Ciência e Tecnologia de Alimentos
ISSN: 0101-2061
revista@sbcta.org.br
Sociedade Brasileira de Ciência e Tecnologia de Alimentos
Brasil

Pereira da SILVA, Cintia; Bezerra SOUSA, Mariana Séfora; SIGUEMOTO, Érica Sayuri; Manólio SOARES, Rosana Aparecida; Gomes ARÊAS, José Alfredo

Chemical composition and antioxidant activity of jatobá- do-cerrado (Hymenaea stigonocarpa Mart.) flour

Ciência e Tecnologia de Alimentos, vol. 34, núm. 3, julio-septiembre, 2014, pp. 597-603
Sociedade Brasileira de Ciência e Tecnologia de Alimentos
Campinas, Brasil

DOI: http://dx.doi.org/10.1590/1678-457X.6405

Chemical composition and antioxidant activity of jatobá-do-cerrado (*Hymenaea stigonocarpa* Mart.) flour

Cintia Pereira da SILVA[1], Mariana Séfora Bezerra SOUSA[1], Érica Sayuri SIGUEMOTO[1], Rosana Aparecida Manólio SOARES[1], José Alfredo Gomes ARÊAS[1]*

Abstract

The Brazilian Savannah, known as "Cerrado," has an extensive biodiversity, but it is under explored. Among the native vegetables is the jatobá-do-cerrado (*Hymenaea stigonocarpa* Mart.), a legume with great potential for exploration for its content of dietary fiber. Legumes are an important source of nutrient compounds, such as phenolic compounds and vitamins that have antioxidant properties. This study aimed at determining the chemical composition and antioxidant activity of the jatobá flour. The jatobá flour showed high fiber content (insoluble and soluble fiber 47.8 and 12.8 g.100 g^{-1}, respectively), significant amounts of carotenoids such as beta-carotene and lutein, and some minerals such as calcium: 145 mg.100 g^{-1}, magnesium: 125 mg.100 g^{-1}, and potassium: 1352 mg.100 g^{-1}. The jatobá flour extracted with different solvents (water, methanol, and acetone) exhibited antioxidant activity by the DPPH, FRAP, and ORAC methods. The solvent used in the extraction affected the total phenolic content and antioxidant activity. Acetone extraction produced the best results. Therefore, the jatobá flour is an ingredient that can be used to develop new products with properties that promote health.

Keywords: jatobá-do-cerrado; fiber; antioxidant activity; functional food.

1 Introduction

The Brazilian Savanna, known as "Cerrado", is the second largest biome in terms of area, surpassed only by the Amazon forest. However, the ecosystems that make up this biome have been rapidly destroyed (Klink & Machado, 2005). The expansion of agriculture in this region has caused the extinction of several plant species (Caramori et al., 2004). Although many species have been identified, the nutritional potential of several species is still unknown (Marin et al., 2009).

The possible uses of the Brazilian Savanna plants, such as jatobá-do-cerrado, include: planting trees in environmental protection areas, the enrichment of areas poor in flora, the restoration of deforested or degraded areas, the creation of domestic and commercial orchards, and their planting in reforestation areas, parks and gardens, and in hilly areas (Avidos & Ferreira, 2000).

Jatobá-do-cerrado also known as *jataí* or *jutaí* (*Hymenaea stignocarpa* Mart.) is a legume belonging to the *Leguminosae* family and *Caesalpinoideae* subfamily (Lorenzi, 2008). It differentiates itself from other legumes, such as soybeans and common beans, because of its low amount of lipids and proteins. Other compounds that may have antioxidant effects, such as soluble and insoluble fiber, some minerals like calcium and magnesium, and carotenoids, are present in its composition (Silva et al., 2001; Marin et al., 2009; Cardoso et al., 2013).

Legumes are an important source of nutrients, and they also contain flavonoids, phenolic acids, lignans, and tannins, which are antioxidant compounds (Amarowicz & Pegg, 2008). Epidemiological studies have reported that the consumption of fibers and bioactive compounds with antioxidant properties, such as polyphenol, carotenoid, and vitamin C, has a significant impact on human health helping to reduce the incidence of chronic diseases (Liu, 2003; Scalbert et al., 2005). The incorporation of legumes, such as jatobá, into the human diet can offer protective effects against chronic diseases.

Therefore, the objective of this study was to determine the chemical composition and the antioxidant activity of the jatobá-do-cerrado flour.

2 Materials and methods

2.1 Materials

The jatobá-do-cerrado flour was obtained from the "Cerrado Center of Production, Research and Training – CEPPEC", Nioaque - Mato Grosso do Sul - Brazil. This flour is produced by local artisans belonging to a sustainable project in that region. The jatobá flour was purchased and delivered in 200 g-aluminun foil bags; it was stored under refrigeration until analysis.

