Phytochemical and bioactive compounds analysis of the lyophilized pulp, peel, and seeds of *Salacia crassifolia* fruit with potential as a functional food

Análise fitoquímica e dos compostos bioativos da polpa, casca e sementes liofilizados do fruto de *Salacia crassifolia* com potencial de alimento funcional

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ABSTRACT

*Salacia crassifolia*, commonly known as “bacupari do Cerrado”, is a fruit highly valued by the local population. However, limited information is available in the literature regarding its constituents and/or functional properties. This study aimed to determine the phytochemical profile, the antioxidative activity using DPPH and ABTS assays, and quantify the and the phenolic compounds, carotenoids, and vitamin C in the freeze-dried pulp, peel, and seeds of bacupari fruits. The phytochemical profile revealed the presence of various bioactive compounds. The total phenol content, determined by the Folin-Ciocalteu method, ranged from 2095 to 1371 mg of gallic acid equivalent/g of dry mass. The antioxidant analysis showed EC50 values ranging from 3.88±0.03 to 0.45±0.12. The total flavonoid content varied from 9.56 to 9.91 mg of quercetin equivalent. Vitamin C content in the lyophilized pulp was found to be 48.55 mg/100 g, while the carotenoid content was 25.72 mg/100 g. These results demonstrate that the species is rich in bioactive compounds, highlighting its significant potential for both food and pharmacological applications.

Keywords: bacupari, Cerrado fruits, antioxidant potential, bioactive.
seca. Na análise de antioxidante encontrou-se o EC$_{50}$ entre 3,88±0,03 a 0,45±0,12. Flavonoides totais 9,56 a 9,91mg de equivalente de quercetina. Obteve-se 48,55 mg/100 da polpa liofilizada de vitamina C e 25,72 mg/100g de carotenoides. Os resultados demonstram que a espécie é rica em compostos bioativos, apresentando grande potencial para aplicação tanto alimentício quanto farmacológico.

**Palavras-chave:** bacupari, frutos do Cerrado, potencial antioxidante, bioativo.

### 1 INTRODUCTION

The many fruits of the Cerrado biome have significant economic potential for income generation, sustainable development, medicinal uses, and inclusion in the human diet. In addition to their high nutritional value, distinct flavor, and aroma, these fruits contain bioactive compounds with antioxidant properties and health benefits (Cardoso *et al.*, 2012; Reis & Schmiele 2019).

These fruits may have nutritional potential and contain bioactive compounds with health-promoting properties, to the point they are used in traditional medicine as anti-inflammatory, antibiotic, and hypocholesterolemic agents. The beneficial effects of these foods have been attributed to the presence of nutrients such as vitamins A, C, and E, as well as the substantial amount of total phenols, particularly found in fruits of the Cerrado (Rosa, 2013). According to Siqueira (2013), the potential prevention of diseases and high antioxidant activity can stimulate the use of these fruits by the food industry for the development of new products.

Among the Cerrado fruit trees with functional potential, *Salacia crassifolia*, from the Celestraceae family, stands out. Popularly known as *bacupari*, its fruit is known for its exotic characteristics and mild, sweet flavor. Studies on species from the same family have reported the presence of bioactive substances, such as phenolic compounds (Rodrigues *et al.*, 2012; Wenkteshwarlei *et al.*, 2003), terpenes, alkaloids, and flavonoids in the leaves (Wenkteshwarlei *et al.*, 2009); as well as terpenes in the leaves (Uparloft, 2000; Vellosa *et al.*, 2009; Rodrigues *et al.*, 2015), roots (Hishan *et al.*, 1995; Carvalho, 2005), and stem (Somwong *et al.*, 2015).
al., 2011). These findings demonstrate that species belonging to this family possess bioactive compounds with high potential for antioxidant activity.

The fruit of *Salacia crassifolia* are currently only used for their pulp, while the peels and seeds, which represent approximately 60% of the fruit, are commonly discarded. A greater utilization of these fractions would add more value to the bacupari fruit, allowing for its complete utilization without waste.

