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# Physicochemical characterization and bioactive compounds in breadfruit (*Artocarpus altilis*) and its dried products.

**Caracterização físico-química e compostos bioativos em fruta-pão (*Artocarpus altilis*) e seus produtos secos.**

**Caracterización fisicoquímica y compuestos bioactivos en fruta del pan (*Artocarpus altilis*) y sus productos desecados).**

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**Abstract**
Breadfruit (*Artocarpus altilis*) is described as an important food source in the diet of several countries, being considered as a valuable food with the potential to positively impact food security in the world. Breadfruit is a fruit of Asian origin with considerable economic and food importance for the region, due to its exceptional nutritional characteristics that bring benefits to the health to its consumers. However in Brazil, the fruit is little known and is underused. Only a very few scientific publications emphasizing the technological characteristics of breadfruit processing have been reported in the literature, which motivated the realization of the present research on its physicochemical characteristics. The fruits used were obtained from domestic orchards at the ripe and "green" ripening stages. The analyses performed were of pH, total soluble solids, total titratable acidity, water activity, ash content, lipids, protein, moisture and color (L*, a*, b*, C* and ºHue). Antioxidant activity through ABTS, DPPH and FRAP assays, and total phenolics and flavonoids compounds were determined. Descriptive data were analyzed by Analysis of Variance (ANOVA), Tukey mean test ($p<0.05$). The results of the physicochemical analysis indicated that the drying to obtain breadfruit flour is a viable alternative, which provides a nutritional increase and a more attractive color to the product, minimizes post-harvest losses, in addition to being a technology with high potential for the availability of new food alternatives. Comparing the two extracts, the antioxidant activity was higher in the ethanol extracts of breadfruit flour. This result may be related to the maturation stage and the concentration of its components. For the phenolics and flavonoids bioactive compounds, there was a significant difference ($p<0.05$), evidencing the aqueous extract, when compared to ethanolic extract.
**Keywords:** *Artocarpus altilis*; Bioactive compounds; Breadfruit; Physicochemical characterization.

**Resumo**
Fruta-pão (*Artocarpus altilis*) é descrita como importante fonte alimentar na dieta de diversos países, sendo considerada um recurso alimentar valioso e com potencial para impactar positivamente a segurança alimentar no mundo. A fruta-pão é uma fruta de origem asiática com considerável importância econômica e alimentar para a região, devido às suas características nutricionais excepcionais que trazem benefícios à saúde de seus consumidores. No Brasil, no entanto, a fruta é pouco conhecida e, por isso, subutilizada. Poucos trabalhos científicos com ênfase as características tecnológicas do processamento da fruta-pão têm sido reportados na literatura, o que motivou a realização da presente pesquisa que estudou suas características físico-químicas. Os frutos utilizados foram obtidos em pomares domésticos nos estádios de maturação maduro e "verde". As análises realizadas foram: pH, sólidos solúveis totais, acidez total titulável, atividade de água, teor de cinzas, lipídeos, proteína umidade e cor (L*, a*, b*, C* e ºHue). A atividade antioxidante foi medida através dos ensaios de ABTS, DPPH e FRAP, compostos fenólicos e flavonoides. Os dados descritivos foram analisados por Análise de Variância (ANOVA), teste de médias Tukey ($p<5\%$). Os resultados das análises físico-químicas indicaram que a secagem para obtenção da farinha da fruta-pão é uma alternativa viável, que proporciona um incremento nutricional e uma coloração mais atrativa ao produto, minimiza as percas pós-colheita, além de ser uma tecnologia com alto potencial para disponibilidade de novas alternativas alimentares. Comparando os dois extratos, a atividade antioxidante foi maior nos extratos etanolicos da farinha de fruta-pão; esse resultado pode estar relacionado com o estágio de maturação e com a concentração de seus componentes. Para os compostos bioativos fenólicos e flavonoides, houve diferença significativa($p<0,05$), entre o

extrato aquoso quando comparado com o extrato etanolico.
**Palavras-chave:** *Artocarpus altilis*; Compostos bioativos; Fruta-pão; Caracterização físico-química.

**Resumen**
La fruta del pan (*Artocarpus altilis*) se describe como una importante fuente de alimento en la dieta de varios países, siendo considerada un recurso alimenticio valioso con el potencial de impactar positivamente la seguridad alimentaria en el mundo. La fruta del pan es una fruta de origen asiático con una gran importancia económica y alimentaria para la región, debido a sus excepcionales características nutricionales que aportan beneficios a la salud de sus consumidores. En Brasil, sin embargo, la fruta es poco conocida y, por lo tanto, infrautilizada. En la literatura se han reportado pocos trabajos científicos que enfatizan las características tecnológicas del procesamiento de la fruta de pan, lo que motivó la realización de la presente investigación que estudió sus características fisicoquímicas. Los frutos utilizados se obtuvieron de huertos domésticos en la etapa de maduración "verde" y madura. Los análisis realizados fueron: pH, sólidos solubles totales, acidez total titulable, actividad del agua, contenido de cenizas, lípidos, humedad proteica y color (L *, a *, b *, C * y ºHue). Actividad antioxidante mediante ensayos ABTS, DPPH y FRAP. Compuestos fenólicos y flavonoides. Los datos descriptivos se analizaron mediante Análisis de Varianza (ANOVA), prueba de media de Tukey (p = 5%). Los resultados de los análisis fisicoquímicos indicaron que los resultados muestran que el secado para obtener harina de fruta de pan es una alternativa viable, que proporciona un aumento nutricional y un color más atractivo al producto, minimiza las pérdidas poscosecha, además de ser una tecnología con alto potencial para la disponibilidad de nuevas alternativas alimentarias. Comparando los dos extractos, la actividad antioxidante fue mayor en los extractos etanólicos de la harina de pan, este resultado puede estar relacionado con la etapa de maduración y la concentración de sus componentes. Para los compuestos bioactivos fenólicos y flavonoides, hubo diferencia significativa (p <0.05), evidenciando el extracto acuoso en comparación con el extracto de etanol.
**Palabras clave:** *Artocarpus altilis*; Compuestos bioactivos; Fruta del pan; Caracterización fisicoquímica.

