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# Chemical composition of processed baru (*Dipteryx alata* Vog.) almonds: Lyophilization and roasting

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**The objective of this study was to evaluate percent and mineral composition, protein digestibility, bioactive compounds (phenols and flavonoids), total soluble solids (TSS), titratable acidity, pH, profiles of fatty acids (FA) and proteins, and the organic acids of baru (*Dipteryx alata* Vog.) almonds, subjected to different treatments (lyophilization and roasting), aiming to determine which process results in a better use of the almond constituents, adding value to the fruit. High levels (g 100 $g^{-1}$ dry matter - DM) were found for proteins: 32.04 and 36.08; lipids: 34.50 and 36.67; dietary fiber: 21.55 and 21.46; and for the following minerals (mg 100 $g^{-1}$ DM); phosphorus: 652.35 and 703.14; and iron: 8.42 and 9.51, respectively, in lyophilized and roasted almonds. Among the FA, oleic and linoleic acids were the major ones, as well as citric acid among the organic acids, both in lyophilized and in roasted almonds. The roasting process increased the levels of lipids, proteins and of the minerals: phosphorus, calcium, magnesium, copper, zinc and iron. However, it resulted in a decrease in the levels of phenolic compounds, flavonoids, protein digestibility and in the number of absorption bands and proteins shown in the electrophoretic profile.**

**Key words:** Chemical characterization, lyophilization, roasting, *Dipteryx alata* Vog.

## INTRODUCTION

*Cerrado* is characterized by a great biodiversity; however, this biome is among the most threatened ecosystems in the world (Zaidan and Carreira, 2008; Santos et al., 2012). Over the past 30 years, extensive cattle ranching, monocultures and the opening of roads destroyed much of this ecosystem. According to the Brazilian Institute of Environment, only 20% of the *Cerrado* area remains without major changes (Vera et al., 2009).

Numerous *Cerrado* species are used as food, for medicinal purposes, or for the production of handicrafts. The appreciation of native species can be encouraged through the research of their capabilities and proper management, thus contributing to profitably add value to native fruits and to the preservation of the biome

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(Aquino et al., 2007).

Baru (*Dipteryx alata* Vog.) is a fruit that belongs to the Leguminosae family, widespread in the *Cerrado* biome, which is part of the group of native species used by the regional population as a source of family income (Sano et al., 1999). It is one of the most promising species for cultivation, due to its multiple uses, such as in food, wood, medicine, industry, landscaping, and in the recovery of degraded areas (Alves et al., 2010). It has drawn the attention of researchers, due to its nutritional quality and health benefits.

The sustainable use of baru is being enhanced through various farmers' associations, regional community organizations and agroextractivist cooperatives. The use of baru almond for commercial purposes has been valued in the state of Goiás (Brazil) (Rocha and Santiago, 2008), but studies of national and international scope are still scarce.

Baru almonds stand out for their high content of proteins, insoluble fiber (Takemoto et al., 2001) and the minerals potassium, magnesium, phosphorus and zinc (Sousa et al., 2011). The oil from the seeds is composed of more than 75% unsaturated fatty acids (FA) (Vera et al., 2009), among which a substance that inhibits melanin was isolated, which demonstrates the presence of medicinal properties in this fruit (Sano et al., 1999).

The fruit of baru is used in the production of cereal bars, breads, cookies, liquors and oil extraction. In addition, there is the possibility of using barueiro in areas to be recovered, such as springs and riverbanks, because it can favor the conservation and maintenance of other associated species of flora and/or fauna (Sano et al., 1999).

The availability of highly rich sources of protein, dietary fiber, unsaturated FA and minerals, can add value to the exploration of baru, since it allows its use in different industrial products. Research has shown that processing conditions, such as roasting, improve the availability of certain nutrients, flavor, texture, besides inhibiting the action of antinutritional factors present in foods (Silva, and Fernandes, 2011).

Considering the importance of research into new products as an alternative to meet the market demand and the need to preserve native species of the Brazilian *Cerrado*, the objective of this study was to analyze the chemical composition of lyophilized and roasted baru almonds, aiming to expand the knowledge about nutritional compounds, justifying and disseminating the spread and use of this native species, besides investigating changes in its composition, resulting from processing.

