Nutritional, anti-nutritional and technological functionality of flour from Libidibia ferrea

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ABSTRACT

The purpose was to develop new ingredients for the food industry. The flours were obtained from the bark and the fruit of juca (Libidibia ferrea) by grinding and drying in an air circulation greenhouse. The flours were analyzed in terms of nutritional, anti-nutritional, antioxidant, and technological functionality propriety. The flours developed are rich in carbohydrates with values ranging from 89.29 g/100g for the fruit and 81.76 g/100g for the bark. Flours showed low water and fat absorption index, high compacted and real density, and intermediate flow values by the Hausner’s ratio and Carr’s index. The hygroscopicity of the flours ranged from 5.56 g/100g for the bark and 10.31 g/100g for the fruit, influencing the solubility property. The anti-nutritional compounds do not discourage the technological application of flours since studies indicate the action of tannic and phytic acids as antioxidants. The flour shows high total phenolic compound and antioxidant activity in vitro (DPPH and FRAP methods), due to the flavonoids compounds as catechin and myricetin identified by HPLC method. Therefore, fruit flour is the best one when compared to the botanical parts, and indicated as an ingredient to improve sensory characteristics such as crispness, increased sensation, and retention of food flavor.

Keywords: antioxidant, carbohydrate source, crispy food, new ingredient, water absorption.

RESUMO

O objetivo foi desenvolver um novo ingrediente para indústria de alimentos. As farinhas do fruto e da casca do jucá (Libidibia ferrea) foram obtidas por trituração e secagem em estufa. As farinhas foram analisadas quanto as propriedades nutricionais, antinutricionais e funcionalidades tecnológicas. As farinhas são ricas em carboidratos com valores de 89,29g/100g para o fruto e 81,76g/100g para a casca do jucá. As farinhas apresentaram baixa retenção de água e gordura, elevada densidade compactada e real, e valores intermediários de fluidez pelo fator de Hausser e pelo índice de compressibilidade de Carr: A higroscopicidade variou de 5,56 g/100g para a casca a 10,31g/100g para o fruto do jucá, influenciando na propriedade de solubilidade. Os compostos antinutricionais identificados não desestimulam as aplicações tecnológicas das farinhas, visto que estudos apontam a ação dos ácidos tânico e fítico como antioxidantes. As farinhas apresentaram elevado teor de compostos fenólicos e atividade antioxidante pelos métodos in vitro (DPPH e FRAP), devido aos flavonoides, como catequina e miricetina, identificados por cromatográfica líquida. Portanto, a farinha do fruto é melhor comparada entre as partes botânicas, e indicada como ingrediente para melhorar as características sensoriais como, crocância, aumento da sensação e da retenção do sabor do alimento.

Palavras-chave: antioxidante, absorção de água, alimento crocante, fonte de carboidrato.
1 Introduction

The food industry seeks new ingredients to innovate its products, basing its studies on the adequacy of technological processes (FELKER et al., 2018), resulting in significant changes in composition, structure, physicochemical behavior, or nutritional value (MEMON et al., 2020). Within the scope of consumers, there is a need to develop new ingredients (LIMA et al., 2019), whose functionality and versatility meet them in terms of bioactive compounds (AYESSOU et al., 2014; DRAKOS et al., 2017; MILLAR et al., 2019; OLIVEIRA et al., 2020).

Flours have been featured among these new ingredients (LIMA et al., 2019; MEMON et al., 2020; MILLAR et al., 2019; SUMMO et al., 2019; TAMSEN; SHEKARCHIZADEH; SOLTANIZADEH, 2018). The flours are defined as products obtained from edible parts of one or more species of cereals, legumes, fruits, seeds, tubers, and rhizomes by milling and/or other technological processes (BRAZIL - MINISTRY OF HEALTH, 2005). Flours are often used in many recipes as a carbohydrate source and for the texture improvement of processed foods (THIYAJAI et al., 2016).