## 1. Introduction

The breadfruit (*Artocarpus altilis*) is a plant native to the islands of the South Pacific, and is now spread throughout the tropical and subtropical regions of the world. It comes in two varieties: apyrena, without seeds, known as “pasta breadfruit”, and seminiferous, with seeds, the “stone breadfruit” (Cavalcante, 1991; Souza et al., 2012).

Although breadfruit is commonly found throughout the humid tropical region, in Brazil it is well acclimatized, especially in the state of Pará, where it´s cultivation became practically spontaneous. Even in small numbers, it is also found in orchards on the coast of the States of Paraíba, Pernambuco, Alagoas, Sergipe and Bahia, where it is very popular. It is found from São Paulo to the extreme North of Brazil, developing better in low and rainy regions (Calzavara, 1987).

Popularly in Brazil it is called breadfruit, known for being starchy, rich in calcium, phosphorus, minerals, vitamins (B1, B2, C), essential amino acids, sucrose, flavonoids, phenols, steroids, phytosterols and glycosides, its pulp is much appreciated because it is rich in carbohydrates, water, low in fat, and can be used as dried fruit, in bread-making flour and a source for starch extraction (Ravichandran et al., 2016).

In recent years, the consumption of vegetables has increased, both in the domestic and foreign markets. This is due to the concern with health in developed and developing countries, os its consumption is associated with a reduction in the risk of mortality and the development of chronic diseases. This increase in consumption is associated with the search for flavor diversification, which makes room for the sale of new vegetables (Montenegro et al., 2017).

Fruits are generally rich in bioactive compounds, which can be preserved. Therefore, there is a need to evaluate this technology from raw materials, through processing to storage, so that the real nutritional quality of the fruit and fruit products can be maintained (Sarower et al. 2015). However, recent studies have shown that most nutrients and antioxidant compounds are concentrated in the peel and seeds of fruits, and the consumption of these foods is related to beneficial health effects, such as reducing the risk of cancer, Alzheimer's, cataracts and Parkinson's; these effects are attributed to the antioxidant properties of bioactive compounds (Ayala-Zavala et al., 2011).

Drying is an excellent practice to conserve the product with characteristics suitable for consumption for long periods, capable of producing a product of high quality and preserving bioactive compounds while having low processing cost (Costa et al., 2015). Drying is defined as a unit operation of removing water from a product by evaporation or sublimation, by applying

heat under controlled conditions, in order to improve new systems in the food preservation area, identifying drying as an effective method of conservation and to extend shelf life, widely applied in food manufacturing (Xu et al., 2017).

According to Adebowale et al. (2005) who studied the functional properties of natural starch from physically or chemically modified breadfruit using drying at 30 °C for 16 hours to obtain starch, the native starch of breadfruit is a food material that even after thermal treatment maintained bioactive compounds and their gelling power.

Souza et al., (2016) in their work of determining and evaluating the mineral composition of breadfruit using the multivariate analysis technique, revealed high levels of phosphorus, calcium and magnesium in breadfruit which suggests this as a good alternative for nutritional supplementation. The concentrations of these elements in samples cooked at high temperatures cause a decrease in these minerals, making more intensive studies on dehydration methods for breadfruit necessary in order to maintain the quality of the fruit. Thus, the aim of this study was to determine the physicochemical characteristics, bioactive compounds, antioxidant capacity of raw and different drying methods on breadfruit.

## 2. Methodology

All experiments were performed at the Laboratory of Flavor and Chromatographic Analysis (LAF), at the Federal University of Sergipe.

**Acquisition of raw material**

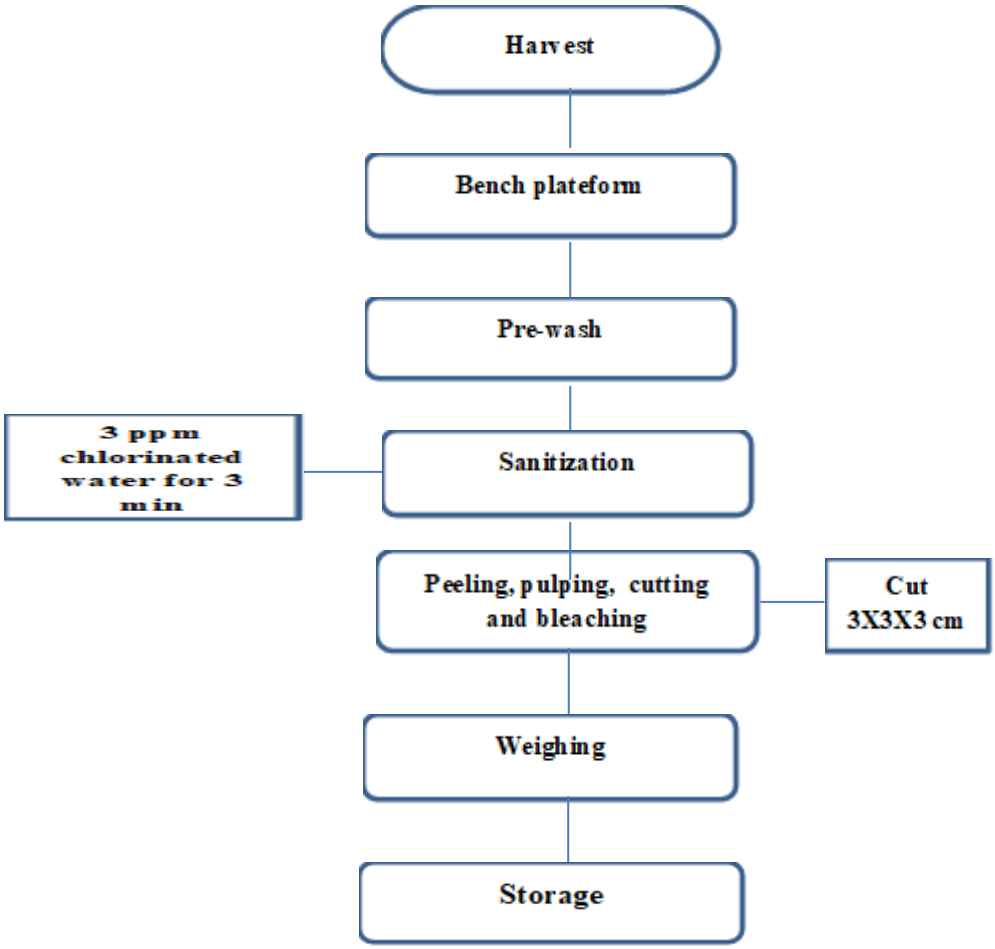
The fruits of the breadfruit (*Artocarpus altilis*) were harvested, in August 2020, in a domestic orchard, in the city of São Cristóvão, Sergipe. The fruits were transported in non-thermal plastic boxes and stored and refrigerated for a period of 24 hrs, until these were minimally processed and then proceeded to storage and freezing. The product development followed the flowchart, described in Figure 1.