## MATERIALS AND METHODS

### Sample collection and preparation

Baru (*D. alata* Vog.) almonds were purchased at the local market in the town of Jataí, in the south of the state of Goiás, in five replications, and transported to the laboratory. A part of the fresh almonds was lyophilized for 24 h, and the other part was subjected to a roasting process in an electric oven, at a temperature of 150°C for 30 min. They were then peeled and crushed in a cooled mill, and all the samples were placed in hermetically sealed flasks in a freezer at -18°C.

### Percent composition

Moisture contents were determined in an oven at 105°C, until constant weight. The ether extract was determined using a Soxhlet continuous extractor. The crude protein was measured by the Kjeldahl method, using the conversion factor of 6.25 (N × 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 fibers were determined by the enzymatic method. The 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. These analyzes of percent composition were performed using the methodology described by the Association of Official Analytical Chemists (AOAC, 2005).

### *In vitro* protein digestibility

The sample (with known nitrogen content) was subjected to digestion by the enzyme pepsin and then by pancreatin in their optimum pH, and the digestion was stopped by the addition of trichloroacetic acid. Then, the samples were centrifuged at 10,000 × 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

In order to quantify the minerals (Fe, Zn, Mn, Cu, Ca, Mg, P, K and S), the samples were subjected to a nitroperchloric 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 analyzes, 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 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).

### Total soluble solids (TSS), total titratable acidity (TTA) and pH

The contents of TSS were determined according to the

methodology proposed by AOAC (2005), and the percentage of moisture which was lost in lyophilization was returned to the samples. Homogenization was performed in a polytron, the filtration of the samples in an organza fabric and readings were performed in a 121 Homis digital refractometer. The results were expressed as °Brix.

For the determination of TTA and pH, after moisture was returned, 40 ml of distilled water were added, followed by homogenization in polytron and filtration in an organza fabric. After the determination of pH in a digital pH meter, the samples were titrated with 0.1 mol $L^{-1}$ NaOH, using phenolphthalein as an indicator, until the samples reached pH = 8.1. Calculations were made considering the weight of sample used, the volume of 0.1 mol $L^{-1}$ NaOH spent and the number of gram equivalent of citric acid. The results were expressed in g citric acid 100 $g^{-1}$ sample (AOAC, 2005).

#### 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, filtered 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 × 7.8mm) and two SHIM-PACK SPR-H columns in series (250 × 7.8 mm). The injection volume used was 20 µl. The mobile phase used was 4 mmol $L^{-1}$ *p*-toluenesulfonic acid, with a flow of 0.8 ml/min and 45°C. Peaks corresponding to each acid were identified by the retention time, using the retention times of the standards as a comparison.

#### Fatty acid (FA) profile

Lipids were extracted according to the methodology proposed by Bligh and Dyer (1959), and esterification was performed using the methodology by Joseph and Ackman (1992).

The composition of FA 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%.

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/min 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.

In order to perform the gas chromatography, it was necessary to redissolve the samples in 0.50 ml hexane.

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

#### Electrophoresis on polyacrylamide gel under reducing conditions

The protein profile of the defatted fractions, obtained from lyophilized and roasted samples, was observed in electrophoresis on polyacrylamide gel (Acrylamide:bis-acrylamide; 19:1) in the presence of sodium dodecyl sulfate (SDS). The extraction was carried out with 50 mg sample in 1 ml phosphate buffered saline (PBS), under agitation for 60 min, followed by centrifugation at 10,000 × g for 20 min. Different volumes (5 to 25 µl) of the supernatant were subjected to an electrophoretic run. The samples were prepared under reducing conditions (boiling at 98°C for 5 min in a β-mercaptoethanol solution); 0.5 mol $L^{-1}$ Tris-HCl (pH 6.8); glycerol; 10% SDS (w/v); 0.1% bromophenol blue (w/v)) for use in 12% polyacrylamide gel, and the electrophoresis was performed in 0.025 mol $L^{-1}$ Tris running buffer; 0.192 mol $L^{-1}$ glycine; 0.1% SDS (pH 8.3) for 4 h under a current of 80 V.

The pattern of relative mass (M*r*) of BIO RAD (α-lactalbumin, trypsin inhibitor, carbonic anhydrase, egg albumin, bovine albumin and phosphorylase β) underwent the same electrophoresis, enabling the calculation of the $Mr_S$ of the protein fractions in the samples. The bands that characterize the protein profile of the samples were stained with Coomassie blue G-250, prepared in the ratio 0.2% dye to 20% acetic acid. The gel was reproduced on Scanner and, with the migration distance of the standards, a graph in logarithmic function of the $Mr_S$ was prepared.