With limited or no previous studies on the fruit of this species, this research aims to evaluate the phytochemical profile, quantify the content of total phenols, flavonoids, vitamin C, carotenoids, and determine the antioxidant activity of the pulp, peel, and seeds of bacupari fruits originating from the municipality of Barreiras, in the state of Bahia, Brazil.

2 MATERIALS AND METHODS

2.1 FRUIT COLLECTION AND PREPARATION OF FRACTIONS

Fruits of *Salacia crassifolia* were directly collected from three individual matrices located in the rural area of the municipality of Barreiras (12º,07’59,4” S; 45º,01’ 54. 8” W) in November 2018. The species identification was carried out by a specialist in the genus, and a voucher specimen is deposited in the BRBA Herbarium at the Federal University of Western Bahia (UFOB), under registration number 7677.

At the fruit technology laboratory of the Federal Institute of Bahia (IFBA), the fruit were cleaned and sanitized in a 200 ppm chlorine solution. All the peels were manually separated, and the pulp was processed using an industrial pulper to separate the seeds from the pulp. The fractions were weighed and individually packed in polyethylene bags, and oxygen was removed using a vacuum packing machine. Subsequently, the samples were frozen at -20 °C.

The previously obtained pulp, peel, and seed fractions were lyophilized using a LS 3000 Terroni freeze-drier in a bench freeze-dryer for 36 hours. After the lyophilization process of each fraction, these were ground into a powdered material using a food processor, resulting in a lyophilized peel fraction (LPEF),
lyophilized pulp fraction (LPUL), and lyophilized seed fraction (LSF). The fractions were then stored separately in polyethylene bags at -20 °C.

For the quantification of phenolic compounds, flavonoids, and determination of antioxidant activity, a methodology adapted from Larrauri et al. (1997) was followed. Approximately 0.5 g of the LPF, LPL, and LSF was weighed, and 40 mL of 50% analytical grade methanol was added. The mixture was homogenized and allowed to rest in the absence of light at room temperature for 60 minutes, followed by centrifugation at 15,000 rpm for 15 minutes. The supernatant was filtered, resulting in the hydroalcoholic (methanol/water) extracts of the respective lyophilized fractions: peel (HE-LPEF), seeds (HE-LSF), and pulp (HE-LPUF).

2.2 PRELIMINARY PHYTOCHEMICAL CHARACTERIZATION

The lyophilized and powdered samples of Salacia crassifolia fruits were subjected to phytochemical screening to assess the presence of saponins, anthraquinones, alkaloids, flavonoids, tannins, steroids, and triterpenes using precipitation and staining methods, following the methodology described by Matos (2009).

2.3 QUANTIFICATION OF TOTAL PHENOLIC CONTENT

The quantification of total phenols was carried out by using the Folin-Ciocalteu (1927) method, with some modifications described by Obanda and Owor (1997). In this assay, the previously obtained extracts (HE-LPEF, HE-LPUF, and HE-LSF) were diluted 10 times, followed by the addition of the Folin-Ciocalteu reagent, a 20% solution of anhydrous sodium carbonate, and distilled water. The mixtures were homogenized in a vortex and allowed to rest for 30 minutes at room temperature in a low-light environment.

Subsequently, the absorbance of the samples was read in a spectrophotometer at 700 nm. Gallic acid was used to elaborate the standard curve at concentrations of 0, 10, 20, 30, 40, and 50 µg/mL. The results were
expressed in terms of gallic acid equivalent (mg of gallic acid/100 g of pulp, peel, or seed on a dry basis).

2.4 DETERMINATION OF ANTIOXIDANT ACTIVITY (DPPH AND ABTS METHODS)

2.4.1 DPPH method

The antioxidant activity was determined using the methodology described by Rufino et al., (2007), which is based on the reduction of 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Mensor et al., 2001).