2.2 Proximate composition

Triplicate analyses of moisture, protein, lipid, ash, and soluble and insoluble fibers were conducted according to the OAC official methods (Association of Official Analytical Chemists, 2010) 950.46, 923.03, 960.52, 920.39, and 985.29, respectively (protein = N × 6.25). Carbohydrates were estimated by difference. Energy content was estimated by Atwater factors (carbohydrate: 17; lipids: 37, and protein: 17 KJ). Total starch was determined according to the OAC official method 996.11

Received 16 June, 2014
Accepted 21 Aug., 2014 (006405)
[1]*Department of Nutrition, Faculty of Public Health, University of São Paulo – USP, São Paulo, SP, Brazil, e-mail: jagareas@usp.br*
**Corresponding author*

(Association of Official Analytical Chemists, 2010) with modifications by (Walter et al., 2008). This method is based on the enzymatic hydrolysis followed by spectrophotometric determination of glucose with the commercially available kit glucose PAP Liquiform (Centerlab, Brazil).

2.3 Determination of amino acid composition

Sample preparation for total amino acid analysis involved hydrolysis, derivatization, and separation by high-performance liquid chromatography, according to the methodology proposed by White et al. (1986). Tryptophan was determined spectrophotometrically at 590 nm after enzymatic hydrolysis with pronase at 40 °C for 24 hours, according to the method described by Spies (1967).

2.4 Fatty acid composition

It was determined as methyl esters of fatty acids by gas chromatography. Extraction of lipids from jatobá-do-cerrado flour was performed according to Bligh & Dyer (1959). An aliquot containing 150 mg of lipid was subjected to saponification with 0.5 N NaOH in methanol, esterified with BF_3 in methanol (Merck, Brazil) by heating, and extracted using HPLC grade n-hexane (High-Performance Liquid Chromatography) (Morrison & Smith, 1964).

The identification of the methyl esters was performed using the Chrompack CP9002 (Middelburg, The Netherlands) and a fatty acid methyl ester mixture (SIGMA - s 47885) for fatty acid identification (fused silica capillary column Ciola-WAX, 20 m long, 0.32 mm internal diameter, carrier gas: hydrogen at 2.0 mL / minute; injector splitter 270 °C, with split ratio 1: 35; FID detector at 300 °C, initial temperature of 60 °C, a rise of 3.5 °C / min to 240 °C, injection volume 1 µL).

2.5 Mineral content

The mineral content was determined according to the OAC official method 985.35 and 984.27 (Association of Official Analytical Chemists, 2010) using inductively coupled plasma optical emission spectrometry (ICP OES) after burning the samples in a muffle furnace at 450 °C.

2.6 Carotenoid (β-carotene, β-cryptoxanthin, and Lutein) and Vitamin C: extraction and quantification

Triplicate analysis of carotenoids and vitamin C were conducted under protection from both sunlight and artificial light with the use of amber glass bottles, aluminum foil and blackout curtains. The samples were also protected from oxygen using lids and nitrogen atmosphere in the glass bottles. All procedures were performed according to De Sa & Rodriguez-Amaya (2004) and Rodriguez-Amaya (2001) with some modifications using a Shimadzu LC-20 AT HPLC system, injection volume 20 µL: auto sampler (Model SIL-20AC); controller (CBM-20A); column oven (CTO-20A); and detector diode array (Model SPD-M20A); and Shim-Pack VP-ODS column (25 cm x 0.5 cm, i.d. x 5 µm). The mobile phase (flow rate of 0.8 mL min^{-1}) was acetonitrile:methanol:ethyl acetate with 0.05 % of triethylamine to improve carotenoid recovery (Hart & Scott, 1995) under gradient conditions ranging from 60:20:20 to 60:0:40 for 43 minutes. Vitamin A was estimated according to the conversion factors reported by the Institute of Medicine (Institute of Medicine, 2000). Retinol Activity Equivalent (RAE) corresponds to one mg of retinol or 12 mg of β-carotene in a mixture of 24 mg of food.

Ascorbic acid (AA) and dehydroascorbic acid (DHA) were determined according to Cardoso et al. (2011a, b), with some modifications. The dehydroascorbic acid (DHA) was calculated by the difference between the total content of AA (after conversion of DHA to AA) and the AA original content (before conversion to DHA). DHA was converted into AA according to the method of Cardoso et al. (2011b). The analyses were conducted by High-Performance Liquid Chromatography, (Shimadzu LC-20 AT HPLC system - as described above), using a C18column (250 × 4.0 mm, 5 µm, Shimadzu), isocratic mobile phase monobasic sodium phosphate 1 mM ($Na_2H_2PO_4$), 1 mM EDTA, pH 3.0, flow 1 mL / min, and injection volume 20 µL. The identification of ascorbic acid was performed comparing retention times and UV absorption spectrum with a reference standard. The results were expressed in mg of ascorbic acid per 100 grams of sample.

2.7 Determination of total phenolic compounds and antioxidant activity

Extraction procedure

Phenolic contents and antioxidant capacity of jatobá-do-cerrado flour were determined in the extracts using three different solvent systems: water, 60% acetone in water (v/v), and 60% methanol in water (v/v). During extraction, 3 g of jatobá flour were homogenized with 25 mL of the solvent using a Turrax for one minute. The mixture was stirred using a magnetic stirrer for one hour at room temperature and centrifuged at 15,000 × g for 15 minutes at 4 °C. The supernatant was collected, and the volume completed to 25 mL [Adapted from Sousa et al. (2011)].