The flours are usually developed from different sources, such as corn, potato, wheat, and more recently rice (THIYAJAI et al., 2016). The use of juca as an alternative to replace traditional flours in the cooking recipes need to be studied. The physicochemical properties and technological functionality aspects of partial/whole substitution of juca flour in noodles, spaghetti, biscuits, and some crispness food were not found in the literature.

The impairment of the nutritional value of natural sources as juca is attributed to the presence of different compounds usually known as anti-nutritional factors that act as direct or indirect antagonists of nutrient availability (OLGUN et al., 2003). Some of these compounds are tannic, phytic, and oxalic acids. These chemicals in plants come from their defense mechanisms, acting efficiently against fungi, bacteria, and herbicidal actions (MUNHOZ et al., 2018). Due to the possible impact on the nutritional value of foods, current Brazilian legislation recommends the determination of anti-nutritional compounds for the development of new ingredients (BRAZIL - Ministry of Health, 1999).

Libidibia ferrea is commonly known as “pau ferro” or “jucá” in Brazil. There is a spontaneously growing plant from Northeast to Southeast Brazil (COSTA; GUILHON-SIMPILICIO; SOUZA, 2015; PEREIRA et al., 2012), it used in different areas ranging from environmental restoration to applications as medicine, due to its proven therapeutic power in ethnomedical and phytochemical studies (BARROS et al., 2014). The juca bioactive substances are found in all parts of the plant (FERREIRA; SOARES, 2015). Those substances can be extracted by infusion for use as a medicinal tea, without any critical toxic effects (CARVALHO et al., 2011). Pharmacological studies have demonstrated that juca exhibits antibacterial, antiviral, anti-inflammatory, anti-tumor, antihypertensive and hypoglycemic properties (CUNHA et al., 2017; DIAS et al., 2013; FIGUEREDO et al., 2017; NASCIMENTO et al., 2015; PORT’S et al., 2013).

Libidibia ferrea has potent antioxidant effects and antibacterial activity against oral pathogens (COSTA; GUILHON-SIMPILICIO; SOUZA, 2015). A highlight is rich in polar compounds of pharmacological interest, especially in their fruits and bark, parts more utilized in traditional medicine (FERREIRA; SOARES, 2015). Despite its prominence as a medicine, the literature does not report the use of juca flour as a carbohydrate source.

Thus, to contribute further to the knowledge of L. ferrea, our research aimed at the evaluation of physicochemical properties and technological functionality aspects of flour produced by the drying process from the fruit and the bark juca. The properties examined include chemical composition (moisture, protein, lipid, ash, carbohydrate, iron content), anti-nutritional compounds (tannic, phytic and oxalic acid), total phenolic compound and antioxidant activity, as well as the densities, porosity, water activity, pH, hygroscopicity, solubility, and absorption capacity.

2 Materials and methods

2.1 Materials

The fruits and bark of the juca (Libidibia ferrea) collected during the dry period (from December 2015 to March 2016) were purchased from the commercial centers of João Pessoa - PB, Brazil.

All the reagents used were of analytical grade. The acids were purchased from Perkin-Elmer (Sulfuric acid, boric acid, sodium hydroxide, hydrochloric acid, phytic acid, oxalic acid, and tannic acid). The petroleum ether, ethanol, iron, and sodium carbonate were purchased from NEON. The 2,2'-diphenyl-2-picrylhydrazyl (DPPH), Folin-Ciocalteau, 2,4,6-tris (2-pyridyl)-s-
2.5 Anti-nutritional compounds

Tannic acid was determined by the standard curve by the Folin-Denis method according to Rangana (1979). The tannins were extracted from samples by boiling (70°C) the samples in distilled water for 1h. The supernatant was obtained by centrifugation and mixed with Folin–Denis reagent and sodium carbonate solution after 30 minutes. Absorbance was measured spectrophotometrically at 760 nm. The result calculated by the standard curve of tannic acid \( y=0.0564x+0.2268 \) \( R^2 = 0.95 \) and expressed as mg of tannic acid/100g dry sample.