Using the HE-LPEF, HE-LSF, and HE-LPUF fractions, five replicates in four different dilutions (1, 0.1, 0.01, and 0.001 mg/mL) were prepared. In a dark environment, aliquots of 0.1 mL from each extract dilution were transferred to test tubes containing 3.9 mL of DPPH radical (diluted in methanol at a concentration of 60 µmol/L). A control solution was prepared following the same procedure, where the sample was replaced with 0.1 mL of a solution containing methanol, acetone, and water. The mixtures were homogenized, and the absorbance was immediately measured at 515 nm using a spectrophotometer, and again after 30 minutes. Ascorbic acid was used as the standard solution for comparison.

A DPPH curve was constructed using concentrations of 10, 20, 30, 40, 50, and 60 µmol, and the antioxidant activity was analyzed by calculating the percentage inhibition of the DPPH solution (%I), according to equation 1:

\[
\text{\% Inhibition} = \left[ 1 - \left( \frac{\text{Sample absorbance at } t_{30}}{\text{Sample absorbance at } t_{0}} \right) \right] \times 100
\]

The half maximal effective concentration (EC50) represents the minimum concentration of antioxidant required to reduce the initial concentration of DPPH by 50%. Therefore, based on the absorbance values obtained from the different dilutions of the extracts, a plot was created with the percentage of DPPH reduction on the Y-axis and the concentration of extracts, in mg/mL, on the X-axis. Thus, a linear equation (equation 2) was determined as follows:
\[ y = -ax + b \]

Where:

\[ y = \% \text{ reduction of DPPH} \]
\[ x = \text{EC50 (mg/mL)} \]

To calculate the EC50, the linear equation (Eq. 2) was used, substituting the value of \( y \) with 50 to obtain the respective concentration of extracts that would reduce 50\% of the DPPH. Extracts with EC50 values closer to zero are considered to have stronger antioxidant activity.

2.4.2 ABTS radical scavenging assay

The ABTS radical capture method was analyzed following the protocol described by Rufino et al., (2007) with some adaptations. In a dark environment, 30 \( \mu \)L of the HE-LPEF, HE-LSF, and HE, LPL samples were pipetted and homogenized with 3,000 \( \mu \)L of the ABTS radical. Readings were taken at 0 and 6 minutes using a spectrophotometer at 734 nm. Ascorbic acid was used as the standard solution for comparison. Subsequently, the antioxidant activity was calculated using the standard curve of ascorbic acid (0.001 to 1.0 mg/mL) and their respective inhibition percentages, as well as the determination of the EC50.

2.4.3 Quantification of total flavonoids

The total flavonoid content was quantified using the method proposed by Woisky and Salatino (1998). The HE-LPEF, HE-LSF, and HE-LPUF fractions were diluted 10 times, followed by the addition of a 5\% methanolic solution of aluminum chloride. The mixture was homogenized and left to rest for 15 minutes, after which the absorbance was measured in a spectrophotometer at 420 nm. The total flavonoid content was determined from a standard curve of quercetin in concentrations of 0, 25, 50, 75, 100, 150, 200, and 250 mg/mL. The calculation of the total flavonoid content was performed using the linear equation
representing the standard curve. Results were expressed in quercetin equivalent per 100 g of dried sample.

2.4.4 Quantification of ascorbic acid

The determination of ascorbic acid content was performed following the methodology outlined by IAL (2008). A sample weighing 1 g of the LPF, LSF, and LPL fractions was prepared, and distilled water, a 10% potassium iodide solution, a 20% sulfuric acid solution, and a 1% starch solution were added. The mixture was homogenized and titrated with potassium iodate solution until the appearance of a dark blue color, indicating the formation of a starch-iodine complex. The titrations were carried out in five replicates. Results were expressed in mg of ascorbic acid per 100 g of dried sample, according to equation 3.

\[
\frac{mg_{VitC}}{100g} = \frac{V_{iod} \times F_{AA}}{M_s} \times 10
\]

Where:

- \( V_{iod} \) = volume of potassium iodate spent during titration (mL)
- \( M_s \) = mass of sample (g)
- \( F_{AA} \) = amount of ascorbic acid necessary to reduce KIO\(_3\) (0.002 M), equivalent to 0.8806.