Harvested breadfruits were washed with clean water in order to remove dirt and peeled using a stainless kitchen knife (Figure 1). Later, the fruits were submerged in a 3 ppm chlorinated water solution for 8 min. The pulp (T1, T2 and T3) was bleached in the process of submerging in boiling water for 3 min and then submerged in ice water for one min to prevent browning. The pulp was removed, cut into small pieces (3 cm x 3 cm x 3 cm) in order to facilitate drying and then dehydrated in a forced circulation dryer facilitated by air renewal (40°C for 24 h). Dehydrated fruits were then crushed and packed in high-density polyethylene with proper labeling.

Twenty kilos of breadfruit were selected according to their ripening stage – green (ten kg) and ripe (10 kg), having dark green skin color and average size of 1,615g.

The leaves of the breadfruit (F1, F2 and F3) were sanitized and also subjected to analysis.

**Figure 1:** Processing of breadfruit pulp (*Artocarpus altilis*) (tradução para o Inglês dos blocos).




Source: Author (2021).

After the processing, the products were subjected to chemical and physico-chemical analysis in triplicate of the following characteristics: Moisture content, ash content, pH, soluble solids (°Brix), protein and fat in accordance with the analytical methods cited in Instituto Adolfo Lutz (IAL, 2008).

Water activity (aw) was determined by direct reading in Aqualab equipment (Dew Point – Water Activity Meter) after stabilization of the samples at 25 °C for 15 min.

Color was measured in terms of the CIE values of L*, a*, b* c and h using a Konica Minolta brand Calorimeter model CM-700d. L* represents luminosity, a* represents red (+) to green (-) axis, and b* represents yellow (+) to blue (-) axis, C* represents saturation, and h is the hue angle.

**Preparation of the dehydrated products**

Different drying methods were carried out at room temperature (for leaves only) following the methodology proposed by Hamrouni-Sallami et al. (2013) and in forced air circulation dryer (40 ºC) according to the conditions cited by Silva et al., (2016).

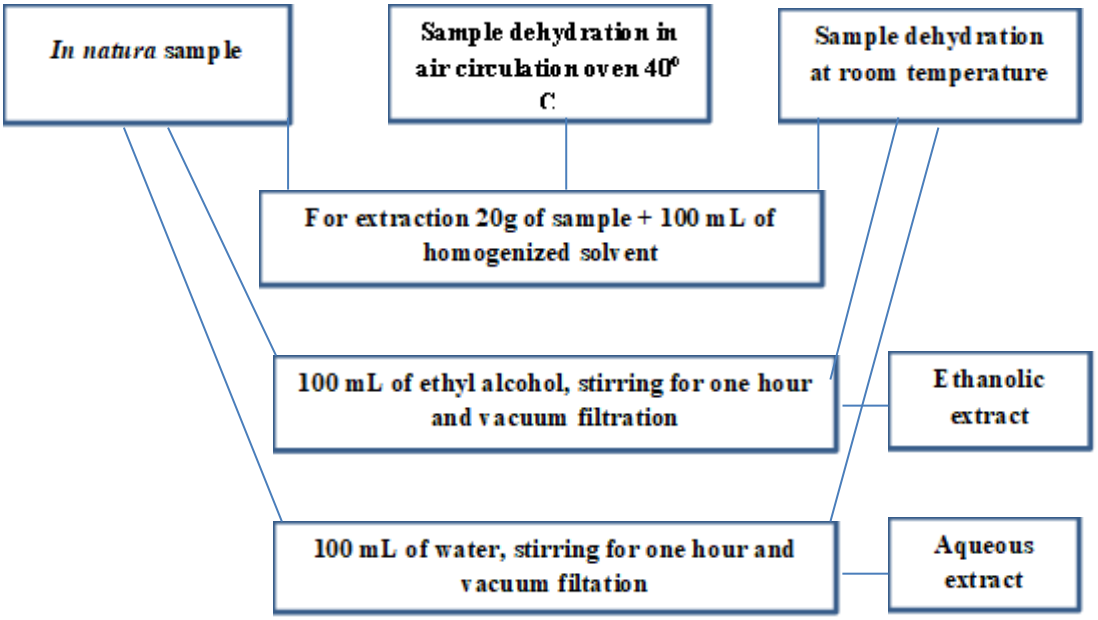
**Extraction Procedures**

For the extraction of plant material (fruit and leaf), the methodology proposed by Green, (2004) was followed, adapted by Jalal et al., (2015), using 100% water (Ext. 1) and 100% ethanol (Ext. 2) as solventes, using 20 grams of the sample

for 100 milliliters of solvents.