The phytic acid content was determined by the methodology of Chang and Xu (2009). The phytate was extracted with HCl for 16 hours of stirring at 25 °C, then the sample was centrifuged at 1000 rpm for 20 minutes at 10 °C. Phytate content was measured at 500 nm using Wade’s reagent after 10 minutes centrifugation at 5500 rpm at 10 °C and using water as white. The result calculated by the standard curve of phytic acid \( y=0.0002x+0.0066 \) \( R^2 = 0.97 \) and expressed in mg of phytic acid/100g dry sample.

Oxalic acid was extracted with HCl, precipitated, and quantified by titration of calcium oxalate with potassium permanganate, according to the methodology described by Moir (1953). The result was expressed in mg of oxalic acid/100g dry sample.

2.6 Total phenolic content and antioxidant activity

The total phenolic compound (TPC) and antioxidant activity (AA) were assessed on an aqueous extract (1:10 m/v) prepared as follows: 1 g of flour was mixed with 10 mL of solvent in a centrifuge tube and stirred for 2 h in the dark. Then, the tube was centrifuged at 4400 rpm for 3 min to recover the supernatant.

Iron content was determined by the ortho-phenanthroline method described in NBR 13934 ABNT (1997) by reading in a spectrophotometer UV-Vis absorbance at 510nm. The results calculated by standard curve of iron \( y=0.0502x – 0.0123 \) \( R^2 = 0.98 \) and expressed in mg iron/100 g dry basis sample.
2.7 Bulk and tapped densities

Densities were calculated as the ratio by mass/volume, expressed in g/ml, according to Achor et al. (2015). For bulk density, samples were weighed into a 5 ml graduated cylinder without tapping, to determine the total mass of the volume occupied. Tapped density was determined from the mass of the sample in the measuring cylinder after 50 manual taps consecutive on the countertop surface at a height of 10 cm, to determine the volume occupied. Carr’s index and Hausner’s ratio were determined from the values of the bulk and tapped densities results obtained (JINAPONG; SUPHANTHARIKA; JAMNONG, 2008).

2.8 True density

True density was determined by the liquid displacement method using the oil as the immersing fluid as described by Pragati; Genitha and Ravish (2014) and computed according to the following equation, with \( m_s \), a mass of solid (g), and \( v_s \), spent volume of oil (ml).

\[
\rho_t = \frac{m_s}{10 - v_s}
\]  

2.9 Porosity

The porosity (\( \varepsilon \)) was determined from the values of bulk (\( \rho_b \)) and true (\( \rho_t \)) densities when fitted into the equation according to the method of Drakos et al. (2017).

\[
\varepsilon = (1 - \frac{\rho_b}{\rho_t}) \cdot 100
\]

2.10 Water activity (Wa) and the potential of hydrogen (pH)

Water activity was determined by the free water meter (AQUALAB: 4TEV-EUA) at 25 °C and calibrated with silica (0% RH). The pH of the samples was directly determined by the digital potentiometer (CIENLAB-MPA-210-BRASIL) at 25 °C, previously calibrated with pH 7.0 and 4.0 buffer solutions.

2.11 Hygroscopicity

Hygroscopicity was determined according to the method proposed by Caparino et al. (2012). 1g of the sample was weighed in an airtight container and placed in the desiccator with 75% relative humidity (saturated NaCl solution) at 25 °C for 7 days. The result was calculated by the ratio of the mass of water absorbed to the mass of the dry sample and expressed in g/100g dry sample.
2.12 Solubility

Solubility was determined using the procedure developed by Dacanal and Menegalli (2009). 1 g of sample to a vessel containing 100 ml of distilled water under agitation, maintaining the height of the vortex at 30 mm. After 1 min of agitation, the solution was quickly filtered and the filter containing the non-dissolved particles was oven-dried at 105 °C for 24h. The solubility was evaluated from the fraction of non-dissolved material and expressed as g /100 g dry sample.