2.4.5 Extraction and quantification of carotenoids

Carotenoid extraction was performed following the methodology described by Lima et al. (1957) and Umiel & Galverman (1971), with modifications proposed by Moretti et al. (1998). For pigment extraction, 5 g of each fraction (LPF, LSF, and LPL) were macerated with 40 mL of acetone. The resulting mixture was vacuum-filtered into a light-protected container, and 45 mL of hexane were added. The mixture was transferred to a separation funnel and allowed to settle for 20 minutes to separate the phases.

The extract was washed with distilled water three times. After the final wash, the hexane-pigment extract was transferred to a 100 mL volumetric flask, and the volume was completed with hexane. The absorbance was measured in
a spectrophotometer at a wavelength of 450 nm, and the concentration of total carotenoids was determined according to equation 4:

\[
\beta - \text{carotene content (mg/100g)} = \frac{A \times V \times 1.000.000}{C \times M \times 100}
\]

Where:

\( A \) = absorbance of the solution at 450 nm;
\( V \) = final volume of the solution;
\( C \) = molar absorptivity coefficient of a pigment in a specific solvent (2592 for \( \beta \)-carotene);
\( M \) = mass of sample.

2.4.6 Statistical analysis

The data were subjected to analysis of variance (ANOVA) using the Sisvar version 5.6 computational software, and the means were compared using Tukey’s test at a 5% significance level.

3 RESULTS AND DISCUSSION

3.1 PRELIMINARY PHYTOCHEMICAL CHARACTERIZATION

The bioactive compounds found in Cerrado fruits are important as therapeutic substances to aid in the prevention and/or treatment of diseases. According to the preliminary phytochemical characterization conducted in this study, the hydroalcoholic extracts of lyophilized pulp, peel, and seed fractions of bacupari fruit showed the presence of saponins, flavonoids, tannins, and triterpenes (table 1).

Table 1 – Preliminary phytochemical screening of hydroalcoholic extracts of lyophilized pulp (HE-LPUF), peel (HE-LPEF), and seeds (HE-LSF) fractions of the fruit of Salacia crassifolia.

<table>
<thead>
<tr>
<th>Secondary metabolites</th>
<th>HE-LPUF</th>
<th>HE-LPEF</th>
<th>HE-LSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saponins</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Foam test</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Molish test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthraquinones</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bornträger (direct)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bornträger (acid hydrolysis)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Alkaloids</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Bouchardat</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>
Among the secondary metabolites found in this study, the presence of saponins, flavonoids, tannins, steroids, and triterpenes stand out. Saponins exhibit detergent and surfactant properties. In the body, they generally form complexes with bile salts and cholesterol in the gastrointestinal tract, thereby hindering their complete absorption. Additionally, saponins possess antifungal and cytotoxic activities (Costa, 2018).

Flavonoids are compounds that exhibit various biological activities, such as antioxidant properties and the ability to exert anti-inflammatory and immune-protective effects, thereby offering significant pharmacological potential (Costa, 2018).

Tannins, primarily known for their astringent characteristics, also demonstrate important antimicrobial and antifungal properties. Triterpenes, apart from their structural role, membrane permeability, and photoprotection functions, also play a role in the growth and development of plants. They hold economic importance and are used in the industry as color and flavor enhancers, in addition to their biological activities, which include immunostimulatory, anticancer, and anti-inflammatory effects, among others (Roberts, 2007; Connolly & Hill, 2002; Phillips et al., 2006; Liby et al., 2007).

Among the analyzed fractions, the bacupari seeds fraction stands out as it exhibited the highest variety of secondary metabolite classes. Further investigation of this fraction is warranted to evaluate its potential for application in pharmaceutical and allopathic products.

| Mayer test | - | - | - |
| Flavonoids | Shinoda test | ++ | + | - |
| Iron chloride test | ++ | +++ | + |
| Tannins and phenols | Iron chloride test | ++ | +++ | +++ |
| Copper acetate | ++ | - | + |
| Steroids and triterpenes | + | + | +++ |

+++ = Strongly positive reaction; ++ = Moderately positive reaction; + = Positive reaction; - = Negative reaction.