Twenty grams of the sample were weighed into 100mL of solvent in a 250mL backer, then placed in the shaker at 200rpm at 25°C for 1h. The supernatant was separated and centrifuged with a G-force of 12000 at 9661 rpm, 4°C for 10 min. The supernatant was filtered and placed in amber vials which were later stored in a refrigerator.

**Figure 2:** Methodology to obtain extracts.




Source: Author (2021).

**Determination of bioactive compounds**

**Total Flavonoids**

TF content was determined according to the method described by Moo-Huchin et al., (2015). Absorbance was measured at 415 nm using a spectrophotometer (Jenway 6705 UV / Vis). TF content was calculated using a prepared standard curve of quercetin (0.05-0.5 mg/mL) and result expressed as quercetin mg equivalent (QE)/100 g of sample.

**Total Phenolics**

To determine the content of total phenolic compounds by the spectrophotometric method, the Folin-Ciocalteu phenol reagente was used, according to the methodology proposed by Singleton and Rossi,(1965) and adapted by Rezende, Nogueira and Narain, (2018). The content was calculated using a standard curve prepared from aqueous solutions of gallic acid (0.1–1 mg/mL) and the result was expressed in mg of gallic acid/100g of the sample.

**Antioxidant Capacity Evaluation**

**ABTS Assay**: This assay was performed based on the method described by Re et al., (1999). Absorbance was measured at 734 nm using a spectrophotometer (Jenway 6705 UV/Vis). Antioxidant activity was calculated using a standard curve prepared from Trolox (0.05–0.35 mg/mL) and the result expressed in µM Trolox equivalent (TE)/g of sample.

**DPPH Assay**: The DPPH radical scavenging activity was determined according to the methodology described by Brand-Williams, Cuvelier. and Berset (1995). The decrease in absorbance at 515 nm was measured from t = 0 min to t = 30 min of reaction, using a spectrophotometer (Jenway 6705 UV/Vis). Antioxidant activity was calculated using a standard curve prepared from Trolox (0–0.3 mg / mL) and result was expressed in µM TE/g of the sample.

**FRAP Assay:** The ferric reducing antioxidant power (FRAP) assay was conducted according to the method reported by Thaipong, et al. (2006). Absorbance was measured at 593 nm using a spectrophotometer (Jenway 6705 UV/Vis). Antioxidant activity was calculated from a standard curve prepared with Trolox (0–0.15 mg/mL) and the result was expressed in μM TE/g of the sample.

**Statistical analysis**

The results obtained were analyzed by using the Statistica 12.0 software (StatSoft Inc., Tulsa, USA). Analysis of variance (ANOVA) was used to determine significant differences ($p \leq 0.05$) between samples. Differences between means were detected by the Tukey test.

## 3. Results and Discussion

The results of the physicochemical characteristics of the breadfruit leaves are shown in Table 1 where TF1 is in natura leaves treatment, TF2 is leaves dehydrated in an air circulation oven at 40o C and TF3 is leaves dehydration at room temperature. It is noteworthy that in a database search, no studies were found for the breadfruit leaves, whereby arousing interest, as the leaves are used for making syrup in traditional popular medicine.

**Table 1:** Physicochemical analysis and proximate composition of the leaves (in natura leaves (TF1) and dehydrated in an air circulation oven at 40o C (TF2) and at room temperature (TF3) of the breadfruit tree (*Artocarpus altilis*).

| **Characteristics** | **Treatments** | | |
|---|---|---|---|
| | TF1 | TF2 | TF3 |
| Moisture (%) | $82.00^{a} \pm 0.01$ | $14.00^{b} \pm 0.01$ | $11.00^{c} \pm 0.01$ |
| Ash (%) | $8.94^{a} \pm 0.05$ | $9.47^{a} \pm 0.81$ | $10.76^{b} \pm 0.38$ |
| Acidity | $2.23^{a} \pm 0.22$ | $2.06^{a} \pm 0.05$ | $1.14^{b} \pm 0.03$ |
| pH | $5.41^{c} \pm 0.06$ | $6.22^{a} \pm 0.01$ | $5.92^{b} \pm 0.01$ |
| Protein (%) | $13.21^{a} \pm 0.09$ | $12.64^{b} \pm 0.29$ | $12.53^{b} \pm 0.12$ |
| Lipids (%) | $2.98^{a} \pm 0.00$ | $1.26^{ac} \pm 0.01$ | $1.18^{ab} \pm 0.01$ |
| $a_w$ | $0.99^{a} \pm 0.01$ | $0.71^{b} \pm 0.00$ | $0.52^{c} \pm 0.01$ |

*Same letters in the means presented in the same line do not differ statistically from each other by Tukey's test at 5% probability;
*TF1= Fresh leaves treatment. *TF2= Dehydrated leaves treatment in oven at 40 ºC. *TF 3= Leaves treatment at ambient temperature. Source: Authors.

It is important to highlight that the moisture content is directly related to the conservation of the product during storage (Viana et al., 2015). The values showed a significant difference ($p \leq 0.05$) between the samples when compared to the sample after drying. The fresh leaves had a high moisture content of 82% and after drying treatments it was observed that TF3 reported lower values compared to TF2. It should be noted that drying at room temperature takes a longer period of time and has the disadvantage of not having temperature control.

The ash contents of the treatments were 8.94% (TF1); 9.47% (TF2); 10.76% (TF3). It was observed that the ash content increased due to the type of drying TF2 (dehydration in an air circulation oven at 40o C) and TF3 (dehydration at room temperature) method used. However. it presented different values and there was a significant difference ($p \leq 0.05$) between TF1 8.94, TF2 9.47 and TF3 10.76 shown in Table 1.

The different treatments showed significant changes in pH and titratable acidity of the leaves of the breadfruit tree (Table 1) with pH values of 5.51 for sample TF1. 6.22 for TF2 and 5.92 for TF3 while titratable acidity was 2.23 for TF1, 2.06 for TF2 and 1.14 for TF3. Acidity is known to quantify the presence of organic acids in vegetables and it is generally low in vegetables.

