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Chemical constituents of chichá (*Sterculia striata* St. Hil. et Naud.) seeds

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The proximate and mineral composition of chichá seeds was evaluated, as well as protein digestibility, bioactive compounds (phenols and flavonoids) and profiles of organic and fatty acids, in order to provide information to support the dietary use of this seed, adding value to the fruit and contributing to the preservation of the Brazilian Cerrado. Chichá (*Sterculia striata* St. Hil. et Naud.) fruits were collected in the city of Jataí, in the southern Goiás state. The seeds were lyophilized, ground and packed in hermetically sealed vials at -18°C. Composition analyses found high contents (g 100 g^{-1} dry matter [DM]) of proteins (22.34), lipids (23.91), dietary fiber (26.29), and the minerals (mg 100 g^{-1} DM) potassium (1,165.78), phosphorus (701.44), and magnesium (277.32). The *in vitro* protein digestibility was 65.67%. Oleic acid (35.17%), palmitic acid (27.13%) and linoleic acid (16.50%) were the major fatty acids; citric acid was the major organic acid. It is concluded that chichá seeds are a source of many nutrients, which supports their inclusion in the formulation of a healthy diet.

Key words: Chichá, proximate composition, minerals, bioactive compounds, citric acid, fatty acid.

INTRODUCTION

Brazil is one of the largest repositories of native plants in the world, with a high genetic diversity, and the Amazon region is the main reserve, followed by the Cerrado in Central Brazil and the Northeast (Carvalho et al., 2008).

In Brazilian native flora, there are some poorly known species, which have the potential for the seed or nut market. Among them is chichá (*Sterculia striata* St. Hil. et Naud.), a plant with fruits containing seeds that are greatly appreciated by the population of the Cerrado regions in Central Brazil and in the Northeast (Carvalho et al., 2008; Silva et al., 2008); however, chichá seeds are not well known in the national and international markets.

Chichá, also known as xixá, amendoim-de-macaco, castanha-de-macaco, castanheiro-do-mato, arachachá, belongs to the family Malvaceae. It is a plant native to the Cerrado, mainly distributed in the states of Minas Gerais, Goiás, Mato Grosso, Tocantins, Bahia, Piauí and

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Maranhão (Silva and Fernandes, 2011). Its fruits are woody, elongated capsules, appearing at the ends of the branches and, when ripe, they open and display the seeds (Silva and Fernandes, 2011).

The seeds are consumed raw, cooked or roasted by humans, and are consumed fresh by native fauna (Silva et al., 2008; Silva and Fernandes, 2011).

Knowing the chemical characteristics and the nutritional and functional value of the fruits of the Cerrado is of paramount importance to encourage consumption and enable the formulation of new products, besides contributing to their preservation. However, few reports are found in the literature regarding the chemical composition of these fruits and their technological application, underscoring the need for scientific research on the subject (Silva et al., 2008).

Studies on proximate composition, amino acid profile (Oliveira et al., 2000; Silva et al., 2008; Carvalho et al., 2008) and chemical characterization of the oil (Chaves, 2004) of raw chichá seeds are reported. However, there are no records on mineral composition, organic acid profile and protein digestibility.

Furthermore, most reports are on chichá fruits from the Northeast region of Brazil. This study differs by using lyophilized chichá seeds from a southern Cerrado region (in the city of Jatai); in the literature, it is not possible to find studies on chichá seeds of this region.

Given the above, the objective of this study was to characterize chichá seeds from the city of Jataí, in the southern Goiás state, determining their proximate and mineral composition, protein digestibility, contents of phenolic compounds and flavonoids, and profiles of fatty and organic acids, in order to provide information which supports the dietary use of this seed, adding value to this fruit and contributing to the preservation of the Cerrado.

MATERIALS AND METHODS

Sample collection and preparation

Chichá (*Sterculia striata* St. Hil. et Naud.) fruits were collected in the city of Jatai, southern Goiás state, in January 2013, in three replicates, and transported to the laboratory. The almonds were then extracted, lyophilized for 24 h, peeled and crushed in a refrigerated mill until a homogeneous flour was formed; the flour was packed in hermetically sealed vials in a freezer at -18°C.

Proximate composition

Moisture contents were determined in an oven at 105ºC, until constant weight. The ether extract was determined using a Soxhlet continuous extractor. Crude protein was measured by the Kjeldahl method, using the conversion factor of 6.25 (N x 6.25). Ash and fixed mineral residue were obtained from a defined quantity of samples by incineration (550°C) in a muffle furnace, thus determining the percentage of residue. Total, soluble and insoluble dietary fiber were determined by the enzymatic method. Nitrogen-free extract was determined by the difference between 100 and the sum, in dry matter, of ether extract, protein, ash and total dietary fiber. Proximate composition analyses were performed using the methodology described by the Association of Official Analytical Chemists (AOAC, 2005).

