Açaí (Euterpe oleracea) ‘BRS Pará’: A tropical fruit source of antioxidant dietary fiber and high antioxidant capacity oil

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A B S T R A C T

This article reports a study of the concentrations of dietary fiber (DF) and antioxidant capacity in fruits (pulp and oil) of a new açaí (Euterpe oleracea) cultivar—‘BRS-Pará’, with a view to determine the possibility of using it as a source of antioxidants in functional foods or dietary supplements. Results show that ‘BRS-Pará’ açaí fruits have a high content of DF (71% dry matter) and oil (20.82%) as well as a high antioxidant capacity in both defatted matter and oil. ‘BRS-Pará’ Açaí fruits can be considered as an excellent source of antioxidant dietary fiber. Antioxidant capacity of açaí ‘BRS-Pará’ oil by DPPH assay was higher (EC 50 = 646.3 g/g DPPH) than extra virgin olive oil (EC 50 = 2057.27 g/g DPPH). These features provide açoí ‘BRS-Pará’ fruits with considerable potential for nutritional and health applications.

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1. Introduction

Açaí (Euterpe oleracea), also known as cabbage palm, is a tropical species which bears a dark purple, berry-like fruit, clustered into bunches. Its exportation to other non-tropical countries, to be used mainly in fruit juices, has increased during several years.

Recently, much attention has been paid to its antioxidant capacity and its possible role as a functional food or food ingredient (Colisson, Trevaglia, Piana, Capasso, & Arlorio, 2005; Jensen et al., 2008; Mertens-Talcott et al., 2008; Pozo-Infran, Percival, & Talcott, 2006; Ribeiro et al., 2010; Sch reckinger, Lotton, Lila, & Mejia, 2010). The phytochemical and nutrient composition of açaí have been investigated (Rufino, Alves, Brito, Silveira, & Moura, 2009; Rufino et al., 2010). Anthocyanins, proanthocyanidins, and other flavonoids were found to be the major phytochemicals in freeze-dried açaí (Schauss et al., 2006) and some works have dealt with the antioxidant capacity of açaí pulp (Souza et al., 2009; Rufino, Alves, Brito, Perez-Jiménez, & Saura-Calixto, 2009; Rufino, Fernandes, Alves, & Brito, 2009; Rufino et al., 2010). However, since açaí is an oil-rich fruit, it may be necessary, when determining its antioxidant capacity, to study separately its oil and its defatted fraction to avoid interferences, as it has been suggested for similar fruits (Arranz, Pérez-Jiménez, & Saura-Calixto, 2008). This has not been carried out up to the moment.

Cereals are usually studied as main sources of dietary fiber (DF). Nevertheless, it is well-known that the DF from some fruits, that contains a higher proportion of soluble dietary fiber (SDF) and associated bioactive compounds than cereals, has properties related to gastrointestinal health and prevention of chronic diseases (Spiller, 2001). Antioxidant DF (ADF) is defined as a natural product that combines the beneficial effects of DF and natural antioxidants, such as polyphenol compounds (Saura-Calixto, 1998). On the one hand, ADF can be used as a dietary supplement to improve gastrointestinal health and to prevent cardiovascular diseases (Pérez-Jiménez, Serrano, et al., 2008), and on the other as an ingredient in seafood and meat products to prevent lipid oxidation (Sánchez-Alonso, Jiménez-Escrig, Saura-Calixto, & Borderías, 2006).

Traditionally açaí grows on flooded areas. However, through a genetic breeding program based on phenotypic selection from its germplasm...
Butanol/Embrapa Western Amazonia (Belém, PA, Brazil) developed a cultivar—the ‘BRS-Pará’—suitable for growing on stable land, as a result the production system of this plant has now been modified making it easier and more productive than the traditional system.

The aim of this work was to study the concentrations of DF and antioxidant capacity in açaí, ‘BRS-Pará’ with a view to determining the possibility of using it as a source of antioxidant in functional foods or dietary supplements. Due to its high oil content, antioxidant capacity was studied separately in the defatted pulp and in the oil, to avoid interferences. Finally, since the association of antioxidants with DF may produce specific physiological effects, the polyphenols and the antioxidant capacity associated to DF were also determined.