#### Statistical analysis

Data are the mean of five replicates ± standard deviation and were statistically evaluated by analysis of variance, and the means were compared using the Scott Knott test ($P < 0.05$) with the aid of the R software (R Development Core Team, 2011).

## RESULTS AND DISCUSSION

The results of percent composition and protein digestibility of lyophilized and roasted baru almonds are shown in Table 1.

The lyophilized almond showed lower contents of lipids and proteins, and the contents of ash and dietary fiber were similar, in relation to the roasted almond (Table 1).

Lipid contents in lyophilized and roasted almonds were higher than those found by Vera et al. (2009) (33.28 g 100 $g^{-1}$) and lower than those reported by Sousa et al. (2011) (41.25 g 100 $g^{-1}$) and Takemoto et al. (2001) (38.40 g 100 $g^{-1}$); these studies were conducted with baru almonds, without any treatment. The differences between these studies may be due to several factors, such as harvest regions, maturity stage of the almonds, climate, soil, experimental conditions, among others.

The protein contents of the lyophilized (32.04 g 100 $g^{-1}$) and roasted (36.08 g 100 $g^{-1}$) almonds were higher than those observed in other studies with these almonds, whose contents ranged from 23.90 to 29.60 g 100 $g^{-1}$ (Togashi and Sgarbieri, 1994; Takemoto et al., 2001; Vera et al., 2009); these differences are possibly related to different environmental and genetic conditions, as well as to experimental conditions (sample preparation).

The protein contents of the almonds in this study are higher than other "almonds", such as Brazil nuts (14.00 to 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 baru.

When comparing, in dry matter, 100 g of baru almond flour with 100 g of black (21.30 g) and purple (22.20 g) beans, which are sources of vegetable proteins (Brazilian Food Database, 2011), it is observed that the flours from

**Table 1.** Percent composition and protein digestibility, in g 100 $g^{-1}$ DM, of lyophilized and roasted baru almonds.

| Variable | Lyophilized baru | Roasted baru |
|---|---|---|
| Ether extract | 34.50 ± 0.23[b] | 36.67 ± 0.82[a] |
| Crude protein | 32.04 ± 0.77[b] | 36.08 ± 0.47[a] |
| *In vitro* digestibility | 20.45 ± 0.29[a] | 16.23 ± 0.13[b] |
| Ash | 2.73 ± 0.13[a] | 2.65 ± 0.16[a] |
| Insoluble fiber | 20.74 ± 2.33[a] | 20.41 ± 0.68[a] |
| Soluble fiber | 0.81 ± 0.13[a] | 1.05 ± 0.11[a] |
| Total fiber | 21.55 ± 2.10[a] | 21.46 ± 0.18[a] |
| [1]NFE | 9.18 ± 0.90[a] | 3.14 ± 0.27[b] |

Data are the mean of five replicates ± standard deviation. Same letters in rows do not differ by the Scott-Knott test ($P < 0.05$). [1]NFE: Nitrogen-free extract. Moisture contents of baru almonds, in g 100 $g^{-1}$: Lyophilized = 2.35 ± 0.10; Roasted = 6.86 ± 0.09.

these almonds had higher protein levels. Since some population groups still have a diet with limited access to animal protein, the consumption of alternative plant sources, rich in protein and high in nutritional value, may be preventive or palliative measures in the treatment of nutritional deficiencies.

Due to the high contents of proteins found in this study, an evaluation of the *in vitro* protein digestibility of the samples was performed, and the values 20.45 and 16.23 g 100 $g^{-1}$ were obtained for the lyophilized and roasted sample, respectively, in relation to the standard protein (casein). This result shows that the roasting process reduces the digestibility of the proteins present in baru almond. Protein digestibility is a very important nutritional parameter, because it evaluates the use of a protein source, thus providing a measure of the susceptibility of the protein to proteolysis. This characteristic may be influenced by heat treatment, presence of polyphenols, trypsin inhibitors and lectins, among others.

The ash contents of baru almonds were similar to those reported in the literature, which range from 2.70 to 3.18 g 100 $g^{-1}$ (Togashi and Sgarbieri, 1994; Takemoto et al., 2001; Sousa et al., 2011).