Determination of total phenolic content (TPC)

Total phenolic content of the extract was determined in triplicate according to the Folin–Ciocalteau method described by Singleton & Rossi-Junior (1965), with some modifications. An aliquot (120 µL) of the extract was mixed with 50 µL of Folin–Ciocalteau reagent. The mixture was allowed to stand for three minutes; 30 µL of saturated sodium carbonate solution (200 g/L) was added to the mixture, and absorbance was measured at 765 nm against a blank after 1 h at 37 °C. Quantification was performed on the basis of a standard curve of gallic acid, and the results are expressed as mg of gallic acid equivalent (GAE)/ 100 g flour.

Determination of DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging activity

The method of Brand-Williams et al. (1995), with slight modifications according to Fukumoto & Mazza, (2000), was adapted to measure the DPPH free radical scavenging activity.

The sample extract (20 µL) was mixed with 200 µL of 150 µmol/L DPPH solution and stirred thoroughly. Absorbance was measured at 515 nm against a blank after 30 minutes. Triplicate results were expressed as percentage of inhibition of the DPPH· free radicals using the Equation 1:

$$AA\ \% = 100 - [((SA - BA) * 100)/ CA] \quad (1)$$

where: SA=sample absorbance (t = 30 min);

BA = Blank absorbance;

CA = Control absorbance.

The amount of the sample sufficient to elicit 50 % reduction of the initial DPPH•, IC_{50}, was calculated from the nonlinear regression of plots of sample concentration (mg/mL) against the mean percentage of antioxidant activity.

Determination of Ferric Reducing Antioxidant Power (FRAP)

FRAP assay, according to Benzie & Strain (1996) with slight modifications of Rufino et al. (2006), was conducted to measure the ferric reducing ability of sample extract. Reagents included 0.3 M acetate buffer, pH 3.6; 10 mM TPTZ in 40 mM HCl, and 20 mM $FeCl_3$_$6H_2O$. Absorbance of the reaction mixture at 595 nm was obtained against a blank. Ferrous sulphate (0–2.5 mM) was used to build a calibration curve for quantification of the percentage of iron reduction, and triplicate results are expressed as µg Fe^{2+}/g flour.

Oxigen Radical Absorbance Capacity (ORAC)

Oxygen Radical Absorbance Capacity (ORAC) was determined with fluorescein as a fluorescent molecule using the SpectraMax M5 Microplate Reader, (Molecular Devices Inc.) (Ou et al., 2002; Prior et al., 2003); incubation for 15 minutes at 37 °C with fluorescein (93.54 nmol/L) was performed before addition of 221 mmol/L AAPH [2,2'-azinobis (2-amidinopropane) dihydrochloride]. Fluorescence was measured at 37 °C, with excitation at 493 nm and emission at 515 nm every minute for 60 minutes, and the results were expressed as µmol Trolox equivalent per g of jatobá flour (µmol ET/g jatobá flour).

Rancimat®

A Rancimat® device (Model 743 - Metrhom®, Herissau - SW) with oxygen flow at 20 L/h and temperature of 110 °C was used to determine the antioxidant activity of the extracts of jatobá flour. The lipid substrate used was pork lard without antioxidants (Central Cooperative Aurora Foods, Brazil), and BHT (butyl hidroxy toluene) was chosen as a standard. The antioxidant activity index was calculated as:

$$IAA = \frac{ITsample}{ITcontrol}$$

where:

ITsample = induction time (h) of lard + extract containing the sample,

ITcontrol = induction time (h) of lard without antioxidant.

Statistical analysis

Statistical analyses were performed using SPSS 17.0 package for Windows (SPSS Inc., Chicago, USA). Descriptive statistics [mean and standard deviation (SD)] is shown in the tables. The mean differences between the groups were compared using the Tukey test. Significance was $p < 0.05$.

3 Results and discussion

3.1 Proximate composition

The proximate composition, energy value, mineral composition, and carotenoids content of jatobá-do-cerrado flour are shown in Table 1. Nutrient content results were expressed per 100 g dry weight.

Although it is a legume, jatobá is not a good source of lipids and proteins. The lipid contents obtained were similar to those reported by Rocha et al. (2013), and lower than those obtained by Silva et al. (2001). Batista et al. (2011) and Cardoso et al. (2013) also found higher lipid contents than those obtained in the present study, 3.03 % ± 0.05, 2.41 % ± 0.48 and 4.16 % ± 1.0, respectively. The protein content obtained was similar to that found by Silva et al. (2001) and Batista et al. (2011), who found, respectively, 7.60 % ± 0.22 and 8.07 % ± 0.10. Therefore, jatobá flour can be considered poor in proteins when compared with other legumes such as cowpea, which has 24.5 g/100 g (Gonçalves Frota et al., 2008), and soy 41.85 g/100 g (Pires et al., 2006). The ash contents found were similar to those reported by Cardoso et al. (2013), who obtained 3.72 % ± 0.10.

