± 0.3 a	35.2 ± 0.7 b	60.51 ± 0.71 a
JFR	2.61 ± 0.20 c	3.20 ± 0.04 b	28.9 ± 0.07 d	7.3 ± 0.4	2.6 ± 0.1 b	34.4 ± 0.2 b	60.53 ± 1.09 a
JFC	2.35 ± 0.01 c	3.29 ± 0.02 b	30.9 ± 0.07 a	7.5 ± 0.2	2.5 ± 0.1 b	35.1 ± 0.1 b	58.38 ± 0.52 b
JF	3.51 ± 0.15 b	3.41 ± 0.03 a	30.4 ± 0.05 b	7.3 ± 0.3	3.4 ± 0.1 a	37.3 ± 0.1 a	58.86 ± 0.78 ab
CV%	1.17	1.63	0.40	8.52	10.37	2.2	1.34

Data are expressed by means + standard deviation (d. b. except for moisture). Means followed by the same letter in the same column do not differ statistically, according to Tukey's test ($p < 0.05$). Moisture, ash, lipid, and protein: n = 3, insoluble dietary fiber and soluble dietary fiber: n = 2. Carbohydrate = 100 - (lipid + protein + ashes). ^{ns} not significantly different. CV = Coefficient of Variation.

JP (Table 1) contained higher carbohydrate contents (60.51 g/100g) and lower lipid (29.3 g/100g) and ash levels (2.99 g/100g), compared to the juçara pulp analyzed by Silva & Santos (2020) (46.8; 39.2 and 5.1 for carbohydrates, lipids and ashes, respectively).

Most of JP consists of water, carbohydrates, and lipids (Table 1). This means that for each 100 g of wet pulp, approximately 23 g corresponds to dry matter, composed basically of carbohydrates, especially fibers, and lipids. Total fiber contents can be considered high (38.9% d.b.) compared to other fruits, such as raspberries (6.5% d.b.), avocado (6.7% d.b.), banana (3.4% d.b.), and apple (2.3% d.b.) (Esteban et al., 2017). In terms of lipids, JP showed lower contents of lipids than *E. olearaceae* (35.0% d.b.), but higher in relation to most consumed fruits (Universidade Estadual de Campinas, 2011).

Ash contents d.b. were significantly increased after the drying process ($p < 0.05$). Juçara flakes (JF and JFC) presented more lipids than fresh pulp, probably due to the reduction in size and pectin degradation during the drum-drying process, which facilitates oil extraction in powder form (Chia & Chong, 2015), although the differences observed were very small.

One of the disadvantages of the drying process refers to the loss of bioactive compounds due to high temperatures. Bioactive compounds and antioxidant activity, as well as soluble sugars, are shown in Table 2.

Table 2. Bioactive compounds, antioxidant capacity, and soluble sugars of fresh juçara pulp (JP), juçara flakes with rice flour (JFR), juçara flakes with corn starch (JFC), and juçara flakes with no carriers (JF).

	TPC^{ns}	TA	DPPH	ABTS	Glucose	Frutose
JP	3840.2 ± 215.8	135.72 ± 2.1 a	1046.2 ± 1.5 a	112.9 ± 1.5 a	-	-
JFR	3646.6 ± 55.13	75.36 ± 2.5 b	206.6 ± 0.1 b	7.47 ± 0.6 b	7.11 ± 0.2 b	17.7 ± 0.3 ab
JFC	3469.1 ± 55.20	58.71 ± 2.6 c	203.8 ± 0.2 b	5.87 ± 0.6 b	8.26 ± 0.2 a	18.8 ± 0.2 a
JF	3373.4 ± 71.90	79.49 ± 2.7 b	203.8 ± 0.1 b	8.69 ± 0.4 b	6.68 ± 0.1 b	17.1 ± 0.7 b
CV%	6.71	5.69	0.36	5.12	4.35	4.76

Data are expressed as means ± standard deviations (d.b.). Means followed by the same letter in the same column do not differ statistically, according to Tukey's test ($p < 0.05$). JP was not assessed in terms of soluble sugars. TPC = Total Phenolic Compounds (mg/100 g); TA = Total Anthocyanins (mg/100 g); ABTS = 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid (mg GAE/g, GAE = gallic acid equivalent); DPPH = 2.2-diphenyl-1-picryl-hydrazyl radical (µmol TE/g, TE= trolox equivalent). ^{ns} not significantly different. CV = Coefficient of Variation.