The studied samples showed similar levels of total dietary fiber in both treatments, and insoluble fiber was, on average, 19 times higher than soluble fiber. The levels of total dietary fiber in the samples are superior to those mentioned in the literature, in studies with baru almonds, whose contents ranged from 9.21 to 19.00 g 100 $g^{-1}$ (Togashi and Sgarbieri, 1995; Takemoto et al., 2001; Sousa et al., 2011). Baru almonds are rich in fiber, which are important in both the prevention and treatment of various diseases, such as diabetes, obesity, among others, and their consumption favors a diet of better nutritional quality.

The nitrogen-free extract or glycidic fraction is made up mainly of sugars. Thus, the highest content was found in the lyophilized almond (9.18 g 100 $g^{-1}$ DM), which shows that roasting reduces sugar levels in almonds. This reduction may have occurred due to their degradation and reactions with other compounds during roasting. Pyrolysis of carbohydrates (thermal dehydration) is an example of a reaction that occurs during roasting.

Table 2 shows the mineral contents of lyophilized and roasted baru almonds. The roasted seeds showed higher levels of phosphorus, calcium, magnesium, copper, zinc and iron, in relation to lyophilized baru seeds, and similar to other minerals. The contents of phosphorus, potassium, magnesium, copper, manganese, zinc and iron of the two samples were higher than those recorded by Takemoto et al. (2001), in a study with baru almonds, who found the following contents for these minerals, in mg 100 $g^{-1}$ DM: phosphorus (358.00); potassium (827.00); magnesium (178.00); copper (1.45); manganese (4.90); zinc (4.10) and iron (4.24); however, a lower calcium content (140.00) was observed.

When compared to the contents observed by Vera et al. (2009), in a study with baru almonds from eleven regions in the state of Goiás, the values obtained in the present study were higher, in relation to the minerals (in mg 100 $g^{-1}$ DM) potassium (920.00); magnesium (130.00); copper (1.67); manganese (5.72) and zinc (2.36); and lower in relation to phosphorus (730.00); calcium (300.00); sulfur (410.00) and iron (19,81). The differences between the contents of minerals may be associated with factors, such as differential soil composition, degree of ripeness of the seeds, season of the year when harvest was performed, among others.

Considering the recommended daily allowance (RDA), according to the Dietary Reference Intakes (DRI, 2001) of minerals for 19 to 50 year-old adults (phosphorus: 700 mg; calcium: 800 mg; magnesium: 260 mg; copper: 9 mg; manganese: 23 mg; zinc: 11 mg and iron: 8 mg), roasted baru almonds in the amount of 100 g $day^{-1}$ would supply the need for the minerals phosphorus, magnesium and iron, while lyophilized seeds would supply the need for iron.

The iron levels observed in this study are superior to

**Table 2.** Mineral composition, in mg 100 $g^{-1}$ DM, of lyophilized and roasted baru almonds.

| Mineral | Lyophilized baru | Roasted baru |
|---|---|---|
| Phosphorus | 652.35 ± 21.79[b] | 703.14 ± 21.75[a] |
| Potassium | 1,248.20 ± 65.37[a] | 1,252.31 ± 121.65[a] |
| Calcium | 71.91 ± 0.00[b] | 102.65 ± 0.00[a] |
| Magnesium | 231.14 ± 7.26[b] | 277.15 ± 0.00[a] |
| Sulfur | 354.42 ± 7.26[a] | 343.87 ± 7.26[a] |
| Copper | 1.82 ± 0.04[b] | 2.30 ± 0.01[a] |
| Manganese | 6.11 ± 0.05[a] | 6.13 ± 0.08[a] |
| Zinc | 6.31 ± 0.14[b] | 7.50 ± 0.08[a] |
| Iron | 8.42 ± 0.05[b] | 9.51 ± 0.04[a] |

Data are the mean of five replicates ± standard deviation. Same letters in rows do not differ by the Scott-Knott test (P < 0.05). Moisture contents of baru almonds, in g 100 $g^{-1}$: Lyophilized = 2.35 ± 0.10; Roasted = 6.86 ± 0.09.