The average percentage of protein in the breadfruit leaves showed a significant difference for the L1 treatment.

The lipid content in general is low when referring to vegetables. in the analyzed treatments. All the raw materials used have a low lipid value, which was expected in the results. The values ranged from 2.98g/100g to 1.18/100g has not undergone major changes.

**Bioactive compounds in the leaves of the breadfruit tree (*Artocarpus altilis*).**

The analysis of bioactive compounds showed an increase for treatments (TF1, TF2 and TF3) of extraction 2 where ethanol was used as a solvent, the values are shown in Table 2.

**Table 2:** Contents of total phenolics and total flavonoids of leaves samples from the breadfruit tree (Artocarpus altilis) from the 3 treatments in the 2 extractions.

| **Characteristics** | **Treatments** | | | | | |
|---|---|---|---|---|---|---|
| | Ext. 1 | | | Ext.2 | | |
| | TF1 | TF2 | TF3 | TF1 | TF2 | TF3 |
| Total phenolics (µmol TE/g DB) | $27.08^{a} \pm 0.01$ | $27.10^{a} \pm 0.00$ | $29.20^{a} \pm 0.00$ | $41.13^{b} \pm 0.00$ | $40.00^{b} \pm 0.01$ | $43.02^{c} \pm 0.02$ |
| Total Flavonoids (µmol TE/g DB) | $18.45^{a} \pm 0.01$ | $18.31^{a} \pm 0.01$ | $18.50^{a} \pm 0.01$ | $22.50^{b} \pm 0.02$ | $23.10^{ab} \pm 0.03$ | $25.10^{c} \pm 0.02$ |

*DB: Dry Base, *Ext.1= Extraction 1, Ext. 2= Extraction 2.
*Same letters in the means presented in the same line do not differ statistically from each other by Tukey's test at 5% probability. *TF1= Fresh leaves treatment. *TF2= Dehydrated leaves treatment in oven at 40 ºC. *TF 3= Leaves treatment at ambient temperature. Source: Authors.

The highest levels of phenolic compounds were found in the TF3 treatment of extraction 2. (43.02 µmol TE/g DB). Most of the total antioxidant activity is associated with phenolic compounds, mainly flavonoids, which protect against free radicals. Armesto et al., (2019) reviewed the available literature on methods for evaluating phenolic compounds and carotenoids and concluded that the continued intake of foods rich in these compounds is associated with the prevention of several degenerative diseases.

The flavonoids content of the leaves showed the highest result for extraction 2 with the highest value for the TF3 treatment. In this study, the flavonoids contents varied from 18.45 µg/g for TF1 of extraction 1 to 25.10 for TF3 for extraction 2.

**Table 3:** Values (mean ± standard deviation) of the antioxidant activity of the breadfruit (*Artocarpus altilis*).

| **Characteristics** | **Treatments** | | | | | |
|---|---|---|---|---|---|---|
| | Ext. 1 | | | Ext.2 | | |
| | TF1 | TF2 | TF3 | TF1 | TF2 | TF3 |
| DPPH (µmolTE/g DB) | 57.01$^{b}$ ± 0.04 | 64.00$^{a}$ ± 0.04 | 51.00$^{a}$ ± 0.06 | 81.20$^{a}$ ± 0.01 | 78.01$^{b}$±0.02 | 77.00$^{b}$ ± 0.05 |
| ABTS (µmol TE/g DB | 59.00$^{a}$ ± 0.02 | 63.02$^{b}$ ± 0.00 | 52.25$^{a}$ ± 0.00 | 39.05$^{a}$ ± 0.00 | 36.10$^{b}$ ± 0.00 | 39.12$^{a}$ ± 0.01 |
| FRAP (µmolTE/g DB) | 38.28$^{c}$ ± 0.00 | 46.20$^{b}$ ± 0.00 | 49.22$^{a}$ ± 0.01 | 71.00$^{a}$ ± 0.03 | 69.09$^{a}$ ± 0.03 | 68.10$^{a}$ ±0 .02 |

*TE: Trolox equivalent; DB: Dry Base. *Ext.1= Extraction 1. Ext. 2= Extraction 2.
*Same letters in the means presented in the same line do not differ statistically from each other by Tukey's test at 5% probability. *TF1= Fresh leaves treatment, *TF2= Dehydrated leaves treatment in oven at 40 ºC, *TF3= Leaves treatment at ambient temperature**.** Source: Authors.

The antioxidant activity of the breadfruit leaf (Table 3). determined by the DPPH, ABTS and FRAP assays varied from 51.00 to 64.00 µM TE/g; 52.25 to 63.02 µM TE/g; 38.28 to 49.22 µM TE/g (extraction 1) and 77.00 to 81.20 µM TE/g; 36.10 to 39.12 µM TE/g; 68.10 to 71.00 µM TE/g (extraction 2), respectively.

For the DPPH assay, the TF2 (Ext. 1) and the TF1 of (Ext. 2) showed higher antioxidant activity. These were significantly different ($p > 0.05$), compared to the ABTS assay. The antioxidant activity being the highlight stands for TF2 of (Ext. 1) and TF3 of (Ext. 2). As can be seen in Table 3, samples from extraction 2 showed greater antioxidant activity of DPPH, where it reported higher values, ranging from 81.20 for TF1 and 77 for TF3, with the highest antioxidant activity in natura breadfruit leaves.

For the FRAP assay, treatments TF3 (Ext. 1) and TF1 Ext. 2 differed ($p \leq 0.05$) from the other results, these being the treatments with the highest antioxidant activity. It is important to use different tests for the safe and conclusive determination of antioxidant activity since each method has its own specificity and acts on a specific site of action.

The above results showed that (Ext. 2) where the solvent used was 100% ethanol showed the best results for the tests of the antioxidant activities DPPH and FRAP assays. For ABTS, the highest means for the treatments of Ext. 1 were observed when water was used as solvent.