In vitro protein digestibility

The samples (with known nitrogen content) were subjected to digestion by the enzymes pepsin followed by pancreatin, at their optimum pH, and digestion was stopped by the addition of trichloroacetic acid. The samples were then centrifuged at 10,000 x g for 15 min, and the content of nitrogen was dosed in the supernatant. Casein was used as a standard (Akeson and Stahmann, 1964). The value obtained for casein digestibility was considered as 100%, and the digestibility values obtained for the samples were calculated based on the value obtained for casein.

Mineral composition

The contents of the following minerals were determined: iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K) and sulfur (S). In order to quantify the minerals, the seed samples were subjected to a nitric-perchloric digestion in digester blocks with temperature control. P and S were determined by colorimetry, K by flame photometry and Ca, Mg, Cu, Mn, Zn and Fe by atomic absorption spectrophotometry. For all analyses, the procedures described by Malavolta et al. (1997) were used.

Phenolic compounds

The extraction of phenolic compounds was carried out with 50% methanol, under reflux for three consecutive times, at 80°C, and the extracts were collected, evaporated up to 25 mL, at 80°C, and submitted to phenolic compound measurement, using the Folin-Denis reagent, and tannic acid as a standard (AOAC, 2005).

Total flavonoids

The contents of total flavonoids were measured using the same extracts used in the phenolic compound analyses, using the aluminum chloride colorimetric method, with catechin used as a standard (Zhishen et al., 1999).

Organic acids

The extraction of organic acids for chromatographic analysis was carried out with 1 g sample in 50 mL ultra pure water, under agitation, for 45 min and, subsequently, filtering through Whatman No. 40 paper. An LC 200 A Shimadzu liquid chromatograph was used, as well as a conductivity detector (CDD-6A), + polarity, using a SHIM-PACK SPR-H(G) pre-column (50 mm x 7.8 mm) and two SHIM-PACK SPR-H columns in series (250mm x 7.8mm). The injection volume was 20 µL. The mobile phase was 4 mmol L^{-1} *p*-toluenesulfonic acid, at a flow rate of 0.8 mL/min and 45°C (Fraguas et al., 2014). Peaks corresponding to each acid were identified by the retention time, using the retention times of the standards as a comparison. The following organic acid patterns were used: citric acid, malic acid, quinic acid, lactic acid, tartaric acid, succinic acid and fumaric acid, all Sigma-Aldrich (St. Louis, MO, USA).

Fatty acid profile

Lipids were extracted according to the methodology proposed by

Table 1. Proximate composition (g 100 g^{-1} dry matter) of chichá seeds.

Chichá constituents	Content
Ether extract	23.91±0.06
Crude protein	22.34 ±1.57
Ash	3.54±0.20
Insoluble dietary fiber	24.52±0.83
Soluble dietary fiber	1.76±0.33
Total dietary fiber	26.28±0.49
NFE[1]	23.93±0.21

Data are the mean of three replicates ± standard deviation. [1]NFE: Nitrogen-free extract. Moisture content of chichá seed flour: 6.86 g 100 g^{-1}.

Table 2. Mineral composition, in mg 100 g^{-1} dry matter, of chichá seeds.

Minerals	Contents
Calcium	nd[1]
Phosphorus	701.44±58.10
Potassium	1,165.78±36.31
Magnesium	277.32±14.52
Sulfur	344.08±7.26
Copper	2.93±0.12
Manganese	0.66±0.01
Zinc	6.20±0.29
Iron	2.18±0.12

Data are the mean of three replicates ± standard deviation. Moisture content of chichá seed flour: 6.86 g 100 g^{-1}; [1]nd: not detected.

Bligh and Dyer (1959), and esterification was performed using the methodology by Joseph and Ackman (1992). The composition of fatty acids was determined by gas chromatography, and the chromatograph GC-2010 (Shimadzu) was used, equipped with a flame ionization detector and a fused silica capillary column (100 m long, 0.25 mm internal diameter), containing polyethylene glycol as a liquid stationary phase. The standard used was a mixture of 37 methyl esters (SupelcoTM 37 Component FAME Mix), from C:4 to C22:6, with a purity of 99.9%. In order to perform the gas chromatography, it was necessary to redissolve the samples in 0.50 mL hexane.