2. Materials and methods

2.1. Chemicals

Pepsin (2000 FIP-U/g), glucose, inositol and N-methylimidazole were obtained from Merck (Darmstadt, Germany). Amyloglucosidase (14 IU/mg) was from, Roche, Manheim, Germany. Pancreatin, α-amylase (17.5 IU/mg), 2,2′-Azino-bis(3-ethylbenzo-thiazoline-6-sulfonic acid) (ABTS), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), catechin, gallic acid, galacturonic acid, sulfuric acid) (ABTS), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid, 3,6-di hydroxy-spiro-[isobenzofuran-1-[3H]-90[9H]-xanthen]-3-one (TPTZ) was from Sigma-Aldrich Química, S.A. (Madrid, Spain). 2,4,6-Tris(2-pyridyl)-s-triazine (TPTZ) was from Fluka Chemicals (Madrid, Spain). Dinitrosalicilic acid, 3,6-dihydroxy-spiro-[isobenzofuran-1-[3H]-90[9H]-xanthen]-3-one (fluorescein) and iron III-chlorure-6-hydrate were from Panreac, Castellar del Vallès (Barcelona, Spain). All reagents used were of analytical grade.

2.2. Samples

Fruits of açaí ‘BRS-Pará’ were harvested at Embrapa Western Amazonia at Belém-PA, Brazil. After harvesting, the fruits were transported to the Postharvest Physiology and Technology Laboratory, at Embrapa Tropical Agroindustry, Fortaleza-CE, Brazil. Two kilograms of fruit were harvested in the second semester of 2007 at the commercial maturity stage (completely ripe). Samples were taken from 10 different trees and from different regions of them, to achieve a homogeneous sample. They were processed in a domestic blender (Walita, Brazil) to obtain a pulp and the seeds were discarded. Pulp was later divided in three sub-samples to carry out the different analysis and each one of them was freeze-dried (LH 4500, Terroni Fauvel, Brazil) and milled to a particle size of less than 0.5 mm in a centrifugal mill. The fact that these fruits were from the same genotype (clone) guaranteed a similarity in the chemical composition of them.

2.3. Methods

Previously the samples were defatted with petroleum ether at 60 °C on a Soxhlet apparatus, using two extraction cycles of 30 min. Figs. 1 and 2 show a scheme of the treatments performed to the samples to determine DF and antioxidant capacity.

Determination were performed in triplicate and reported on a dry matter. Results are expressed as mean values ± standard deviation.

2.3.1. Dietary fiber determination

The DF was measured based on the procedure described by Saura-Calixto, García-Alonso, Gohi and Bravo (2000). This method combines enzymatic treatments and separation of digestible compounds by dialysis using physiological conditions (temperature and pH), obtaining the fraction of food that is not digested (Fig. 1). Total DF was calculated as the sum of insoluble dietary fiber or IDF (constituted by nonstarch polysaccharides or NSP, Klason lignin, resistant protein, ash, extractable polyphenols, proanthocyanidins, and hydrolyzable tannins) and soluble dietary fiber or SDF (constituted by soluble nonstarch polysaccharides or NSP and extractable polyphenols).

Samples (300 mg) were incubated with pepsin (0.2 mL of a 300 mg/mL solution in 0.08 M HCl–KCl buffer, pH 1.5, 40 °C, 1 h), pancreatin (1 mL of a 5 mg/mL solution in 0.1 M phosphate buffer, pH 7.5, 37 °C, 6 h) and α-amylase (1 mL of a 120 mg/mL solution in 0.1 M Tris–maleate buffer, pH 6.9, 37 °C, 16 h). Samples were centrifuged (15 min, 3000 × g) and supernatants removed. Residues were washed twice with 5 mL of distilled water, and all supernatants were combined. Each supernatant was incubated with 100 μL of amylglucosidase for 45 min at 60 °C before being transferred to dialysis tubes.
(12,000–14,000 molecular weight cutoff, Visking dialysis tubing; Medicell International Ltd., London, U.K.) and dialyzed against water for 48 h at 25 °C to eliminate digestible compounds. The products of all these treatments were therefore a residue after enzymatic treatments, corresponding to IDF, and a supernatant of enzymatic treatments later subjected to dialysis, corresponding to SDF. In SDF, soluble NSP were hydrolyzed with 1 M sulfuric acid at 100 °C for 90 min and measured as the sum of neutral sugars, determined by GC, and uronic acids, determined spectrophotometrically (Scott, 1979) using galacturonic acid as standard. Regarding GC, neutral sugars were derivatized to alditol acetates (Englyst, Wiggins & Cummings, 1984) by a first treatment with NH4OH, octan-2-ol and NaBH4 during 30 min at 40 °C, followed by a second treatment with methylimidazole and acetic anhydride during 15 min and a final addition of KOH. A Shimadzu GC-14A chromatograph (Shimadzu Co., Kyoto, Japan) fitted with a flame ionization detector and a SP-2330 capillary column (30 m × 0.32 mm i.d., catalog no. 2-4073, Supelco, Bellefonte, PA) were used. Analytical conditions were as follows: column temperature, 240 °C (isothermal); injector temperature, 270 °C; detector temperature, 270 °C; carrier gas, nitrogen. Inositol was used as internal standard. Finally, extractable polyphenols were also determined in SDF as described in the later part—see Section 2.3.2.3.