Source: The authors.
In general, the bacupari fruit contains several classes of compounds with significant pharmacological potential. This highlights the need for further studies on this fruit, as well as other fruits found in the Cerrado biome.

3.2 FLAVONOIDS AND PHENOLIC COMPOUNDS

Phenolic compounds are generally distributed in fruits, influencing their chemical and organoleptic properties. They can serve as biological markers, as their occurrence is influenced by factors such as species, growth conditions, degree of ripeness, and storage, among others (Oliveira et al., 2009; Salta et al., 2010).

According to the results obtained in this study, the statistical analyses demonstrate that there is no significant difference in the quantification of total phenols found in the bacupari fruit pulp, peel, and seed samples. The total phenols (TP) results are expressed as gallic acid equivalents (GAE) per g of crude extract and per g of dried plant material. Following Rufino (2010), TP content can be classified as low (<100 mg GAE/100 g), moderate (100 – 500 mg GAE/100 g), and high (>500 mg GAE/100 g).

The bacupari fruit showed a high content of total phenols, ranging from 1095 to 1371 mg of GAE/g in the overall fruit composition (pulp, peel, and seed). Table 2 presents the values of total phenolic compounds expressed as gallic acid equivalents in the hydroalcoholic extract of lyophilized pulp, peel, and seed fractions (HE-LPUF, HE-LPEF, and HE-LSF).

Table 2 – Mean values and standard deviations (SD) of total phenolic content (TP) and total flavonoids, found in the lyophilized pulp, peel, and seeds fractions of fruit of Salacia crassifolia, are expressed as mg gallic acid per g of extract and as mg quercetin equivalent per g of extract, respectively.

<table>
<thead>
<tr>
<th></th>
<th>TP (mg GAE/g) ± DP</th>
<th>Total flavonoids (mg QE/g) ± DP</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE-LPUF</td>
<td>1254.00 ± 0.218</td>
<td>9.86 ± 0.001</td>
</tr>
<tr>
<td>HE-LPEF</td>
<td>1391.00 ± 0.079</td>
<td>9.56 ± 0.002</td>
</tr>
<tr>
<td>EH-LSF</td>
<td>1375.00 ± 0.061</td>
<td>9.91 ± 0.000</td>
</tr>
</tbody>
</table>

Mean values followed by equal letters in the same column do not significantly differ according to the Tukey test at a 5% significance level.

Source: The authors.
It is noteworthy that there is no significant difference between the fruit fractions. Thus, peels and seeds, which are usually discarded by consumers of the fruit in natura, can be a promising source of phenolic compounds.

In a study conducted by Vilson et al. (2001), it was observed that 86% of the phenolic compounds consumed daily by the American population came from eight fruits: bananas, apples, grapes, watermelons, pears, cantaloupes, peaches, and strawberries. In this sense, bacupari, with its high level of phenolic compounds, can significantly contribute to the diet, in collaboration with its antioxidant activity.

Flavonoids have been extensively studied for their various pharmacological properties, such as antiviral, antioxidant, anti-inflammatory, analgesic, and antitumor activities. Flavonoids also play a role in reducing the occurrence of pathologies such as cancer, atherosclerosis, cardiovascular diseases, diabetes, and arthritis. However, the effectiveness of these compounds depends directly on their bioaccessibility (Zuanazzi et al., 2017).

Bacupari fruit showed significant flavonoid content, especially in the pulp (9.86 mg/100 g) and in the seeds (9.91 mg/100 g).

According to Arabbi et al. (2004), the Brazilian population has an estimated flavonoid intake ranging from 60 to 106 mg/day, with average intakes of 79 and 86 mg/day for women and men, respectively. The estimation of flavonoid intake was based on food consumption data obtained from various dietary surveys and food habit studies conducted in (and available in) the country. However, flavonoid intake varies greatly, mainly due to different dietary habits of the Brazilian population. It is important to highlight that sensory, cultural, and social aspects can also interfere with said numbers.