**Table 3.** Phenolic compounds, flavonoids, TSS, TTA, pH and organic acids of lyophilized and roasted baru almonds.

| Variable | Lyophilized baru | Roasted baru |
|---|---|---|
| Phenolic compounds (mg 100 $g^{-1}$ DM) | 326.35 ± 14.44[a] | 228.24 ± 14.72[b] |
| Flavonoids (mg 100 $g^{-1}$ DM) | 9.63 ± 1.73[a] | 1.61 ± 0.09[b] |
| TSS (ºBrix) | 3.26 ± 0.05[a] | 2.47 ± 0.06[b] |
| TTA (g citric acid 100 $g^{-1}$ sample) | 5.85 ± 0.01[a] | 5.85 ± 0.02[a] |
| pH | 6.59 ± 0.05[a] | 6.50 ± 0.07[a] |
| Maleic (µg $g^{-1}$ DM) | 149.70 ± 7.11[b] | 188.67 ± 10.01[a] |
| Citric (µg $g^{-1}$ DM) | 381.43 ± 17.10[b] | 500.70 ± 21.14[a] |
| Quinic (µg $g^{-1}$ DM) | 65.75 ± 2.31[a] | 0.00[b] |
| Succinic (µg $g^{-1}$ DM) | 0.00[b] | 1.45 ± 0.08[a] |
| Lactic (µg $g^{-1}$ DM) | 0.44 ± 0.01[a] | 0.00[b] |

Data are the mean of five replicates ± standard deviation. Same letters in rows do not differ by the Scott-Knott test (P < 0.05). Moisture contents of baru almonds, in g 100 $g^{-1}$: Lyophilized = 2.35 ± 0.10; Roasted = 6.86 ± 0.09.

various foods popularly referred to as sources of iron and described in Brazilian Food Database (2011), such as cooked beets (2.13 mg), braised collard greens (2.70 mg), braised spinach (4.48 mg), raw lentils (7.91 mg) and raw beans (black - 7.64 mg), highlighting the potential use of baru almonds as a food supplement.

The contents of phenolic compounds, flavonoids, TSS, TTA, pH and organic acids in lyophilized and roasted baru almonds are described in Table 3.

The roasting process decreased the contents of phenolic compounds (30%) and flavonoids (83.28%) in the samples, in relation to the lyophilized sample. Such reduction may have occurred due to factors associated with processing, since heating can lead to the degradation of this class of compounds.

Several epidemiological studies show that phenolic compounds have multiple biological effects, such as antioxidant, anti-allergic, anti-inflammatory, anti-bacterial, antithrombotic, cardioprotective and vasodilatory (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 lyophilized sample showed a higher content of TSS (3.26° Brix) than the roasted one (2.47° Brix), which is consistent with the contents of the glycidic fraction, that were lower in roasted samples (Table 1). No significant difference between the values of TTA (5.85 and 5.85) and pH (6.50 and 6.59) was observed in lyophilized and roasted almonds, respectively (Table 3).

The determination of organic acids in lyophilized and roasted baru almonds showed citric acid as a major

**Table 4.** FA composition (%) of lyophilized and roasted baru almonds.

| FA | Lyophilized baru | Roasted baru |
|---|---|---|
| C14:0 | 0.17 ± 0.01[a] | 0.17 ± 0.01[a] |
| C15:0 | 0.16 ± 0.01[b] | 0.96 ± 0.01[a] |
| C16:0 | 7.70 ± 0.02[a] | 7.73 ± 0.03[a] |
| C18:0 | 4.93 ± 0.30[a] | 4.62 ± 0.02[a] |
| C18:1n9c | 49.81 ± 1.01[a] | 45.66 ± 2.03[b] |
| C18:1n9t | 0.08 ± 0.01[b] | 0.57 ± 0.01[a] |
| C18:2n6 | 25.25 ± 1.03[a] | 22.90 ± 1.31[a] |
| C20:0 | 0.94 ± 0.02[a] | 0.94 ± 0.01[a] |
| C18:3n3 | 2.39 ± 0.03[a] | 1.82 ± 0.03[b] |
| C20:3n3 | 2.36 ± 0.04[b] | 2.66 ± 0.02[a] |
| C20:4n6 | 1.87 ± 0.04[a] | 1.80 ± 0.01[b] |
| C20:4n6 | 1.80 ± 0.20[b] | 2.46 ± 0.04[a] |
| C20:5n3 | 1.89 ± 0.20[b] | 2.39 ± 0.06[a] |
| C22:5n3 | 0.42 ± 0.01[b] | 1.06 ± 0.01[a] |
| C22:6n3 | 0.30 ± 0.01[b] | 0.33 ± 0.01[a] |
| ∑SFA | 13.90 ± 1.00[a] | 14.42 ± 0.03[a] |
| ∑MUFA | 49.89 ± 2.13[a] | 46.23 ± 3.02[a] |
| ∑PUFA | 36.28 ± 2.45[a] | 35.42 ± 3.01[a] |
| PUFA/SFA | 1.37 ± 0.03[a] | 1.30 ± 0.01[b] |
| ω-6 /ω-3 | 3.92 ± 1.00[a] | 3.28 ± 0.13[a] |