Regarding IDF, the residue was weighed to determine gravimetrically IDF content in the sample, and it was divided in three fractions to analyze its different constituents. A first fraction was used to determine insoluble NSP and Klasson lignin (Southgate, 1969): after treatment with sulphuric acid (12 M, 20 °C for 3 h; dilution to 1 M and incubation for 2 h, 100 °C), insoluble NSP were determined as the sum of neutral sugars and uronic acids as described above for soluble NSP, and Klasson lignin was determined gravimetrically. In the supernatant of this treatment hydrolyzable tannins content was also determined—as discussed after Section 2.3.2.3. A second fraction of the residue was used to determine in it resistant protein and ash—see 2.3.3. The third fraction was subjected to a first treatment to determine extractable polyphenols—see Section 2.3.2.1, followed by a second treatment to determine condensed tannins content—see Section 2.3.2.3.

2.3.2. Antioxidant capacity and phenolic compounds determination

2.3.2.1. Extraction of antioxidants. 0.5 g of either IDF of açai (Fig. 1) or defatted açaí pulp (Fig. 2) was placed in a capped centrifuge tube; 20 mL of acidic methanol/water (50:50, v/v; pH 2) was added and the tube was thoroughly shaken at room temperature for 1 h. The tube was centrifuged at 2500 × g for 10 min and the supernatant recovered. Twenty milliliters of acetone/water (70:30, v/v) were added to the residue, and shaking and centrifugation repeated. Methanolic and acetonitrile extracts were combined and used to determine the antioxidant capacity associated with extractable antioxidants (Figs. 1 and 2). The residues of these extractions were subjected either to hydrolysis with H2SO4 to release hydrolyzable tannins (Figs. 1 and 2) or to treatment with n-butanol/HCl/FeCl3 to release anthocyanins from proanthocyanidins or condensed tannins (Figs. 1 and 2)—see conditions in Section 2.3.2.3. Antioxidant capacity was determined in both hydrolyzable tannins and condensed tannins.

Total antioxidant capacity was determined directly in vegetable oils, after diluting aliquots in ethyl acetate. To determine separately antioxidant capacity associated to polar and apolar compounds, 5 mL of oil were mixed with 5 mL of methanol. The mixture was vigorously stirred for 20 min and centrifuged at 2500 × g for 10 min and the supernatant was recovered. Another 5 mL were added and the same process was repeated. Antioxidant capacity was measured directly in the methanolic extract (that extracts polar compounds) and in the remaining oil (apolar fraction), after dilution with ethyl acetate (Espín, Soler-Rivas, & Wickers, 2000).

2.3.2.2. Antioxidant capacity methods

2.3.2.2.1. DPPH (free-radical scavenging) assay. It was used the method described by Brand-Williams, Cuvelier, and Berset (1995), later modified by Sánchez-Moreno, Larrauri, and Saura-Calixto (1998), in order to determine kinetic parameters. After adjusting the blank with methanol, 0.1 mL of the sample was mixed with 3.9 mL of a DPPH* methanolic solution (60 μM). The absorbance at 515 nm was measured until the reaction reached the plateau. A calibration curve at that wavelength was made to calculate the remaining DPPH*.

The parameter EC50, which reflects 50% depletion of DPPH* was expressed in terms of grams of açaí equivalent per gram of DPPH* in the reaction medium. The time taken to reach the steady state at EC50 (tEC50) and the antiradical efficiency (AE = 1/EC50 tEC50) were also determined.