Corrêa et al. (2015) found an average flavonoid intake by the Brazilian population of 138.92 mg/day. The intake of phenolic compounds such as flavonoids is low due to insufficient consumption of fruits and vegetables. It should be noted that the black beans and coffee are the main sources of phenolic compounds in the country. Furthermore, the daily intake of flavonoids is still poorly documented due to a lack of data on flavonoid content in foods. According
to Williamson (2008), the Food and Nutrition Board of the US National Academy of Sciences does not provide specific dietary reference intakes (DRIs) for these compounds.

Therefore, knowledge of the content of these compounds, as well as their antioxidant activity in fruits, is important because current data is scarce or nonexistent in the literature.

3.3 ANTIOXIDANT ACTIVITY

The antioxidant activity of tropical fruits should be understood as the result of the combination of various bioactive compounds, emphasizing the importance of variety in the composition of meals. In general, the more diverse and colorful the meal, the greater the presence of nutrients in its composition (Oliveira et al., 2011).

To evaluate the antioxidant activity of the constituents of the HE-LPEF, HE-LSF, and HE-LPUF of the fruit of *Salacia crassifolia*, the DPPH• and ABTS• scavenging assays were performed. The results were expressed as a percentage of oxidation inhibition, as shown in figures 1 and 2.

Figure 1 – Percentage inhibition by the HE-LPEF, HE-LSF, and HE-LPUF fractions of *Salacia crassifolia* fruit in different concentrations, using the DPPH method.
Figure 2 – Percentage inhibition by the HE-LPEF, HE-LSF, and HE-LPUF fractions of *Salacia crassifolia* fruit in different concentrations, using the ABTS method.

Both analyses demonstrated that the seed fraction exhibited a higher oxidation inhibition potential compared to the pulp, peel, and ascorbic acid standard, as shown in figure 1. In this regard, the consumption of DPPH was directly proportional to the concentration of extract, meaning that the higher the concentration, the greater the antioxidant potential. Thus, the concentration of 1.0 mg/mL showed the highest activity for all samples, with the seed fraction showing significant 75% inhibition of oxidation, which was notably higher compared to the pulp and peel fractions, and even superior to the standard. For analysis using DPPH and ABTS radicals, table 3 shows the results.

Table 3 – Mean values and standard deviations (SD) of the EC<sub>50</sub> values for DPPH and ABTS radicals, obtained from lyophilized extracts of pulp, peel, and seed fractions of Salacia crassifolia, and ascorbic acid.

<table>
<thead>
<tr>
<th>Sample</th>
<th>EC&lt;sub&gt;50&lt;/sub&gt; DPPH (mg/mL) + SD</th>
<th>EC&lt;sub&gt;50&lt;/sub&gt; ABTS (mg/mL) + SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE-LPUF</td>
<td>2.79ª ±1.43</td>
<td>2.40ª ±0.04</td>
</tr>
<tr>
<td>HE-LPEF</td>
<td>2.62ª ±0.42</td>
<td>3.88ª ±0.03</td>
</tr>
<tr>
<td>HE-LSF</td>
<td>0.56ª ±1.63</td>
<td>0.86ª ±0.09</td>
</tr>
<tr>
<td>Ascorbic acid standard</td>
<td>0.91ª ±0.90</td>
<td>0.45ª ±0.12</td>
</tr>
</tbody>
</table>

HE-LPUF: hydroalcoholic extracts of lyophilized pulp; HE-LPEF: peel, HE-LSF: seeds. Mean values followed by equal letters in the same column do not significantly differ according to the Tukey test at a 5% significance level. Source: The authors.
Some studies have demonstrated a high correlation between phenolic compounds content and antioxidant activity (Contreras-Calderón et al. 2010; Ramful et al. 2011; Rufino et al. 2010). In this study, a positive correlation was observed between total phenols and antioxidant EC$_{50}$ values in the analyzed fractions, which is consistent with the preliminary phytochemical screening that revealed the presence of secondary metabolites such as phenols, flavonoids, and triterpenes (Benariba et al., 2013; Yusri et al., 2012; Du et al., 2014).