Fiber contents were high and similar to those obtained by Silva et al. (2001), who found 42.86 % ± 0.27 for insoluble fiber and 11.01 % ± 0.50 for soluble fiber, and they slightly different from the values reported by Cardoso et al. (2013), who obtained 44.3 % ± 2.3 for total dietary fiber. The recommended daily intake for total fiber is 25 g for women and 38 g for men. Therefore, jatobá flour can be used as a fiber source to improve the nutritional quality of the population diet.

Table 1. Proximate composition and carbohydrate content of jatobá-do-cerrado (*Hymenaea stignocarpa* Mart.) flour.

Components	Jatobá-do-cerrado*
Moisture (%)	13.0 ± 0.05
Ash	3.5 ± 0.06
Lipids	1.5 ± 0.10
Proteins[b]	8.0 ± 0.21
Insoluble Fiber	47.8 ± 1.71
Soluble Fiber	12.8 ± 1.36
Available carbohydrate[c]	26.4
Starch	11.0 ± 0.70
Energy (kJ/100 g)[a]	640

All values are means ± standard deviation of three analyses of the same sample; [a]Estimated by multiplying the percentage of total protein, total fat, and digestible carbohydrates by the respective modified Atwater factors 17, 37, and 17; [b]N x 6.25; [c]The available carbohydrate content was determined by calculating the percentile difference from all other constituents according to the formula: [100 g dry weight - (g crude protein + g crude lipid + g ash + g dietary fiber)]/100 g.

3.2 Amino acid composition

The amino acid composition of jatobá-do-cerrado flour, the minimum requirements established for children 2-5 years of age (Food and Agriculture Organization, 1991), and the amino acid score, are presented in Table 2. The primary limiting amino acids of jatobá-do-cerrado flour are: leucine, threonine, tryptophan, the sulfur amino acids methionine and cysteine, and the aromatic amino acids (phenylalanine + tyrosine). Isoleucine and lysine are also present as secondary limiting amino acids. The existence of limiting sulfur amino acids has also been reported in other legumes such as cowpea (Gonçalves Frota et al., 2008) and soy beans and pearl (Pires et al., 2006). These data suggest that the protein from jatobá-do-cerrado has low biological value due to the limitation of at least four essential amino acids.

3.3 Fatty acid profile

The main fatty acid found in the jatobá-do-cerrado flour was oleic acid (C18:1), and the second was palmitic acid (C16:0); other saturated fatty acids present in lower concentrations were arachidic (C20:0) and eneicosanoic (C21:0) acids. The polyunsaturated fatty acids present were linoleic acid (C18: 2), γ-linolenic acid (C18:3), and omega 6 (C20:2) eicosadienoic acid. Dias et al. (2013) analyzed the fatty acid profile of another jatobá species (*Hymenaea courbaril* L.) and found a profile similar to that of the present study. The mono and polyunsaturated fatty acids are important for the reduction of the low-density lipoprotein fraction (LDL) and the very low density lipoprotein fraction (VLDL). However, the contribution of jatobá flour to the diet would be small due to the low amount of lipids in the composition of this legume.

3.4 Mineral content

Significant quantities of minerals such as calcium, magnesium, and potassium (Table 3) were found. These results are similar to those reported by Marin et al. (2009) and Batista et al. (2011), for zinc (1.0, 1.7), iron (1.1, 0.7), and phosphorus (not detected; 104.7), and are different in terms of the levels of calcium (73.9, 249), copper (0.3, not detected), magnesium (48.5, 135), and potassium (nd, 4.275), respectively.

3.5 Carotenoid (β-carotene, β-cryptoxanthin, and Lutein) and Vitamin C

Considerable quantities of β-carotene were found in jatobá flour (Table 4) , higher than those obtained by Cardoso et al. (2013), which were 0.4 ± 0.1 mg.100g^{-1}. Vitamin A deficiency is a public health problem in several regions of Brazil (Geraldo et al., 2003). Therefore, consumption of jatobá flour may contribute to prevent such deficiency.

The presence of β-cryptoxanthin was not detected in the samples analyzed in this study. On the other hand, significant amounts of lutein were found. Consumption of lutein and zeaxanthin can protect the retina from age-related degeneration (Horst & Moreno, 2009) and contribute to a healthier diet.

Information on the content of vitamin C in native Cerrado species is scarce in the literature. Cardoso et al. (2013) and Dias et al. (2013) determined the ascorbic acid content in jatobá and found, respectively, 8.9 ± 1.9 mg.100g^{-1}, 121,45 ± 0.65 mg.100g^{-1} The vitamin content in foods can vary because of the degree of ripeness and processing (Silva et al., 2006; Fernandes et al., 2007. In the present study, the presence of ascorbic acid was not detected in the jatobá flour.