The following operating parameters were used: "split" injection mode, split ratio 1:100; injected volume: 1 µL; detector and injector temperature: 260°C; temperature program: 4°C/minute up to 140°C, remaining at this temperature for 5 min, keeping the heating ramp in 4°C/min up to 240°C, remaining at this temperature for 30 min.

The identification of the peaks was performed by a comparative method with the retention times of the standard fatty acid esters, and the results were performed by integration of the peak areas and expressed in area percentage.

RESULTS AND DISCUSSION

The results for proximate composition of chichá seeds are shown in Table 1. In a study on the chemical composition of chichá from the state of Ceará, Oliveira et al. (2000) found a higher content of ether extract (28.65 g 100 g^{-1} dry matter - DM), lower contents of ash (3.03 g 100 g^{-1} DM) and similar contents of proteins (22.50 g 100 g^{-1} DM). On the other hand, Silva and Fernandes (2011), in a study with chichá seeds obtained from the state of Piauí, found results similar to those observed for the lyophilized almond in this study regarding the contents of protein (22.11 g 100 g^{-1} DM) and ash (3.92 g 100 g^{-1} DM); however, they reported higher contents of lipids (26.74 g 100 g^{-1} DM) and lower contents of dietary fiber (13.08 g 100 g^{-1} DM). The difference among seeds of the same species, but from different regions, is explained by the influence that soil, fertilization, climate and other environmental factors have on their composition.

The protein contents of the seeds in this study are higher than other common nuts, such as Brazil nuts (14.00-16.00 g 100 g^{-1}), pine nuts (13.00 g 100 g^{-1}), pecan (9.00 g 100 g^{-1}), cashew nuts (17.50 g 100 g^{-1}), hazelnuts (14.50 g 100 g^{-1}), and pistachio (20.00 g 100 g^{-1}) (Yang, 2009), emphasizing the nutritional value of chichá.

Due to the high content of protein found in this study, an evaluation of *in vitro* protein digestibility of the almonds was performed, and the value found was 65.67% ± 1.85. Protein digestibility is very important, since this parameter provides a measurement of protein susceptibility to proteolysis.

Chichá seeds had a total dietary fiber content of 26.29 g 100 g^{-1} DM, and the content of insoluble fiber was, on average, 14 times higher than that of soluble fiber. Food is considered high in fiber when its content is above 6 g 100 g^{-1}, and is considered a source when its content is higher than 3g 100 g^{-1} (Brasil, 1998); therefore, chichá seeds are rich in fiber, which is important in the prevention and treatment of various diseases, such as diabetes and obesity, among others, and their consumption would improve the nutritional quality of a diet.

The content of nitrogen-free extract (23.92 g 100 g^{-1} DM) of chichá seeds was lower than values reported in the literature, which range from 38.10 to 47.23 g 100 g^{-1} DM (Oliveira et al., 2000; Silva et al., 2008; Silva and Fernandes, 2011).

The seeds had high levels, in mg 100 g^{-1} DM, of potassium (1,165.78), phosphorus (701.44) and magnesium (277.32) (Table 2). Considering the Recommended Daily Allowance (RDA), according to the Dietary Reference Intakes (DRI, 2001) of minerals for adults from 19 to 50 years old (phosphorus: 700 mg; calcium: 800 mg; magnesium: 260 mg; copper: 9 mg; manganese: 23 mg; zinc: 11 mg and iron: 8 mg), chichá seeds, in the amount of 100 g day^{-1}, would supply the need for phosphorus and magnesium, highlighting the potential use of chichá seeds as a food supplement.

Due to the fact that the mineral composition of chichá

Table 3. Phenolic compounds, flavonoids and organic acids of chichá seeds.

Constituents	Contents
Phenolic compounds (mg 100 g^{-1} DM)	305.08±7.80
Flavonoids (mg 100 g^{-1} DM)	9.72±1.26
Maleic acid (µg g^{-1} DM)	262.68±8.35
Citric acid (µg g^{-1} DM)	389.43±17.10
Fumaric acid (µg g^{-1} DM)	8.43±0.71

Data are the mean of three replicates ± standard deviation. Moisture content of chichá seed flour: 6.86 g 100 g^{-1}.

Table 4. Fatty acid composition of chichá seeds.