Data are the mean of five replicates ± standard deviation. Same letters in rows do not differ by the Scott-Knott test ($P < 0.05$). ∑SFA = sum of saturated FA; ∑MUFA = sum of monounsaturated FA; ∑PUFA = sum of polyunsaturated FA; PUFA/SFA = ratio between the sum of polyunsaturated and saturated acids; ω-6 /ω-3 = ratio between the sum of omega-6 and omega-3. Moisture contents of baru almonds, in g 100 $g^{-1}$: Lyophilized = 2.35 ± 0.10; Roasted= 6.86 ± 0.09.

component in both samples, and the roasted sample showed the highest content (500.70 µg $g^{-1}$ DM), which was also observed for maleic acid. Quinic acid was observed at a low concentration in the lyophilized sample, and was not detected in the roasted sample. It is believed that, during the roasting process, the temperature rise has promoted deacetylation and subsequent loss of water molecules, and its degradation product was not observed in the roasted sample, due to the absence of the pattern (Table 4).

The emergence of succinic acid in the sample that underwent the roasting process can be attributed to the hydrogenation process since, even after lyophilization, the sample retained a small amount of water, as well as the low concentration of lactic acid, a fermentation product, observed in the lyophilized sample, also reflects the presence of significant amounts of water in the sample.

Fifteen FA were detected in lyophilized and roasted baru almonds, with oleic (C18:1n9c; 49.81 and 45.66%) and linoleic (C18:2; 25.25 and 22.90%) as the major ones, respectively (Table 4). It was also observed that the roasting process for some FA induced an increase in their contents and, for others, a reduction, but without statistical significance.

The total amount of FA was, on average, 13.90 and 15.00% for saturates, 49.89% and 48.12 for monounsaturates and 36.28 and 36.86% for polyunsaturates, for lyophilized and roasted baru almonds, respectively. On the other hand, the ratio polyunsaturated/saturated (PUFA/SFA) was, on average, 1.37 and 1.30, and ω-6/ω-3, 3.92 and 3.28, with a higher percentage of unsaturated FA, compared to the saturated ones.

The contents of oleic and linoleic acid, in the samples of this study, were similar to those found in other studies, such as those conducted by Takemoto et al. (2001) (oleic, 50.40%; linoleic, 28.00%) and Vera et al. (2009) (oleic, 47.15%; linoleic, 25.51%), which also describe oleic and linoleic acids as the majority in baru almonds.

Diets that present the ratio PUFA/SFA superior to 0.45 and the ratio ω-6/ω-3 inferior to 5 (Simopoulos, 2002) are considered healthy for humans, from a nutritional point of view. Considering that the FA composition of lyophilized and roasted baru almonds was within the recommendations, these seeds can be considered good dietary sources.

The electrophoretic profile on polyacrylamide gel with samples of defatted baru flour, lyophilized and roasted, prepared under reducing conditions (with the addition of