2.3.2.2.2. ABTS assay at a fixed end-point. ABTS radical cation (ABTS+) was produced by reacting 7 mM ABTS stock solution with 2.45 mM potassium persulfate and allowing the mixture to stand in the dark at room temperature for 12–16 h before use. The ABTS+ solution was

![Flow chart showing determination of antioxidant capacity of the defatted sample and oil of açaí 'BRS-Pará'. AC: antioxidant capacity; EPP: extractable polyphenols; HT: hydrolysable tannins; CT: condensed tannins.](https://example.com/flow_chart.png)
of the extraction of açaí defatted pulp (Fig. 2). Concentration was achieved by hydrolysis with methanol and sulfuric acid for 20 h at 85 °C. They previously described (Hartzfeld, Forkner, Hunter, & Hagerman, 2002) the use of the cyanidin standard (Nestlé, Ltd., Vers-Chez-les Blancs, Switzerland). Fatty acid composition was determined using a Soxhlet System HT extractor with petroleum ether, and fatty acid composition was expressed as Triolein equivalents. Ash content was gravimetrically determined by incinerating samples in an electric muffle furnace at 550 °C for 16 h.

3. Results and discussion

3.1. Proximate composition

Proximate composition values are presented in Table 1. The most significant aspect of açaí 'BRS-Pará' is its high DF content (70% dry matter), the bulk of it being insoluble DF. Açaí DF content, as in other tropical fruits, is much higher than in common fruits like apples, oranges or bananas in which it ranges from 17 to 36% (Saura-Calixto et al., 2000). Moreover, açaí contains comparable levels of DF to other products described as rich in DF, such as pineapple or grape pomace (Larrauri, Rupérez, & Saura-Calixto, 1997; Pérez-Jiménez, Arranz, et al., 2008), and higher than other tropical fruits like guava or papaya (Jiménez-Escrig, Rincón, Pulido, & Saura-Calixto, 2001; Mahattanatawee et al., 2006).

Table 2 shows the composition of açaí 'BRS-Pará' DF, including neutral sugars (determined individually), uronic acids, Klasson lignin, resistant protein, and ash. Glucose and galactose were the main neutral sugars in DF, while arabinose and xyllose were the major monosaccharides in IDF indicating the presence of arabinoxylans.

These portions of non-digestible carbohydrates reach the colon where they are potentially fermentable by colonic microbiota. Some of the metabolites generated during colonic fermentation of carbohydrates, such as short chain fatty acids (especially butyrate), were described as beneficial for intestinal health (Wong, Souza, Kendall, Emam, & Jenkins, 2006).

Açaí also has high oil content (Table 1). Analysis of fatty acids (Table 3) showed that this fruit is a source of fatty acids of potential nutritional interest; containing almost as much oleic acid as olive oil, which contains 70% oleic acid on average, and more than other oil rich sources such as soy, corn and sunflower. This is in line with results reported by other authors on açaí from the Amazon estuary (Schauss et al., 2006).

Açaí also possesses a high phenolic content that presumably contributes to its antioxidant capacity, as it is discussed in the later part. Finally, the protein, soluble sugars and mineral content agreed with other reported data (Menezes, Torres, & Srur, 2008).

<table>
<thead>
<tr>
<th>Component</th>
<th>g/100 g dry matter</th>
</tr>
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<tbody>
<tr>
<td>Protein</td>
<td>6.27 ± 0.31</td>
</tr>
<tr>
<td>Ashes</td>
<td>1.99 ± 0.17</td>
</tr>
<tr>
<td>Soluble sugars</td>
<td>7.93 ± 2.11</td>
</tr>
<tr>
<td>Total lipids</td>
<td>20.82 ± 1.50</td>
</tr>
<tr>
<td>Soluble dietary fiber</td>
<td>2.75 ± 0.16b</td>
</tr>
<tr>
<td>Insoluble dietary fiber</td>
<td>68.49 ± 1.21c</td>
</tr>
<tr>
<td>Total dietary fiber</td>
<td>71.22 ± 1.22</td>
</tr>
<tr>
<td>Polyphenols</td>
<td>1.50 ± 0.05</td>
</tr>
</tbody>
</table>

The antioxidant activity of any food sample comes from the combined synergic action of a mixture of compounds, including phenolics, carotenoids, vitamins C and E, etc. Except for certain fruits such as acerola (Alves, Chitarra, & Chitarra, 1995), in which vitamin C is one of the main components, in fruits like açaí which contain relatively little of this vitamin, polyphenols are the main contributors to antioxidant capacity.
Polyphenol content determined in the pulp aqueous–organic extracts can be seen in Table 4. The values are similar to those reported by other authors (Schauss et al., 2006). The main phenolic compounds reported in açai pulp have not been previously determined. The antioxidant capacity associated with phenolic compounds was determined by FRAP, ABTS, DPPH and ORAC (Table 4).