**Table 4:** Presents the results obtained from the physico-chemical characterization and proximate composition in natura pulp obtained from two stages of green (T1 ripe breadfruit pulp) and ripe (T2 green breadfruit pulp) maturation.

| **Characteristics** | **Fresh pulp** | |
|---|---|---|
| | T1 | T2 |
| Moisture (%) | $84.00^{b} \pm 0.01$ | $83.00^{a} \pm 0.00$ |
| Ash (%) | $0.73^{a} \pm 0.01$ | $0.71^{a} \pm 0.02$ |
| Acidity | $1.05^{b} \pm 0.11$ | $1.11^{a} \pm 0.01$ |
| pH | $6.46^{a} \pm 0.02$ | $6.35^{b} \pm 0.01$ |
| °Brix | $2.41^{a} \pm 0.01$ | $2.21^{b} \pm 0.10$ |
| Protein (%) | $1.09^{a} \pm 0.01$ | $1.21^{a} \pm 0.02$ |
| Lipids (%) | $0.23^{a} \pm 0.00$ | $0.18^{b} \pm 0.01$ |
| $a_w$ | $0.99^{a} \pm 0.00$ | $0.97^{b} \pm 0.00$ |

*Same letters in the means presented in the same line do not differ statistically from each other by Tukey's test at 5% probability. *T1= Fresh pulp treatment. *T2= Dehydrated pulp dried at 40ºC. Source: Authors.

Regarding moisture contents, breadfruit presented 84.00% for T1 and 83.00% for T2, a value higher than that found by Moreira et al., (2007) for breadfruit pulp (66.94%) and also higher than that described in the Food Composition Table (Taco, 2011) for breadfruit (80.9%). High moisture contents favor the development of microorganisms and deterioration caused by biochemical reactions, demonstrating that the application of the previous drying process to use this residue can promote the obtaining a product with better physicochemical and microbiological stability (Ordóñez et al., 2005).

The percentage of ash content in the breadfruit pulp was 0.73% for T1 and 0.71% for T2, being higher than found by Ribeiro (2015) which was 0.23% and Bodstein et al., (2015) who reported 0.72% of ash in the characterization of the breadfruit pulp. High ash contents can retard microbial growth. The analysis of the ash content provides with prior information about the nutritional value and depends on the nature of the food and the method of determination used. It is known that this variation can happen due to the climatic conditions, period of the year and the type of soil of the cultivar which also influences in the ash content.

Acidity can indicate an important quality factor in fruit appreciation and conservation. Souza et al., (2012) found mean values of 1.64% for total titratable acidity, values similar to those found in this work. According to Santos et al., (2018) and Aroucha, and Soares, (2010).), acidity is important not only to determine the sweetness ratio of a product but also because of its great utility in the food industry as a preservative that can prolong shelf life. This i salso used as an index for evaluating quality and maturity, reflecting on sensory attributes of the product.

It is observed that the value found for the pH of the breadfruit pulp was 6.46 for T1 and 6.35 for T2, classifying this fruit as less acidic, a fact confirmed by the value obtained for total acidity which was 1.05% for T1 and 1.11% for T2. Bodstein et al., (2015) studied the physical-chemical characterization of breadfruit and stated the pH value as 7.12 while Souza et al. (2012), when characterizing fresh breadfruit, found mean values of 6.01 where deterioration, growth of microorganisms, enzyme activity, flavor/odor retention in fruit may occur (Ordóñez et al., 2005).

The content of soluble solids in fruit is a quantitative indicator of sugars present in it. and is considered a parameter that directly influences the sweet taste, being a determining factor in consumer purchases. This soluble solids content also depends on extrinsic factors of the environment in which the fruits are grown as well as the maturation stage and the type of variety.

The mean value found for proteins was 1.09% for T1 and 1.21% for T2, the values being similar to that found by Turi et al. (2016).

Lipid contents showed an average value of 0.23% for T1 value similar to that reported by TACO (2011) while its value was 0.18% for T2.

The water activity for breadfruit was 0.99 for T1 and 0.97 for T2, a value considered very high which representes most fruits and vegetables. According to Ordóñez et al., (2005), the water activity in food determines the water that is available for microbial growth and higher values favor advancement of different chemical and biochemical reactions.

**Breadfruit pulp flour**

**Physicochemical characterization of dehydrated breadfruit**

Aiming at drying the breadfruit pulp for industrial purposes, dehydration was carried out in a forced circulation cabinet dryer as this is the most economic process and has a lower cost. After drying, considering that the dehydrated breadfruit powder presented an appearance similar to other existing flours (Figures 3 e 4), it was decided to determine their physicochemical characteristics (Table 5).

**Figure 3:** Breadfruit flower obtained from ripe fruit.

Source: Author (2021).

Figure 3 resulted in a yellow-green flour, having very similar characteristics when compared to the breadfruit pulp. It also had a pleasant taste and odor, being a possible substitute for wheat flour in bakery products.

**Figure 4:** Breadfruit flower obtained from green fruit.

Source: Author (2021).

The Figure 4 resulted in a flour with more accentuated green tones, which could have been caused due to the ripeness of the fruit, which had green color, this characteristic remaining after the drying process.

The Table 5 reports the values related to the physical chemical characterization of the bread fruit flour, as well as its means, standard deviation and significant difference.