JP is very rich in phenolic compounds (3840 mg/100g d.b.), similar to araçá (*Psidium guineenses* Sw.), murici (*Byrsonima verbascifolia* (L.) DC.), and pitanga (*Eugenia uniflora* L.), other Brazilian fruits (Stafussa et al., 2021). During the drum drying process of JP, no significant TPC losses were observed, even without the addition of carrier agents (JF). This is relevant in the context of food ingredients sales, which usually use polyphenols to standardize premium botanical ingredients. Similar results were found by Troiani et al. (2022) in the drum drying of mango peel. However, Nunes et al. (2020) reported a small but significant loss of phenolic compounds (about 7%) in jabuticaba pulp after drum drying with corn starch. This same author also observed an increase in TPC during the drum drying of jabuticaba pulp with cassava flour as a carrier (Nunes et al., 2021).

Juçara fruits are also rich in anthocyanin contents, which substantially vary during ripening as follows: from 91 to 210 mg/100 g d.b. (Bicudo et al., 2014); as well as region of origin: from 22.81 to 660.30 mg/100 g d.b. (Borges et al., 2011). In this work, JP presented 135.72 mg/100 g d.b. of total anthocyanins (TA, Table 2), which is in line with Bicudo et al. (2014) and Borges et al. (2011), but much lower than those found by Paim et al. (2016), which was 1688.10 mg/100g d.b.. This wide variation is expected, given that anthocyanin content can vary according to maturation stage, region of origin, cultivation conditions, genotype and anthocyanin extraction method (Carvalho et al., 2017; Bicudo et al., 2014; Borges et al., 2011).

Carrier agents used to increase glass transition temperatures are also employed to protect bioactive fruit compounds from oxidation (Santana et al., 2016). In the present study, a comparison among different carrier regimes is found in Figure 3, in terms of retention of TPC and TA, calculated as the ratio of bioactive level in the flakes (d. b.) to the bioactive level in the fresh pulp (d.b.), expressed as a percentage.

High retention values for TPC were found for all obtained flakes (> 80%). The use of organic rice flour (JFR) as a carrier agent seems to favor the retention of TPC significantly. Corn starch (JFC), however, presented an intermediate TPC retention, statistically similar to both JF and JFR. As mentioned before, drying can increase or decrease TPC levels (Nunes et al., 2020, 2021; Troiani et al., 2022), depending on the food composition. This is because the availability of different phenolic precursors may favour non-enzymatic reactions, with accumulation of Maillard-derived melanoidins (Que et al., 2008), that can have a variation of antioxidant activity according to the origin (Kim et al., 1986 as cited in Que et al., 2008). Also, the formation of intermediates of the Maillard reaction, such as hydroxymethylfurfural, was reported by Piga et al. (2003) during hot drying of plums, highlighting the occurrence of non-enzymatic phenolic interconversions when drying fruits.

Anthocyanins contents in fruits and vegetables are inevitably affected by processing steps (Pascual-Teresa & Sanchez-Ballesta, 2008), especially when heat is involved in the process (Cavalcanti et al., 2011). Juçara flakes exhibited anthocyanin levels ranging from 58.71 to 79.49 mg/100g (d.b.) (Table 2), with a retention rate of anthocyanins between 40 and 60% (Figure 3). It is lower than those reported in the drum drying of jabuticaba pulp: 78% of anthocyanin retention (Nunes et al., 2020); and in the spray drying of defatted juçara pulp, that can vary from 63.97 to 87.94%, according to inlet/outlet temperature and carrier agent concentration (Bicudo et al., 2014). These differences in anthocyanin retention may be a result of its antioxidant activity acting as a protective effect on lipid oxidation (Viljanen et al., 2004; Svanberg et al., 2019), since this work assessed juçara whole pulp, which is much richer in lipids than jabuticaba and defatted juçara pulp.