3.6 Determination of total phenolic compounds and antioxidant activity

The total phenolic content (TPC) of leguminous seeds or extracts is one of the main parameters for determination of the potential antioxidant capacity of seeds. The solvents used in the extraction of several phenolic compounds of legumes include: water, methanol, ethanol, methanol/water, ethanol/water, and acetone/water. Therefore, TPC can vary depending on the source of the leguminous seed and on how it was processed or extracted (Amarowicz & Pegg, 2008). In the present study, the solvents used in the extractions had significant effects on the levels of phenolic compounds and on the antioxidant capacity

Table 2. Amino acid profile of jatobá-do-cerrado (*Hymenaea stignocarpa* Mart.) flour (g.100g^{-1}), recommendation of essential amino acids according to the FAO/WHO (Food and Agriculture Organization, 1991) and amino acid score.

Amino acid	Jatobá-do-cerrado (g.100^{-1} protein)	Requirements FAO/WHO (1991)*	Amino acid score**
Arginine	6.1	-	-
Cystine+methionine	1.6	2.5	64.8[a]
Phenylalanine+tyrosine	5.6	6.3	88.8[b]
Histidine	2.3	1.9	124.2
Isoleucine	2.3	2.8	84.2[b]
Leucine	4.1	6.6	62.4[a]
Lysine	5.0	5.8	86.2[b]
Threonine	1.9	3.4	56.1[a]
Tryptophan	0.59	1.1	53.6[a]
Valine	4.2	3.5	122
Glycine	3.6	-	-

*Amino acid requirement for children 2-5 years; **amino acid score = (100 x amino acid test) / amino acid reference; [a]primary limiting amino acids; [b]secondary limiting amino acids.

of jatobá-do-cerrado flour extracts. The major TPC value was obtained using acetone 60 %, followed by water and methanol 60 %. Therefore, these data suggest that acetone 60 % can be the best choice for the extraction of antioxidants from jatobá-do-cerrado flour (Table 5).

Rocha et al. (2013) determined the total phenolic content of jatobá using ethanol and water to obtain the extracts and found values lower than those obtained in this study. Caramori et al. (2004) determined the total phenolic content in *Hymenaea coubaril* L. and found 56.8 mg/100 g; a value that is also lower than that the reported in this study. The type of antioxidant compound dissolved also varies if the polarity of the solvent is changed. In this study, antioxidants of jatobá-do-cerrado flour demonstrated higher solubility in water (highly polar) and acetone (less polar than water and methanol). In addition, solvents with low viscosity have low density and high diffusivity, which allows them to diffuse easily into the pores of plant material thereby extracting bioactive components (Wijekoon et al., 2011).

Currently, there is not an official method for the determination of antioxidant activity in foods of plant origin and their by-products due to the variety of antioxidant mechanisms that can occur and the diversity of bioactive compounds. The literature reports several methods for antioxidant evaluation, each with a different principle using free radicals and/or different patterns. Thus, studies aimed at evaluating antioxidant properties of plant extracts need to use more than one method to accurately conclude that the analyzed extracts may also be able to combat the harmful effects of free radicals on the human body (Sousa et al., 2011).

Among the methods commonly used, the following should be highlighted: those that use the DPPH and ABTS+ radicals, for being fast and practical; the ORAC method, because the use of peroxyl or hydroxyl radicals as pro-oxidants provide greater biological significance; and the Rancimat method, which evaluates antioxidant activity in lipid medium.

All jatobá-do-cerrado flour extracts showed DPPH radical-scavenging activity, and the acetone extract showed the best antioxidant activity (Table 5). Rocha et al. (2013) found lower antioxidant activity of jatoba-do-cerrado pulp by this method. Acetone extract also exhibited the highest antioxidant activity by the ferric reducing antioxidant power (FRAP) assay and the oxygen radical absorbance capacity (ORAC) assay. The values obtained in this study were similar to those obtained in the of Fuji apple peel acetone extract and beetroot and broccoli acetone extracts (Ou et al., 2002; Henriquez et al., 2010).

The Rancimat® method showed that the BHT standard (1 mg/mL) effectively inhibited the oxidative process (IAA = 3.36 ± 0.25). However, all extracts were ineffective in inhibiting the oxidation of fat in this system. Probably, the high temperatures used in this system destroyed antioxidant thermo-labile compounds hindering protection of the extracts against lipid oxidation.

Orsi et al. (2012) demonstrated that methanol extracts of *Hymenaea stigonocarpa* pulp produce antidiarrheal, gastroprotective, and cicatrizing effects on experimental gastric and duodenal ulcers. The protective effect observed was associated with antioxidant properties.

Polyphenols associated with the dietary fiber matrix have been ignored because are not usually detected by the conventional analytical procedures. However, these compounds are major dietary antioxidants and, they can contribute significantly to the health benefits assigned to the dietary fiber and dietary antioxidants (Saura-Calixto, 2011).

Table 3. Mineral content of jatobá-do-cerrado (*Hymenaea stignocarpa* Mart.) flour.

Minerals (mg.100 g^{-1})	Jatobá-do-cerrado*
Ca	145±2.00
Cu	0.79±0.01
Fe	0.74±0.02
P	107±3.00
Mg	125±6.00
Mn	16.78±0.89
K	1352±59.00
Na	2.80±0.26
Zn	1.11±0.02

*All values are means ± standard deviation of three analyses of the same sample.