### Antioxidant capacity of defatted pulp

The antioxidant capacity associated with these non-extractable phenolic compounds in açai had not been previously determined. Regarding the oil, it was found only one reference in which the antioxidant capacity of açai oil was measured by ORAC assay (Arranz et al., 2008). The aqueous–organic extracts obtained from defatted açai, showed high antioxidant capacity, mainly due to extractable polyphenols, as well as the residues of açai defatted pulp, where hydrolyzable and condensed tannins are the main contributors to antioxidant capacity. In the case of condensed tannins, only ABTS was a suitable procedure to determine their antioxidant capacity, since the other methods are not suitable to be performed in the butanol media needed the release of anthocyanins from proanthocyanidins.

Regarding kinetic measurements, extractable polyphenols were better radical scavengers than hydrolyzable tannins when ABTS assay was used (lower EC50), but worse radical scavengers towards DPPH assay (EC50 of 4.92 g/g for hydrolyzable tannins vs 10.20 for extractable polyphenols), indicating different mechanisms of reactions in these two assays (Huang, Ou, & Prior, 2005). Fig. 3 shows the kinetic behaviour of açai extracts vs DPPH.

### Antioxidant capacity of the oil

Açai ‘BRS-Pará’ oil antioxidant capacity results are shown in Table 5. Only total oil and apolar fraction values can be directly compared, since both were measured using ethyl acetate as solvent, while the polar fraction measurements were performed in methanol. The EC50 of the apolar fraction (536.5 g/g) was higher than that of total oil (646.3) indicating a higher antioxidant capacity; therefore, it seems that most antioxidants in açai oil are of an apolar nature, and the extraction of this fraction works as a mechanism to concentrate antioxidants.

### Antioxidant capacity associated with phenolic compounds

The antioxidant capacity associated with these non-extractable phenolic compounds was determined by FRAP, ABTS, DPPH and ORAC (Table 4)—the different pros and cons linked to each one of the available antioxidant capacity assays make necessary the use of at least two of these techniques (Pérez-Jiménez, Arranz, et al., 2008). The aqueous–organic extracts obtained from defatted açai, showed high antioxidant capacity, mainly due to extractable polyphenols, as well as the residues of açai defatted pulp, where hydrolyzable and condensed tannins are the main contributors to antioxidant capacity. In the case of condensed tannins, only ABTS was a suitable procedure to determine their antioxidant capacity, since the other methods are not suitable to be performed in the butanol media needed the release of anthocyanins from proanthocyanidins.

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The antioxidant capacity associated with these non-extractable phenolic compounds was determined by FRAP, ABTS, DPPH and ORAC (Table 4)—the different pros and cons linked to each one of the available antioxidant capacity analysis.
3.2.3. Polyphenols and antioxidant capacity associated with dietary fiber

DF, measured as indigestible fraction (Saura-Calixto et al., 2000), is composed of two fractions: a soluble fraction (supernatant from enzymatic digestion) and an insoluble fraction (residue from enzymatic digestion). Antioxidant capacity and phenolic compounds associated with DF were determined in both fractions (Table 6).

The SDF contained associated (in an aqueous buffer) extractable polyphenols, while the IDF contained associated (in an aqueous organic solvent) extractable polyphenols, hydrolyzable tannins, and condensed tannins. These constitute an important fraction of the polyphenols present in açai pulp (Table 1), that is, most of them are associated with DF.

Although the values in Table 6 cannot be directly compared with those in Table 4, since the extraction methods were different (aqueous-organic vs enzymatic extraction), it can be seen that açai DF exhibits considerable associated antioxidant capacity. For example, the ABTS value of condensed tannins in the IDF was 20.51 ± 0.13 μmol Trolox/g dm, while hydrolyzable tannins in IDF gave an ORAC value of 155.61 ± 8.40 μmol Trolox/g dm. For comparative purposes, the antioxidant capacity associated with DF in a mixture of the fruits consumed in the Spanish diet has been calculated to be 2 μmol Trolox/g by ABTS assay (Serrano, Goñi, & Saura-Calixto, 2007). Moreover, the antioxidant capacity of açai DF is of nutritional significance, since these antioxidant compounds are thought to reach the colon intact in which they can produce a variety of beneficial effects.