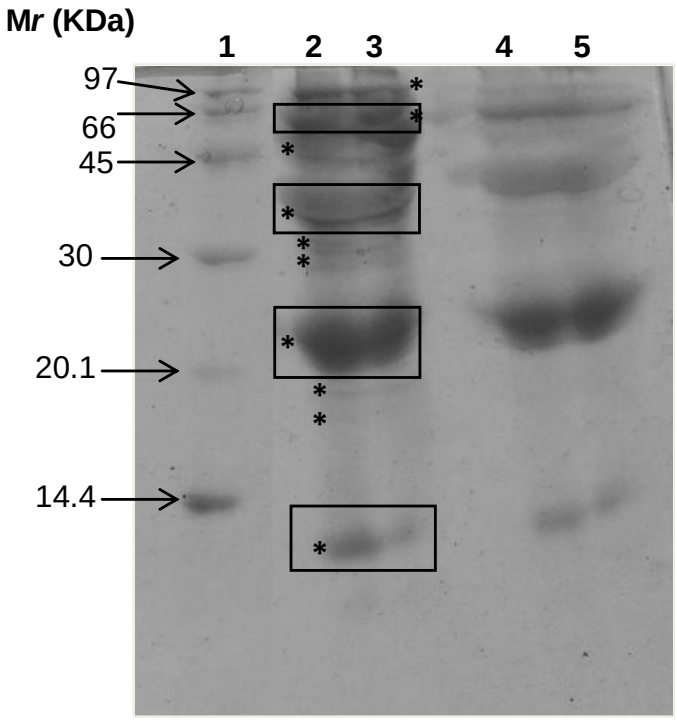


**Figure 1**. Electrophoresis on polyacrylamide gel in the presence of SDS (SDS-PAGE). Samples prepared under reducing conditions: **1-** Molecular weight standard (α-lactalbumin, 14.4 KDa; trypsin inhibitor, 20.1 KDa; carbonic anhydrase, 30 KDa; egg albumin, 45 KDa; bovine albumin, 66 KDa; phosphorylase β, 97 KDa; **2-** Lyophilized baru (10 µl); **3-** Lyophilized baru (20 µl); **4-** Roasted baru (10 µl); **5-** Roasted baru (20 µl). *Bands considered for the calculation of the values of relative mass in protein profiles. Boxes indicate the majority bands, highlighting a higher content of proteins with high and medium molecular weight.

β-mercaptoethanol and boiling) is shown in Figure 1, and the M*r* values, calculated based on the migration distances of proteins of the molecular weight standard, are shown in Table 5.

Observing Figure 1 and based on the intensity of staining, it is possible to note a larger amount of proteins with a molecular weight between 97 and 20 KDa. Although protein quantitation has resulted in higher values for roasted samples, the electrophoretic profile highlights a smaller number of types of protein molecules and in a smaller amount in the roasted sample, compared to the lyophilized, since a smaller amount of bands is observed and they still have a less intense staining. It is suggested that the roasting process has resulted in fragmentation of proteins and small molecules, possibly with a M*r* inferior to 4.0 KDa, as well as with free amino acids, which could not be observed on the electrophoresis gel, although they are detectable by the protein quantitation method, since it quantifies the nitrogen present in the samples.

Table 5 shows values calculated based on the migration distances of proteins in each sample evaluated (lyophilized baru and roasted baru); however, the small changes observed in molecular weight correspond to methodological problems related to the run, for example, very high voltage, with characteristic bands that can be visualized in both profiles (Figure 1), corresponding to the same types of protein molecules.

## Conclusion

*D. alata* Vog. (baru) almonds constitute a significant source of lipids, proteins, dietary fiber and minerals, besides having some bioactive compounds that provide health benefits. Thus, the use of this almond is suggested to enrich the diet, and it can also be used in the preparation of various food products.

The roasting process resulted in samples containing higher levels of lipids, proteins, phosphorus, calcium, magnesium, copper, zinc and iron. However, it led to a decrease in the levels of phenolic compounds, flavonoids, protein digestibility and number of types and amount of proteins from the protein profile observed on

**Table 5.** Migration distance and relative mass (M*r*) of the protein profile of lyophilized and roasted baru almonds.

| Lyophilized baru | | Roasted baru | |
|---|---|---|---|
| **Migration distance (cm)** | **M*r* (KDa)** | **Migration distance (cm)** | **Mr (KDa)** |
| 9.31 | 14.72 | nd | nd |
| 6.32 | 19.01 | nd | nd |
| 5.37 | 21.17 | 8.84 | 14.23 |
| 3.86 | 26.34 | 4.97 | 22.38 |
| 3.57 | 26.75 | nd | nd |
| 3.36 | 28.87 | 3.68 | 27.18 |
| 2.75 | 32.92 | nd | nd |
| 1.75 | 44.42 | 1.77 | 44.09 |
| 1.19 | 57.32 | 0.90 | 68.94 |
| 0.50 | 101.66 | 0.45 | 108.99 |

nd: Not detected.

the electrophoresis gel.

The knowledge of these chemical constituents and of different ways of processing this almond contributes to its better use, either by the population or by the food industry, resulting in a greater use and economic value of this fruit from the Brazilian *Cerrado*.

## Conflict of Interests

The authors have not declared any conflict of interests

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