2.13 Water (WAC) and oil (OAC) absorption capacity

The absorption capacity test consisted of adding 1 g of sample to a centrifuge tube containing 10 ml of distilled water or refined soya-bean oil under agitation for 3 min. The samples were allowed to stand for 30 min and then centrifuged at 2500 rpm for 10 min. The supernatants were drained off, and the wet sediment was weighed. Water or oil absorption capacity was expressed as g of water or oil held per g dry sample (DRAKOS et al., 2017).

2.14 Statistical analysis

ASSISTAT software version 7.7 was used to analyze the result by ANOVA and the Tukey test at a 95% level of significance. Data are reported as means ± standard, each replication consisted of 3 independent measurements.

3 Results and Discussion

3.1 Proximate composition analysis, iron content and total energy value

The proximal composition and the total energy provide information on common nutrients. Based on our research there is limited data in the literature describing the relationship of nutrient content and anti-nutritional compounds of the juca flour. In table 1 are expressed in the values of reducing sugars, non-reducing sugars, protein, lipid, ash, moisture, and energy values for the fruit and the bark of the juca flour.

Table 1 – Results of proximal composition and total energy value.

| Samples             | Fruit flour | Bark flour |
|---------------------|-------------|------------|
| Reducing sugars     | 41.38±0.34 b| 75.15±0.00 a|
| Non-reducing sugars | 43.61±0.35 a| 4.51±0.00 b |
| Protein             | 0.86±0.12 b | 3.95±0.17 a |
| Lipid               | 2.83±0.40 a | 2.06±0.25 b |
| Ash                 | 2.58±0.00 b | 7.61±0.00 a |
| Moisture            | 4.44±0.02 a | 4.62±0.23 b |
| Energetic value     | 386.07      | 411.33     |

* Values are mean ± SD (n=3). **Different superscript letters indicate significant differences (p<0.05) by Tukey test.

Source: Prepared by the authors.

The major macronutrient found in both parts were carbohydrates with values ranging from 89.29 g/100g for the fruit and 81.76 g/100g for the bark. Nutritional and technological point of view the presence of carbohydrates in large quantities adds value to the plant, as they are the main energy source of living beings and contribute to various texture properties of food products.

Among the carbohydrates, the reducing sugars in the shell presented the highest value, 75.15 g glucose per 100 g sample for bark, while the fruit was 41.28 g glucose per 100 g sample. For non-reducing sugars, these values ranged from 4.51 g sucrose per 100 g of bark to 43.61 g sucrose per 100 g of fruit. This high value of the fruit is mainly due to hydrocolloid polysaccharides such as galactomannans, present in juca seed, which has physical properties as emulsifiers, stabilizers, gel in aqueous solutions and thin films as reported by Cunha et al. (2017).

The high carbohydrates content of juca should be the environmental characteristics of the plant, since it is a native of Brazil and is distributed throughout the tropical and subtropical region of the country, especially in the North and Northeast (COSTA; GUILHON-SIMPLICIO; SOUZA, 2015), causing the plant suffers from a high level of incidence of sunlight and UV radiation (FIGUEREDO et al., 2017). Also, the regions have low rainfall, causing plants to perform high photosynthesis rates, consequently causing an excess of carbon and nitrogen in their structure.
3.2 Anti-nutritional compounds and bioactive compounds

Tannic acid and phytic acid results are presented in table 2. Significant statistic difference (p<0.05) is observed within the samples.

Table 2 – Results of anti-nutritional and bioactive compounds.

| Samples          | Fruit flour | Bark flour |
|------------------|-------------|------------|
| Tannic Acid (mg TA/100g) | 88.91 ± 0.07a | 87.83 ± 0.15b |
| Phytic Acid (103mg PA/100g) | 3.86 ± 0.22a | 1.80 ± 0.06b |
| Oxalic Acid (mg OA/100g) | 0.00 ± 0.00a | 0.00 ± 0.00a |
| TPC (mg GAE/g) | 219.75 ± 0.10a | 212.19 ± 0.96b |
| DPPH (%) | 93.75 ± 0.10a | 93.00 ± 0.96a |
| FRAP (mmol Fe2SO4/g) | 315.23 ± 0.14a | 300.72 ± 0.36b |

* Values are mean ± SD (n=3). **Different superscript letters indicate significant differences (p<0.05) by Tukey test.