Table 4. Carotenoid Content of jatobá-do-cerrado (*Hymenaea stignocarpa* Mart.) flour.

Carotenoids (mg. 100 g^{-1})	Jatobá-do-cerrado*
β-carotene	1.7 ± 1.2
β-cryptoxanthine	nd
Lutein	28.0 ± 24.5
Vitamine A (RAE. 100 g^{-1})	281.7

*All values are means ± standard deviation of three analyses of the same sample.

Table 5. Total phenolic compounds and antioxidant properties of jatobá-do-cerrado (*Hymenaea stignocarpa* Mart.) flour.

Solvent	TPC	DPPH	FRAP	ORAC	Rancimat
Water	315.36 ± 3.64^{b}	8.78 ± 0.46^{b}	28.65 ± 0.77^{b}	91.85 ± 5.46^{b}	0.99±0.08^{a}
Methanol 60 %	124.97 ± 3.90^{a}	14.66 ± 0.3^{c}	15.32 ± 0.41^{a}	49.24± 6.80^{a}	1.01±0.08^{a}
Acetone 60 %	536.15 ± 9.63^{c}	1.44 ± 0.08^{a}	106.40 ± 1.04^{c}	119.79±5.06^{c}	1.05±0.03^{a}

TPC, total phenolic content expressed as mg gallic acid equivalents (GAE)/ 100 g jatobá flour; DPPH: DPPH assay expressed as IC_{50} (mg/mL); FRAP, ferric reducing ability expressed as μM Fe(II)/g jatobá flour; ORAC: oxygen radical absorbance capacity expressed as μM Trolox equivalents/g jatobá; Rancimat: expressed as antioxidant activity index (IAA). Results are expressed as means ± standard deviation; Values with different letters in the same column are significantly different at $p < 0.05$.

4 Conclusion

Jatobá flour showed high-fiber content, significant amounts of the carotenoids, beta-carotene, and lutein, and some minerals like calcium, magnesium, and potassium. It also showed antioxidant activity when assessed by different methods, except for the Rancimat method. The total phenolic content and antioxidant activity were affected by the solvent used, and the best results were obtained with acetone. Therefore, jatobá flour is an ingredient that can be used in the development of new products with properties that promote health and preserve the environment.

Acknowledgements

The authors are grateful for the financial support provided by FAPESP (São Paulo Research Foundation).

References

Amarowicz, R., & Pegg, R. B. (2008). Legumes as a source of natural antioxidants. *European Journal of Lipid Science and Technology*, *110*(10), 865-878. http://dx.doi.org/10.1002/ejlt.200800114

Association of Official Analytical Chemists - AOAC. (2010). *Official methods of analyses* (18th ed.). Gaithersburg: AOAC Press.

Avidos, M. F. D., & Ferreira, L. T. (2000). Frutos dos cerrados: preservação gera muitos frutos. *Biotecnologia Ciência e Desenvolvimento*, *3*(15), 36-41.

Batista, A. G., Esteves, E. A., Dessimoni-Pinto, N. A. V., Oliveira, L. G., Pires, S. T., & Santana, R. C. (2011). Chemical composition of Jatobá-do-cerrado (*Hymenea stigonocarpa* Mart.) flour and its effect on growth of rats. *Alimentos e Nutrição*, *22*(2), 173-180.

Benzie, I. F. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. *Analytical Biochemistry*, *239*(1), 70-76. PMid:8660627. http://dx.doi.org/10.1006/abio.1996.0292

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, *37*(8), 911-917. PMid:13671378. http://dx.doi.org/10.1139/o59-099

Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free-radical method to evaluate antioxidant activity. *Food Science and Technology-Lebensmittel-Wissenschaft & Technologie*, *28*(1), 25-30. http://dx.doi.org/10.1016/S0023-6438(95)80008-5

Caramori, S. S., Lima, C. S., & Fernandes, K. F. (2004). Biochemical characterization of selected plant species from Brazilian savannas. *Brazilian Archives of Biology and Technology*, *47*(2), 253-259. http://dx.doi.org/10.1590/S1516-89132004000200013

Cardoso, L. M., Bedetti, S. F., Ribeiro, S. M. R., Esteves, E. A., & Pinheiro-Sant'ana, H. M. (2013). 'Jatoba do cerrado' (*Hymenaea stigonocarpa)*: chemical composition, carotenoids and vitamins in an exotic fruit from the Brazilian Savannah. *Fruits*, *68*(2), 95-107. http://dx.doi.org/10.1051/fruits/2013056

Cardoso, L. M., Martino, H. S. D., Moreira, A. V. B., Ribeiro, S. M. R., & Pinheiro-Sant'Ana, H. M. (2011a). Cagaita (Eugenia dysenterica DC.) of the Cerrado of Minas gerais, Brazil: physical and chemical characterization, carotenoids and vitamins. *Food Research International*, *44*(7), 2151-2154. http://dx.doi.org/10.1016/j.foodres.2011.03.005