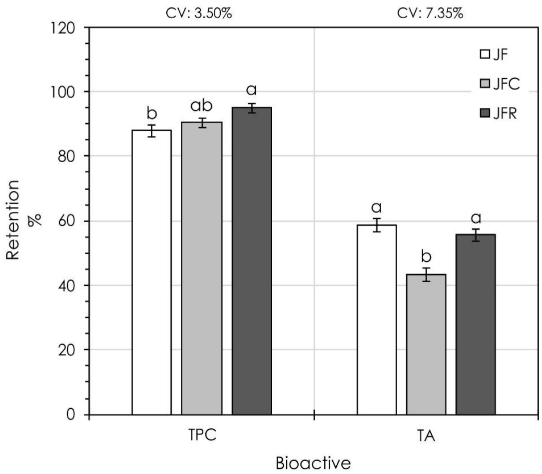

Figure 3. Retention of bioactive compounds in juçara pulp after drum drying with and without different carrier agents. CV = Coefficient of Variation, TPC = Total Phenolic Compound, TA = Total Anthocyanin, JF = Juçara Flakes, JFC = Juçara Flakes with Corn starch, JFR= Juçara Flakes with Rice flour

The use of carrier agents has not shown a protective effect in anthocyanins retention, although not the most common finding, other studies have also reported similar retention values for bioactive compounds dried with and without the use of carriers. This is the case of vitamin C, carotene, and β-carotene retention in the drum drying of mango peel (Antoniolli et al., 2023). In this work, JFC presented a lower retention index for TA compared to both JFR and JF (Figure 3). Regarding the lower (but not significant) moisture content of JFC, it could be argued that this sample performed a more efficient drying, possibly caused by corn starch properties during the film formation, which may have led to a higher temperature of the paste during drying. Corn starches present a higher breakdown viscosity compared to the rice ones (Ali et al., 2016), which indicates a higher granule fragmentation during heat, possibly resulting in a more fluid solution, forming thinners and a more homogeneous film.

Antioxidant activity was negatively affected by the drum drying process, independent of the use of carriers; this reduction in antioxidant activity was also observed during spray drying of juçara (Paim et al., 2016) and açai (*E. oleracea*) pulp (Tonon et al., 2011). Nunes et al. (2020) also reported decreased antioxidant activity in jabuticaba pulp after the drum drying process, with the mean value of around 250 μmol TE/g d.b. Several studies have reported both decreased (Nunes et al., 2020; Chia & Chong, 2015) and increased (Chang et al., 2006) antioxidant activity after drying. Decreased antioxidant compound contents can be a result of thermal processing, which can breakdown phytochemicals, affecting cell structure integrity and resulting in component migration and other chemical reactions (Chia & Chong, 2015). Increases, on the other hand, may be due to the release of phenolic compounds from cellular structures, the inactivation of endogenous enzymes (Chang et al., 2006), and even the occurrence of non-enzymatic reactions (Que et al., 2008; Piga et al., 2003). In this work, no significant differences were observed in terms of antioxidant capacity ($p < 0.05$) among the different carriers used.

Juçara fruit is not considered rich in soluble sugars. All juçara flakes presented more fructose than glucose and no detectable levels of sucrose, which corroborates Inada et al. (2015) and Schultz et al. (2021). JF had a slight but significantly higher glucose and fructose levels than JFR and JFC, which can be a consequence of incorporating mass through the use of carriers (Nunes et al., 2020).

The increasing trend of clean label products, which exclusively utilize natural ingredients, like 100% fruit powders and flakes, has challenged the traditional ingredient production within the food supply chain. This study not only provides an alternative low operational cost drying method which meets this demand, but also offers a suitable opportunity for small farmer communities to scale up their production by avoiding the cold chain.

4 Conclusion

Drum drying of juçara pulp is viable with or without the use of carrier agents. The kind of carrier agents used during the drying process did not affect antioxidant activity, protein, or phenolic content compared to juçara dried pulp without carriers. On the other hand, the use of carriers revealed a slight effect in lipids, fibers, ashes, and anthocyanin contents.

From the clean label point of view, the drum drying process seems to be feasible for juçara pulp without the use of carriers. However, further studies should be conducted to assess juçara flakes's stability during storage, to validate product quality.

This technology may be feasible for small farmer communities in the Ribeira Valley that are already harvesting juçara fruits and have the potential to scale up their production if they can overcome the cold chain barrier.

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