Source: Prepared by the authors.

The tannic acid content of fruit flour (88.91 mg/100g) is higher than that of bark flour (87.83 mg/100g). The difference in tannin concentration varies according to plant tissues, as well as depending on age, plant size, time, and place of collection, as explained by Munhoz et al. (2018) in your search.

The phytic acid content of fruit flour (3.86 g/100g) is higher than that of bark flour (1.80 g/100g), with the same behavior found in tannic acid content. Phytic acid can chelate several important divalent cations (e.g. Fe, Zn, Ca and Mg) forming insoluble complexes and making them unavailable for absorption and utilization in the small intestine (SUMMO et al., 2019). Phytate has also been implicated in decreasing protein digestibility by forming complexes and also by interfering with enzymes such as trypsin and pepsin. Phytic acids can also affect starch digestions by combining with digestive enzymes or bind minerals such as Ca, via phosphate linkages (RAJ BHANDARI; KAWABATA, 2006).

The occurrence of oxalic acid can decrease calcium absorption and aiding the formation of kidney stones, most of the urinary stones formed in humans are calcium oxalate stones (RAJ BHANDARI; KAWABATA, 2006). Oxalic acid was not detected in both samples,
stating its absence in the flour composition developed. As well as, it was not found in the literature data reporting these values for juca fruits and bark, as it is commonly detected in leaves as explained by Ponka (2006) in his research.

The presence of tannic acid and phytic acid does not only represent a negative aspect. Since studies prove its action as anticarcinogenic and antioxidant, besides acting complexing minerals, enzymes, and proteins (MILLAR et al., 2019; MURTHY et al., 2019).

The antioxidant activity occurs mainly due to their potential for ox-reduction, which enables them to act as reducing agents, donating hydrogen, and neutralizing free radicals. As reported in table 2, both samples presented the high content of total phenolic compound (TPC) ranging from 212.19 mg GAE/ g for bark and 219.75 mg GAE/ g for fruit flour.

Antioxidant activity (AA), the samples are equal values of DPPH radical scavenging capacity assay (93%) and FRAP’s method has significant differences (p<0.05) between the samples (315.23 for fruit flour and 330.72 for bark flour). Although the antioxidant activity measured by the method of free radical scavenging (DPPH) has a different mechanism of action than the method of the reduction potential of iron ions, the results showed similar trends. Antioxidant activity is associated with phenolic compounds since extracts of higher TPC also had greater antioxidant activities regardless of the method used.

Table 3 shows the quantification of the main phenolic substances present in juca flours were determined by HPLC. The peaks were positively evidenced and confirmed based on the retention time corresponding to the existing reference standards.

The phenolic compounds present in juca flour are potential sources of natural antioxidants for commercial operation, confirm the results obtained in the spectrophotometric methods of TPC, DPPH, and FRAP. There are typically compounds of benzoic acids (7), cinnamic acids (4), and their esters and flavonoids (6). The main phenolic compounds identified and quantified in both samples are the flavonoids catechin, myricetin, rutin, quercetin, and the acids syringic, vanillic, dihydroxybenzoic, gallic, p-coumaric, and caffeic, what