Cardoso, P. C., Tomazini, A. B., Stringheta, P. C., Ribeiro, S. R., & Pinheiro-Sant'Ana, H. M. (2011b). Vitamin C and carotenoids in organic and conventional fruits grown in Brazil. *Food Chemistry*, *126*(2), 411-416. http://dx.doi.org/10.1016/j.foodchem.2010.10.109

De Sa, M. C., & Rodriguez-Amaya, D. B. (2004). Optimization of HPLC quantification of carotenoids in cooked green vegetables: comparison of analytical and calculated data. *Journal of Food Composition and Analysis*, *17*(1), 37-51. http://dx.doi.org/10.1016/S0889-1575(03)00100-5

Dias, L. S., Luzia, D. M. M., & Jorge, N. (2013). Physicochemical and bioactive properties of Hymenaea courbaril L. pulp and seed lipid fraction. *Industrial Crops and Products*, *49*, 610-618. http://dx.doi.org/10.1016/j.indcrop.2013.06.005

Food and Agriculture Organization - FAO, World Health Organization - WHO. (1991). *Protein quality evaluation*. Roma: FAO/WHO. FAO Food and Nutrition Paper, 51.

Fernandes, A. G., Maia, G. A., Sousa, P. H. M., Costa, J. M. C., Figueiredo, R. W., & Prado, G. M. (2007). Comparação dos teores em vitamina C, carotenóides totais, antocianinas totais e fenólicos totais do suco tropical de goiaba nas diferentes etapas de produção e influência da armazenagem. *Alimentos e Nutrição*, *18*(4),431-438.

Fukumoto, L. R., & Mazza, G. (2000). Assessing antioxidant and prooxidant activities of phenolic compounds. *Journal of Agricultural and Food Chemistry*, *48*(8), 3597-3604. PMid:10956156. http://dx.doi.org/10.1021/jf000220w

Geraldo, R. R. C., Paiva, S. A. R., Pitas, A. M. C. S., Godoy, I., & Campana, A. O. (2003). Distribuição da hipovitaminose A no Brasil nas últimas quatro décadas: ingestão alimentar, sinais clínicos e dados bioquímicos. *Revista de Nutrição*, *16*(4), 443-460. http://dx.doi.org/10.1590/S1415-52732003000400008

Gonçalves Frota, K. D. M., Manolio Soares, R. A., & Gomes Areas, J. A. (2008). Chemical composition of cowpea (*Vigna unguiculata* L. Walp), BRS-Milenio cultivar. *Food Science and Technology*, *28*(2), 470-476.

Hart, D. J., & Scott, K. J. (1995). Development and evaluation of an HPLC method for the analysis of carotenoids in foods, and the measurement of the carotenoid content of vegetables and fruits commonly consumed in the UK. *Food Chemistry*, *54*(1), 101-111. http://dx.doi.org/10.1016/0308-8146(95)92669-B

Henriquez, C., Almonacid, S., Chiffelle, I., Valenzuela, T., Araya, M., Cabezas, L., Simpson, R., & Speisky, H. (2010). Determination of antioxidant capacity, total phenolic content and mineral composition of different fruit tissue of five apple cultivars grown in Chile. *Chilean Journal of Agricultural Research*, *70*(4), 523-536. http://dx.doi.org/10.4067/S0718-58392010000400001

Horst, M. A., & Moreno, F. S. (2009). *Funções plenamente reconhecidas de nutrientes*. São Paulo: ILSI Brasil. Série de Publicações ILSI-Brasil.

Institute of Medicine - IOM. (2000). *Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids*. Washington: National Academy Press.

Klink, C. A., & Machado, R. B. (2005). A conservação do cerrado brasileiro. *Megadiversidade*, *1*(1), 147-155.

Liu, R. H. (2003). Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals. *American Journal of Clinical Nutrition*, *78*(3), 517S-520S. PMid:12936943.

Lorenzi, H. (2008). *Árvores brasileiras*: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. Nova Odessa: Instituto Plantarum.

Marin, A. M. F., Siqueira, E. M. A., & Arruda, S. F. (2009). Minerals, phytic acid and tannin contents of 18 fruits from

the Brazilian savanna. *International Journal of Food Sciences and Nutrition*, *60*(s7), 180-190. PMid:19353365. http://dx.doi.org/10.1080/09637480902789342

Morrison, W. R., & Smith, L. M. (1964). Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride-methanol. *Journal of Lipid Research*, *5*, 600-608. PMid:14221106.