Fatty acids	Chain	Percentage
Palmitic	C16:0	27.13±0.02
Stearic	C18:0	3.10±0.30
Oleic	C18:1n9c	35.17±1.01
Elaidic	C18:1n9t	1.84±0.01
Linolenic	C18:3	0.10±0.01
Eicosatrienoic	C20:3n3	0.15±0.01
Arachidic	C20:0	0.39±0.02
∑ SFA		30.62
∑MUFA		37.01
∑PUFA		16.75

Data are the mean of three replicates ± standard deviation. ∑SFA = sum of saturated fatty acids; ∑MUFA = sum of monounsaturated fatty acids; ∑PUFA = sum of polyunsaturated fatty acids.

has not been previously reported in the literature, it was not possible to compare these results with other studies of this almond.

The contents of phenolic compounds, flavonoids and organic acids in chichá seeds are presented in Table 3. The contents of phenolic compounds (305.08 mg 100 g^{-1} DM) and flavonoids (9.72 mg 100 g^{-1} DM) for theevaluated chichá seeds were higher than those found by Rocha et al. (2013) (phenolic compounds, 85.37 mg 100 g^{-1}; flavonoids, 2.81 mg 100 g^{-1}) and by Costa et al. (2010) (phenolic compounds, 63.94 mg 100 g^{-1}) in studies conducted with chichá seeds from the state of Piauí. These differences can be explained due to several factors, such as harvest regions, maturation stage of seeds, climate, soil, experimental conditions, among others.

Several epidemiological studies show that phenolic compounds have multiple biological effects, such as antioxidant, anti-allergic, anti-inflammatory, anti-bacterial, antithrombotic, cardioprotective and vasodilatory effects (Rao, 2003; Balasundram et al., 2006; Silvério et al., 2013). Several natural antioxidants have been isolated from different plant materials, such as oilseeds, cereals, legumes, fruits, leaves, roots and herbs (Ramarathnam et al., 1995). However, studies that evaluate the antioxidant activity of seeds of tropical and subtropical fruits have been rarely reported, suggesting the need for studies with these fruits, since this is a vast field to be explored.

The determination of organic acids in chichá seeds showed citric acid (389.43 µg g^{-1} DM) as a major component, and maleic and fumaric acids were also identified.

Organic acids present in food affect taste, odor, color, stability and quality maintenance (Cecchi, 2003). The determination of total acidity in food is very important, since it is possible to obtain valuable data for the evaluation of food processing, as well as its conservation status.

Eight fatty acids were detected in chichá seeds, and oleic acid (35.17%), palmitic acid (27.13%) and linoleic acid (16.50%) were the major ones (Table 4). The proportion of fatty acids was, on average, 30.62% saturated, 37.01% monounsaturated and 16.75% polyunsaturated, with a higher percentage of unsaturated than saturated fatty acids.

The contents of oleic (35.17%) and palmitic acid (27.13%) of seeds in this study were similar to those found in other studies, such as those conducted by Silva and Fernandes (2011) (oleic, 35.28%; palmitic, 28.99%) and Chaves et al. (2004) (oleic, 35.90%; palmitic, 25.50%), who also described oleic and palmitic acids as the major ones in chichá seeds. On the other hand, the content of linoleic acid in this study (16.50%) was higher than that found by Silva and Fernandes (2011) (3.77%) and Chaves et al. (2004) (12.21%).

The variation in the composition of fatty acids for the same species may be due to various reasons, such as different stages of seed maturation, differences among populations, equipment used for quantification and different sampling times.

Monounsaturated fatty acids, such as oleic acid, aid in the reduction of total cholesterol and low density lipoprotein (LDL), without reducing high density lipoprotein (HDL), resulting in health benefits (Lopes et al., 2009).

Linoleic acid is necessary to keep cell membranes, brain function and the transmission of nerve impulses under normal conditions. This fatty acid also participates in the transfer of atmospheric oxygen to the blood plasma, as well as in hemoglobin synthesis and cell division, and is essential, since it is not synthesized by the body from fatty acids from the de novo synthesis (Yehuda et al., 2002; Youdim et al., 2000). Therefore, chichá seeds have important fatty acids to contribute to a healthy diet.

CONCLUSION

Chichá seeds have high contents of proteins, lipids, dietary fiber and the minerals potassium, phosphorus and magnesium, besides the presence of bioactive substances, such as phenolic compounds and flavonoids. The major organic acid was citric acid. The fatty acid profile indicates that these almonds are a good source of unsaturated fatty acids, mainly oleic and linoleic acids. Therefore, chichá seeds have a chemical composition which supports their use in human diets and can contribute to a considerable extent to the recommended dietary intake, as an alternative source of nutrients.

Conflict of Interest

The author(s) declare that they have no conflict of interest to disclose.

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