| Phenolic compound       | Fruit Flour (mg/g) | Bark Flour (mg/g) |
|-------------------------|--------------------|-------------------|
| Hydroxybenzoic acid     |                    |                   |
| Syringic Acid           | 94.40              | 3.00              |
| Vanillic acid           | 79.00              | 9.20              |
| Salicylic acid          | 59.60              | ND                |
| Dihydroxybenzoic Acid   | 19.20              | 6.00              |
| Ellagic Acid            | 5.20               | 17.60             |
| Gallic acid             | 17.40              | 0.80              |
| Hydroxybenzoic acid     | 6.40               | 0.20              |
| Hydroxycinnamic acid    |                    |                   |
| p-Coumaric acid         | 60.80              | 5.40              |
| Ferulic acid            | 46.20              | ND                |
| Caffeic acid            | 34.80              | 6.60              |
| trans-Cinnamic acid     | 0.40               | 0.40              |
| Flavonoid               |                    |                   |
| Catechin                | 330.00             | 20.60             |
| Myricetin               | 158.20             | 38.40             |
| Rutin                   | 72.40              | 2.20              |
| Quercetin               | 36.80              | 5.60              |
| Chrysirin               | 1.20               | 1.40              |
| Kaempferol              | 0.60               | 0.60              |

*ND= not identified.
Source: Prepared by the authors.

The major compounds identified in both samples were the flavonoids, representing 58.59% for fruit flour and 58.30% for bark flour of phenolic compounds identified. The catechin was the most important detected and quantified compound in the juca flours, in concentrations up to 330.00 mg/g in juca fruit flour. The catechin has several therapeutic properties on human health, as anti-inflammatory, antiviral, and antibacterial effects (FERREIRA; SOARES, 2015).
3.3 Densities, Hausner’s ratio, Carr’s index, and Porosity

Table 4 shows the results of densities, Hausner’s ratio, Carr’s index, and porosity. There were statistically significant differences ($p < 0.05$) between the samples for most results.

| Samples          | Fruit flour | Bark flour |
|------------------|-------------|------------|
| Bulk density (g/ml) | 0.60 ± 0.00	a | 0.60 ± 0.00	a |
| Tapped density (g/ml) | 0.83 ± 0.00	a | 0.76 ± 0.01b |
| True density (g/ml)     | 0.86 ± 0.01a | 0.77 ± 0.01b |
| Hausner’s ratio       | 1.38 ± 0.01a | 1.27 ± 0.02b |
| Carr’s index (g/100g) | 27.68 ± 0.33a | 21.13 ± 0.47b |
| Porosity            | 0.30 ± 0.00a | 0.22 ± 0.02b |

* Values are mean ± SD (n=3). **Different superscript letters indicate significant differences ($p<0.05$) by Tukey test.

Source: Prepared by the authors.

Density is an important cost parameter in the flour production chain. Low-density materials require larger storage space and increase the cost of logistics and packaging. However, flours with low bulk density values are suitable for the preparation of infant and weaning foods due to their easy digestibility, since this parameter influences the texture of food.

The bulk density for both samples studied is a low value (0.60 g/ml), because of that, it can be used for better texture children’s foods. The values of tapped and true density are similar in the same sample due to the specificity of the samples, for fruit flour was 0.83 g/ml and 0.86 g/ml, and for bark flour was 0.76 g/ml and 0.77 g/ml, respectively.

Hausner’s ratio and Carr’s compressibility percentage index are considered indirect measures of flour flow property. The Hausner’s ratio is indicative of particle friction, while Carr’s index shows the material’s ability to decrease volume. Hausner’s ratio for fruit flour (1.38) was higher than bark flour (1.27), showing an intermediate fluidity as stated by Jinapong; Suphantharika and Jamnong (2008). Carr’s index for fruit flour (27.68) was higher than for stem shell flour of (21.13), showing average fluidity with values between 16% and 35% as stated by Achor et al. (2015).

Porosity is an important property in many aspects. It can indicate the presence of oxygen resulting in more rapid degradation of oxidizing compounds, but it may also improve the water absorption material (DRAKOS et al., 2017). The porosity found in the fruit flour (0.30)
was higher than the bark flour (0.22). Pragati et al. (2014) were studying the green and ripe banana flour produced through the drying oven found values similar to the present research, this can be attributed due to similar processing.