Orsi, P. R., Bonamin, F., Aparecida Severi, J., Cássia Santos, R., Vilegas, W., Hiruma-Lima, C. A., & Stasi, L. C. (2012). Hymenaea stigonocarpa Mart. ex Hayne: a Brazilian medicinal plant with gastric and duodenal anti-ulcer and antidiarrheal effects in experimental rodent models. *Journal of Ethnopharmacology*, *143*(1), 81-90. PMid:22750452. http://dx.doi.org/10.1016/j.jep.2012.06.001

Ou, B. X., Huang, D, Hampsch-Woodill, M., Flanagan, J. A., & Deemer, E. K. (2002). Analysis of antioxidant activities of common vegetables employing oxygen radical absorbance capacity (ORAC) and ferric reducing antioxidant power (FRAP) assays: a comparative study. *Journal of Agricultural and Food Chemistry*, *50*(11), 3122-3128. PMid:12009973. http://dx.doi.org/10.1021/jf0116606

Pires, C. V., Oliveira, M. G. A., Rosa, J. C., & Costa, N. M. B. (2006). Qualidade nutricional e escore químico de aminoácidos de diferentes fontes protéicas. *Ciência e Tecnologia de Alimentos*, *26*(1), 179-187. http://dx.doi.org/10.1590/S0101-20612006000100029

Prior, R. L., Hoang, H., Gu, L., Wu, X., Bacchiocca, M., Howard, L., Hampsch-Woodill, M., Huang, D., Ou, B., & Jacob, R. (2003). Assays for hydrophilic and lipophilic antioxidant capacity (oxygen radical absorbance capacity (ORAC(FL))) of plasma and other biological and food samples. *Journal of Agricultural and Food Chemistry*, *51*(11), 3273-3279. PMid:12744654. http://dx.doi.org/10.1021/jf0262256

Rocha, M. S., Figueiredo, R. W., Araújo, M. A. M., & Moreira-Araújo, R. S. R. (2013). Physical and chemical characterization and antioxidant activity (in vitro) of fruit of the Piaui Savanna. *Revista Brasileira de Fruticultura*, *35*(4), 933-941. http://dx.doi.org/10.1590/S0100-29452013000400003

Rodriguez-Amaya, D. B. (2001). *A guide to carotenoid analysis in food*. Washington: ILSI Life Sciences Institute.

Rufino, M. S. M., Alves, R. E., Brito, E. S., Morais, S. M. Sampaio, C. G., Pérez-Jiménez, J., & Saura-Calixto, F. D. (2006). *Metodologia científica: determinação da atividade antioxidante total em frutas pelo método de redução do ferro (FRAP)*. Fortaleza: EMBRAPA. Comunicado Técnico *on line* 125.

Saura-Calixto, F. (2011). Dietary fiber as a carrier of dietary antioxidants: an essential physiological function. *Journal of Agricultural and Food Chemistry*, *59*(1), 43-49.

Scalbert, A., Johnson, I. T., & Saltmarsh, M. (2005). Polyphenols: antioxidants and beyond. *American Journal of Clinical Nutrition*, *81*(1), 215S-217S. PMid:15640483.

Silva, M. R., Silva, M. S., Martins, K. A., & Borges, S. (2001). Utilização tecnológica dos frutos de jatobá-do-cerrado e de jatobá-da-mata na elaboração de biscoitos fontes de fibra alimentar e isentos de açúcar. *Ciência e Tecnologia de Alimentos*, *21*(2), 176-182. http://dx.doi.org/10.1590/S0101-20612001000200010

Silva, P. T., Lopes, M. L. M., & Valente-Mesquita, V. L. (2006). Efeito de diferentes processamentos sobre o teor de ácido ascórbico em suco de laranja utilizado na elaboração de bolo, pudim e geléia. *Ciência e Tecnologia de Alimentos*, *26*(3), 678-682. http://dx.doi.org/10.1590/S0101-20612006000300030

Singleton, V. L., & Rossi-Junior, J. A. (1965). Colorimetry of total phenolics with phosphomolybidic acid reagents. *American Society for Enology and Viticulture*, *16*(3), 144-158.

Sousa, M. S. B., Vieira, L. M., & Lima, A. (2011). Fenólicos totais e capacidade antioxidante *in vitro* de resíduos de polpas de frutas tropicais. *Brazilian Journal of Food Technology*, *14*(3), 202-210. http://dx.doi.org/10.4260/BJFT2011140300024

Spies, J. R. (1967). Determination of tryptophan in proteins. *Analytical Chemistry*, *39*(12), 1412-1416. PMid:6073804. http://dx.doi.org/10.1021/ac60256a004

Walter, M., Silva, L. P., & Perdomo, D. M. X. (2008). Amido disponível e resistente em alimentos: adaptação do método da AOAC 996.11. *Alimentos e Nutrição*, *16*(1), 39-43.

White, J. A., Hart, R. J., & Fry, J. C. (1986). An evaluation of the waters pico-tag system for the amino-acid-analysis of food materials. *Journal of Automatic Chemistry*, *8*(4), 170-177. PMid:18925132 PMCid:PMC2547673. http://dx.doi.org/10.1155/S1463924686000330

Wijekoon, M. M. J. O., Bhat, R., & Karim, A. A. (2011). Effect of extraction solvents on the phenolic compounds and antioxidant activities of bunga kantan (Etlingera elatior Jack.) inflorescence. *Journal of Food Composition and Analysis*, *24*(4-5), 615-619. http://dx.doi.org/10.1016/j.jfca.2010.09.018