In summary, antioxidant capacity and dietary fiber were determined in the fruit pulp of açai ‘BRS-Pará’. Pulp contains polyphenols with high antioxidant capacity, most of them being associated with DF. Its oil has higher antioxidant capacity than olive oil and a comparable fatty acid profile. The high DF content of açai pulp and its associated polyphenols make this fruit a suitable source of antioxidant DF which may be used as a food ingredient to prevent lipid oxidation in seafood and meat products, as well as in dietary supplements. These data suggest that açai could have considerable potential for nutritional and health purposes.

Authors’ responsibilities

The authors’ responsibilities were as follows—F.S-C. and R.E.A., planned and monitored the work; M.S.M.R., J.P-J. and S.A., conducted the experimental work; M.S.P.O., provided the samples to carry out the work and contributed to their preparation; M.S.M.R., J.P-J. and R.E. A., wrote the first draft of the manuscript; and all authors contributed to writing the manuscript and approved the final version. None of the authors had a personal or financial conflict of interest.

Acknowledgements

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Table 5

<table>
<thead>
<tr>
<th>Antioxidant capacity of açai ‘BRS-Pará’ fruit pulp oil and extra virgin olive oil (DPPH method)a.</th>
<th>Total antioxidant capacityb</th>
<th>Polar fractionc</th>
<th>Apolar fractiond</th>
</tr>
</thead>
<tbody>
<tr>
<td>Açai BRS Pará oil</td>
<td>646.30 ± 38.40</td>
<td>35.69 ± 1.80</td>
<td>0.4 × 10⁻⁴</td>
</tr>
<tr>
<td>EC₅₀ (g oil/g DPPH)</td>
<td>1249.97 ± 32.29</td>
<td>17.87 ± 0.33</td>
<td>0.4 × 10⁻⁴</td>
</tr>
<tr>
<td>AEe</td>
<td>536.53 ± 11.78</td>
<td>37.25 ± 3.75</td>
<td>1.0 × 10⁻⁴</td>
</tr>
<tr>
<td>Extra virgin olive oil</td>
<td>2057.27 ± 75.56</td>
<td>4.86 ± 0.05</td>
<td>1 × 10⁻⁴</td>
</tr>
<tr>
<td>EC₅₀ (g oil/g DPPH)</td>
<td>1210.96 ± 44.09</td>
<td>43.92 ± 0.86</td>
<td>7.0 × 10⁻⁴</td>
</tr>
<tr>
<td>AEe</td>
<td>155.61 ± 8.40</td>
<td>35.31 ± 1.63</td>
<td>0</td>
</tr>
</tbody>
</table>

a Mean value ± standard deviation, n = 3.
b Determined in oil solved in ethyl acetate.
c Antioxidant capacity determined in methanolic extract.
d Antioxidant capacity determined in the remaining oil after methanolic extraction.
e Antiradical Efficiency, AE = 1/(EC₅₀ fEC₅₀).

Table 6

| Polyphenols and antioxidant capacity associated to dietary fiber of Açai ‘BRS-Pará’ fruit pulp.a |
|---|---|---|---|
| Analysis | Soluble dietary fiber | Insoluble dietary fiber |
| | Extractable polyphenols | Extractable polyphenols | Hydrolyzable tannins | Condensed tannins |
| Polyphenols (mg/g dm) | 11.2 ± 1.3 | 4.2 ± 0.2 | 5.7 ± 0.5 | 19.4 ± 1.0 |
| FRAP (μmol Trolox/g dm) | 46.82 ± 4.65 | 11.91 ± 0.92 | 11.64 ± 0.84 | n.d. |
| ORAC (μmol Trolox/g dm) | 603.03 ± 9.18 | 53.72 ± 0.65 | 155.61 ± 8.40 | n.d. |
| ABTS at a fixed end-point (μmol Trolox/g dm) | 78.16 ± 0.40 | 3.96 ± 0.22 | n.d. | 20.51 ± 0.13 |
| ABTS expressed kinetically | 8.95 ± 0.04 | 67.58 ± 2.11 | n.d. | 14.41 ± 0.06 |
| EC₅₀ (g dm/g ABTS) | 10.00 ± 0.80 | 20.47 ± 2.04 | n.d. | 26.87 ± 0.40 |
| AEb | 0.011 | 0.001 | n.d. | 0.002 |
| DPPH | 39.43 ± 0.10 | 119.20 ± 5.42 | 47.31 ± 1.16 | n.d. |

a Mean value ± standard deviation, n = 3. d. m. dry matter. n.d. non determined.
b Antiradical Efficiency, AE = 1/(EC₅₀ fEC₅₀).
References