3.4 Hydration properties and Oil absorption capacity

Table 5 shows the results of properties analysis which influence quality control, packaging type, and storage conditions of the product.

The main hydration properties are measured by hygroscopicity, water-solubility, water absorption capacity (WAC), and water activity (Wa). Hygroscopicity addresses the amount of water spontaneously fixed in the matrix, influenced by density, porosity, and solubility, and is one of the most important carbohydrate properties (PRAGATI; GENITHA; RAVISH, 2014). The hygroscopicity of fruit flour (10.31 g/100g) is higher than the bark flour (5.56 g/100g) influenced by the high carbohydrate content of fruit flour.

The solubility of fruit flour (54.04 g/100g) is lower than that of bark flour (56.67 g/100g), showing a decrease in dispersibility and reconstitution property. This feature can be attributed to the low content of water-soluble substances such as minerals (REYNIERS et al., 2019).

Table 5 – Results of properties of hydration, oil absorption capacity, and pH.

| Samples          | Fruit flour | Bark flour |
|------------------|-------------|------------|
| Hygroscopicity   | 10.31 ± 0.18a | 5.56 ± 0.12b |
| Solubility       | 54.04 ± 0.70b | 56.67 ± 0.28a |
| WAC (gH₂O/g)     | 1.20 ± 0.21a | 1.06 ± 0.1a |
| Wa (25°C)        | 0.26 ± 0.01a | 0.30 ± 0.01b |
| OAC (gOil/g)     | 0.83 ± 0.02a | 0.75 ± 0.02b |
| pH (25°C)        | 3.52 ± 0.03h | 4.64 ± 0.04a |

* Values are mean ± SD (n=3). **Different superscript letters indicate significant differences (p<0.05) by Tukey test. ***WAC, water absorption capacity; OAC, oil absorption capacity; Wa, water activity; pH, potential of hydrogen.

Source: Prepared by the authors.

The water absorption capacity index reflects on the sensory characteristics of food and indicates the amount of water that flour granules are capable of absorbing (FELKER et al., 2018). This is related to the availability of hydrophilic groups (-OH) to bind to water molecules and the gelling ability of starch molecules (REYNIERS et al., 2019). The values did not show a statistically significant difference (p<0.05) between the samples with low values close to 1 gH₂O/g. Those flours may be suitable for products requiring low water retention and high crispness.

Flour water activities presented values below 0.60, being considered stable to the development of microorganisms and susceptible to oxidative reactions. For this reason, storage in oxygen-impermeable packaging such as vacuum packaging is recommended.

The oil absorption capacity index addresses the combination of fat with nonpolar groups of proteins that are composed of hydrophilic and hydrophobic parts. As well as the availability of lipophilic groups whose oil absorption mechanism is mainly due to the physical entrapment of the oil by capillary attraction (DRAKOS et al., 2017). The values did not show a statistically significant difference (p<0.05) between the samples as values below 1 g oil/g. The low oil absorption capacity is associated with the low protein content of the flour. This feature can play an important role in enhancing the feel and retention of product taste.

When comparing the potential of hydrogenic (pH) of flour, the fruit derivative is classified as very acidic (3.52) while the stem bark flour (4.64) is low acidic. This may be related to the high protein content of bark flour.

4 Conclusions

The present research describes a pioneering study of technological functionality propriety of the juca fruits and bark flour, thereby contributing to the scientific knowledge of this species, as well as facilitating sustainable exploitation of this plant. The objective of this study was achieved completely.

The flours have significant carbohydrate values. Antinutrient compounds such as tannic and phytic acids do not devalue the produced flours once they are potential antioxidant agents. The flour is a source of phenolic compounds with high antioxidant activity, due to the flavonoids compounds as catechin and myricetin.

Therefore, fruit flour is the best one when compared to the studied botanical parts, in terms of carbohydrates, antioxidants, and technological functionality propriety. The fruit flour is suitable for products that require low water and fat retention, to improve the sensory characteristics of crispness, increase the feel and retention of product taste.
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