Based on these results, the fruit of *Salacia crassifolia* have significant antioxidant potential, particularly in the seeds fraction. This highlights the need for further detailed studies on the fruit (including peel, pulp, and seeds) to explore their potential use in various sectors, including the food and pharmaceutical fields.

### 3.4 Quantification of Vitamin C and Carotenoids

Ramful et al. (2011) classified fruits based on their ascorbic acid content into three categories: low (<30 mg/100 g), moderate (30 – 50 mg/100 g), and high (>50 mg/100 g). According to this classification and the results obtained in the present study, the fruit of *Salacia crassifolia* has a moderate amount of ascorbic acid, as the obtained value for the pulverized sample of the pulp of bacupari fruit (LPUF), the edible part of the fruit, was 48.55 mg/100 g.

Other fruits from the Cerrado biome, such as the marolo (63.07 mg/100 g) and murici (52.00 mg/100 g) fruits, show similar values to those obtained in this study, which supports the use of lyophilization as a method to preserve fruits (Bezerra 2014; Vieira et al., 2015; Santos et al., 2020). It is worth noting that the determination of vitamin C content is important, as it is the most thermolabile vitamin, and its presence in food indicates that other nutrients are likely being preserved as well.
Table 4 – Vitamin C and β-carotene quantification in 100 g of lyophilized pulp (LPUF) of Salacia crassifolia fruit.

<table>
<thead>
<tr>
<th>Evaluated parameters</th>
<th>Vitamin C (mg/100 g)</th>
<th>β-carotene (mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall average</td>
<td>53.38 ± 0.68</td>
<td>25.72 ± 0.47</td>
</tr>
<tr>
<td>MSD (5%)</td>
<td>2.37</td>
<td>0.14</td>
</tr>
<tr>
<td>CV (%)</td>
<td>9.62</td>
<td>10.18</td>
</tr>
</tbody>
</table>

Results expressed as mean values (n = 5) ± standard deviation. MSD = Minimum Significant Difference; CV = Coefficient of Variation.
Source: The authors.

The carotenoids content in fruits depends on the species, variety, harvest, and degree of ripeness, and the distribution of these compounds also shows considerable variation, usually being more concentrated in the peel than in the pulp of some fruits (Lima, 2002). Regarding the quantity of β-carotene in the present study, the lyophilized pulp fraction showed significant levels of the compound: 25.72 mg/100 g (table 4).

Carotenoids have antioxidant properties and protect cells from oxidative damage caused by free radicals, playing an important role in the prevention of diseases associated with oxidative stress, such as cancer, cataracts, atherosclerosis, and aging processes, in addition to being important precursors of vitamin A (Rufino et al., 2010).

4 CONCLUSIONS

According to the obtained results, bacupari fruits are rich in bioactive substances, including phenolic compounds, ascorbic acid, and carotenoids. Moreover, they showed high efficacy in scavenging free radicals, indicating their potential as a natural antioxidant, specially by the seeds fraction.

The results of this study confirm the importance of further investigating the pulp, peel, and seed fractions of the fruit of Salacia crassifolia and isolating their constituents. The functional benefits of this fruit remain unexplored by the food industry, but they display a great potential for use as a food ingredient or in dietary supplementation.

The fractions of bacupari fruit should be further studied to explore their potential use in various sectors, especially food and pharmacology. Future tests can be conducted to investigate the effects of the antioxidant compounds from
this fruit on consumer health. Additionally, *in vivo* assays and methods with extracts from different fractions of this species are necessary to explore and encourage their potential use in biotechnological areas.
REFERENCES


congeladas de acerola, cajá e caju. Ciência e Tecnologia de Alimentos, Campinas, v. 19, n. 3.