**Table 5:** Physicochemical characterization of breadfruit (*Artocarpus altilis*) flour.

| **Characteristics** | **Pulp dried at 40 °C** | |
|---|---|---|
| | T3 | T4 |
| Moisture (%) | $12.00^{a} \pm 0.05$ | $11.00^{a} \pm 0.01$ |
| Ash (%) | $2.41^{a} \pm 0.03$ | $2.59^{a} \pm 0.34$ |
| Total Titratable Acidity | $1.31^{b} \pm 0.01$ | $1.51^{a} \pm 0.00$ |
| pH | $6.33^{a} \pm 0.01$ | $5.50^{b} \pm 0.10$ |
| Soluble Solids (°Brix) | $2.33^{a} \pm 0.06$ | $2.11^{b} \pm 0.11$ |
| Protein (%) | $3.68^{a} \pm 0.14$ | $3.69^{a} \pm 0.14$ |
| Lipids (%) | $1.29^{a} \pm 0.02$ | $1.17^{b} \pm 0.05$ |
| $a_w$ | $0.42^{a} \pm 0.00$ | $0.42^{a} \pm 0.00$ |

*Same letters in the means presented in the same line do not differ statistically from each other by Tukey's test at 5% probability.T3 - ripe pulp dehydrated at 40ºC, T4 - green pulp dehydrated at 40ºC. Source: Authors.

The moisture content in the samples were at the recommended safety level (12% - 13%) for storage (FAO. 1992). There was no significant difference ($p \leq 0.05$) in the moisture contente between flours T3 (12%) and T4 (11%), which suggests that the

samples would have good shelf stability. On the other hand, Souza et al. (2012) in determining the composition of breadfruit flour, reported 9.41% moisture; Cavalinni, (2015) in the characterization of the composition of breadfruit flour, obtained an average value of about 6.91% moisture; Beterro, (2014), when comparing the mean values of the nutritional composition between breadfruit flour and corn flour, mentioned mean moisture values of 11.78 and 11.80%, respectively.

In the total solids contents it is observed that the average values of total solids differed from each other. The breadfruit powder T3 had a higher total solids content (2.33%) compared to the T4 powder obtained, whose mean values was 2.11%.

Regarding the ash content of the breadfruit flour, which is indicative of the amount of mineral elements in the flour, it was 2.41% for T3 and 2.59% for T4. Comparing this data with the Cavallini, (2015) who found in the physicochemical characterization of breadfruit flour a value of 2.19% of ash. Malomo, Eleyinmi, and Fashakin, (2011). in the evaluation of the proximate composition for breadfruit flour mentioned 2.69% for the ash content.

For protein there was no significant difference ($p \leq 0.05$) between the treatments and their values varied between 3.68 and 3.69. These results show that even using the drying process, there is a concentration of protein content compared to the fresh fruit.

The lipid content of the breadfruit flour samples was relatively low 1.29% for T3 and 1.17% for T4. These results become advantages as the relatively high fat content may be undesirable since it can lead to development of unpleasant odorous compounds during storage.

In the pH of the two flour samples, there was a statistically significant difference ($p \leq 0.05$) obviously because of the treatment at different stages of maturation. These results did not establish a significant negative effect ($p \leq 0.05$) on the breadfruit flour profile and hence it can be adopted as pre-treatments to stabilize the breadfruit flour quality during storage.

According to Gomes and Oliveira, (2012), aw values from 0.2 to 0.3 are good for dehydrated foods which results in maximum shelf life, as above this value chemical reactions begin to occur. In this study, the values for water activity were not significantly different ($p \leq 0.05$).

**Color determinations**

Color definition based on values represented by X, Y, Z coordinates are usually converted by the CIELAB system, which is a system that results in the measurement of 5 parameters (L*, a*, b*, C* and ºHue) and the values are presented in Table 6. L* is the central axis of luminosity, which goes from a scale of 0 to 100, representing the path of the color space from black to white. The a* is the axis that represents the variation between green (when negative values) and red (when positive values). The b* axis represents the variation of blue (when negative values) and yellow (when positive values). Values of C* indicate the saturation, purity or intensity of the color. The angle h (ºhue) indicates the hue of the sample and varies from 0º and 360º to the red hue; and 90º the yellow, 180º the green and 270º the blue (Chitarra & Chitarra, 2005).

**Table 6:** Values (mean ± standard deviation) of color parameters for breadfruit pulp and flour.

| **Parameters** | **Treatments** | | | |
|---|---|---|---|---|
| | T1 (ripe pulp) | T2 (green pulp) | T3 (ripe pulp dried at 40º C) | T4 (green pulp died at 40º C) |
| L* | $61.16^{a}$± 0.26 | $59.23^{a}$ ± 0.20 | $53.21^{b}$ ± 0.12 | $48.00^{c}$ ± 0.11 |
| +a* | $3.7^{a}$ ± 0.12 | $3.6^{a}$ ± 0.11 | $3.2^{b}$ ± 0.02 | $3.4^{b}$ ± 0.09 |
| +b* | $45.81^{b}$ ± 0.11 | $38.81^{c}$± 0.01 | $43.34^{a}$ ± 0.11 | $42.10^{a}$ ± 0.10 |
| c* | $24.63^{a}$ ± 0.03 | $23.00^{a}$ ± 0.17 | $23.17^{a}$ ± 0.10 | $21.27^{b}$ ± 0.12 |
| h* | $85.44^{b}$ ± 0.21 | $83.17^{a}$± 0.11 | $83.69^{a}$±0.08 | $81.44^{a}$±0.01 |

*Same letters in the means presented in the same line do not differ statistically from each other by Tukey's test at 5% probability. Source: Authors.

The values shown in Table 6 report values from 48.00 to 61.16 for luminosity, a value close to the negative for the a* coordinate that indicates a shade closer to green while a positive value for the b* coordinate shows a yellowish tone, a color with intensity or saturation (C*) and a ºHue quite close to yellow. The chromaticity indicates the saturation or intensity of the color, showing fruits with yellowish intensity. For the Hue angle (H), the treatments presented values between 81.00 and 85.13, showing a yellowish hue.

According to Silva et al., (2012). the quality and the technological procedure of the flour are factors of great importance for the raw material industries and for the consumers of this product. Flour color is a very important parameter for its quality, commercialization and use as an ingredient in various product formulations. It is interesting that the product presents intensity and uniformity of color, which can be evaluated in the peel and pulp of fruits and vegetables (Chitarra & Chitarra, 2005).

**Bioactive compounds from breadfruit (*Artocarpus altilis*)**

Data on the initial concentrations of bioactive compounds and in the extracts of the pulp (T1 and T2) and flour (T3 and T4) of the breadfruit are presented in Table 7

**Table 7:** Contents of total phenolics and total flavonoids of breadfruit samples (*Artocarpus altilis*) from the 4 treatments in the 2 extractions.

| **Characteristics** | **Treatments** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | T1 (Ext.1) | T2 (Ext.1) | T3 (Ext.1) | T4 (Ext. 1) | T1 (Ext. 2) | T2 (Ext. 2) | T3 (Ext. 2) | T4 (Ext.2) |
| Total phenolics (µmol TE/g DB) | $17.12^{a}$± 0.01 | $19.11^{a}$±0.00 | $28.11^{c}$±0.01 | $32.15^{d}$±0.01 | $21.16^{b}$±0.00 | $22.18^{b}$±0.00 | $23.27^{ab}$± 0.02 | $20.36^{a}$±0.00 |
| Total Flavonoids (µmol TE/g DB) | $17.98^{a}$± 0.01 | $18.01^{a}$±0.00 | $20.20^{b}$±0.00 | $20.21^{b}$±0.00 | $18.03^{a}$±0.01 | $18.78^{a}$±0.00 | $17.72^{a}$± 0.03 | $18.78^{a}$±0.01 |

* DB: Dry Base, *Ext.1= Extraction 1, Ext. 2= Extraction 2.
*Same letters in the means presented in the same line do not differ statistically from each other by Tukey's test at 5% probability. *T1= Fresh pulp treatment. T2= Dehydrated pulp dried at 40ºC, T3 = Ripe pulp dried at 40ºC, T4 = Green pulp died at 40ºC. Source: Authors.

The total phenolics content was determined by using the Folin Ciocalteau phenol reagent, where some components

such as citric acid and sugars have an interfering effect in this analysis. Phenolic compounds are part of the secondary metabolism of plants, playing an important role in plant´s defense (Shinwari & Rao, 2018)ording to the data (Table 8), the T4 (32.15 µmol TE/g DB) of extraction 1 had higher results than the other treatments for total phenolics, differing significantly ($p<0.05$) from the other treatments.

As for the contents of flavonoids. there was a significant difference ($p<0.05$) between the means that ranged from 20.20 and 20.21 µmol TE/g DB, both from extraction 1. There is a small increase in the values of this parameter for treatments 3 and 4 from extraction 1. Flavonoids have been of great scientific interest because of their beneficial effects on human health. They have been associated with antiviral, antiallergic, antiplatelet, anti-inflammatory, immunomodulatory, antitumor and antioxidant activity (González-Gallego et al., 2014).

**Antioxidant activity**

The antioxidant activity (Table 8) may depend on several factors viz. the oxidation conditions and stages, the formation and stability of radicals as well as the possible location of antioxidants and stability in different stages of processing in food (Pérez-Jiminez et al., 2008).

**Table 8**: Antioxidant activity of breadfruit (*Artocarpus altilis*).

| Assays | Treatments | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | T1 (Ext. 1) | T2 (Ext. 1) | T3 (Ext. 1) | T4 (Ext. 1) | T1 (Ext. 2) | T2 (Ext. 2) | T3 (Ext. 2) | T4 (Ext. 2) |
| DPPH (µmol TE/g DB) | 57.00$^{b}$±0.04 | 64.00$^{a}$±0.04 | 51.20$^{a}$±0.06 | 59.00$^{a}$±0.10 | 71.00$^{a}$±0.01 | 69.00$^{b}$±0.02 | 65.00$^{b}$±0.05 | 78.03$^{a}$±0.07 |
| ABTS (µmol TE/g DB) | 59.00$^{a}$±0.02 | 52.00$^{b}$±0.00 | 69.01$^{a}$±0.00 | 63.00$^{b}$±0.01 | 36.10$^{a}$±0.00 | 39.00$^{b}$±0.00 | 49.00$^{b}$±0.01 | 41.00$^{a}$±0.00 |
| FRAP (µmol TE/g DB) | 43.00$^{a}$±0.00 | 46.00$^{a}$±0.03 | 39.22$^{b}$±0.004 | 44.00$^{a}$±0.011 | 71.00$^{a}$±0.03 | 69.00$^{a}$±0.03 | 78.00$^{a}$±0.02 | 88.34$^{b}$±0.01 |

*TE: Trolox equivalent; DB: Dry Base. *Ext.1= Extraction 1. Ext. 2= Extraction 2.
*Same letters in the means presented in the same line do not differ statistically from each other by Tukey's test at 5% probability.
*T1= Fresh pulp treatment. T2= Dehydrated pulp. Source: Authors.

## 4. Conclusion

The instant flour obtained from breadfruit presents characteristics similar to other types of flour described in the literature with reference to the acidity, water activity and moisture contents standards required by legislation.

The breadfruit powder obtained by drying in a forced circulation dryer with air renewal presents good characteristics to be used in other products, especially in bakery which brings an alternative for the food industry, being able to obtain high quality of products.

The inclusion of the drying of breadfruit using the hot air dryer method proved to be a real tool in protecting the physicochemical and chemical characteristics of the fresh fruit.

The results show that there was a retention of bioactive compounds mainly in the samples from extraction 1, showing that the dehydrated breadfruit product is indeed a viable source of these nutritional compounds.

Finally it could be concluded that the use of dehydrated breadfruit proved to be a viable option with favorable characteristics for its consumption, presenting an additional option for the use and marketing of the breadfruit with a significant impact on the producer and on the Brazilian fruit industry.

Being the most abundant breadfruit produced in less favored places from an economic point of view, its consumption is still unknown and not very widespread. Thus, it is justified to use the dehydration technique, which could bring greater income to

small local producers and greater use of this still little consumed fruit, which may lead to a reduction in waste and contribute better from a nutritional point of view. Therefore, a much broader study is needed regarding its bioactive compounds in order to ensure a higher quality of the product.

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