Tucum-do-Pantanal (*Bactris setosa* Mart.): Physicochemical Characterization of Almonds, Press Cake and Crude Oil

Leonardo Recena Aydos
https://orcid.org/0000-0002-9883-5094

Luane Aparecida do Amaral
https://orcid.org/0000-0002-1448-2472

Gabriel Henrique Oliveira de Souza
https://orcid.org/0000-0002-6378-2930

Leandro Fontoura Cavalheiro
https://orcid.org/0000-0002-9962-8521

Márcio Olívio Figueiredo Vargas
https://orcid.org/0000-0002-5861-3198

Bruna Paola Murino Rafacho
https://orcid.org/0000-0001-8825-6980

Carlos Eduardo Domingues Nazário
https://orcid.org/0000-0001-5097-3298

Rodrigo Juliano Oliveira
https://orcid.org/0000-0003-3514-3346

Maria Ligia Rodrigues Macedo
https://orcid.org/0000-0002-6063-0763

Elisvânia Freitas dos Santos
https://orcid.org/0000-0002-1528-6035

1 Federal University of Mato Grosso do Sul, Faculty of Medicine, Postgraduate Program in Health and Development in the Midwestern Region, Campo Grande, Mato Grosso do Sul, Brazil; 2 Federal University of Mato Grosso do Sul, Graduating in Food Technology at the Faculty of Pharmaceutical Sciences, Food and Nutrition, Campo Grande, Mato Grosso do Sul, Brazil; 3 Federal University of Mato Grosso do Sul, Institute of Chemistry, Postgraduate Program in Chemistry, Campo Grande, Mato Grosso do Sul, Brazil; 4 Federal University of Mato Grosso do Sul, Technician in Physics-Chemistry at the Faculty of Pharmaceutical Sciences, Food and Nutrition, Campo Grande, Mato Grosso do Sul, Brazil. 5 Federal University of Mato Grosso do Sul, Associate Professor at the Faculty of Pharmaceutical Sciences, Food and Nutrition, Postgraduate Program in Pharmaceutical Sciences, Campo Grande, Mato Grosso do Sul, Brazil. 6 Adjunct Professor at the Federal University of Mato Grosso do Sul at the Institute of Chemistry, Postgraduate Program in Chemistry, Campo Grande, Mato Grosso do Sul, Brazil. 7 Federal University of Mato Grosso do Sul, Faculty of Medicine, Program in Health and Development in the Midwestern Region, Stem Cell, Cell Therapy and Toxicological Genetics Research Centre, Maria Aparecida Pedrossian, University Hospital, Brazilian Hospital Services Company, Campo Grande, Mato Grosso do Sul, Brazil; 8 Federal University of Mato Grosso
do Sul, Director of the Faculty of Pharmaceutical Sciences, Food and Nutrition, Postgraduate Program in Health and Development in the Midwestern Region, Campo Grande, Mato Grosso do Sul, Brazil; 9 Federal University of Mato Grosso do Sul, Associate Professor at the Faculty of Pharmaceutical Sciences, Food and Nutrition, Postgraduate Program in Health and Development in the Midwestern Region, Campo Grande, Mato Grosso do Sul, Brazil.

Received: 2018.08.08; Accepted: 2019.07.08.

*Correspondence: elisvania@gmail.com; Tel.: +55-67-81155325 (E.F.S.)

HIGHLIGHTS

- Interest in vegetable oils has increased in recent years and it is important to find ways to reuse their byproducts with nutritional properties.
- The Tucum (Bactris setosa Mart.) is a palm fruit native to the Pantanal with nutritional and functional potential.
- In Physical chemical characterization of this almond, press cake and crude oil of this fruit.
- Possible applicability of products and byproducts of this species of palm

Abstract: Brazil has high diversity of native fruits with high nutritional and biochemical value. Bactris setosa Mart. (tucum-do-Pantanal) stands out by its oil-rich almond. This study aimed to determine the physicochemical characteristics of tucum-do-Pantanal almond and its by-products: press cake and crude oil. The almond of tucum-do-Pantanal had total weight of 0.81g, larger diameter 10.87mm, small diameter 8.21mm, height 12.50, weight of almond 0.38g, weight of endocarp 0.25g. In relation to the chemical analysis, the cake had higher ash, protein and carbohydrate contents than the almond. On the other hand, the content of moisture, lipids and calories were higher in the almond. The press cake showed 636.80 g kg\(^{-1}\) of total fiber. The fatty acids that predominated in tucum-do-Pantanal oil were lauric (58.48), myristic (12.59) and oleic (10.15%) acids. The oil of tucum-do-Pantanal had an acid index of 3.01 KOH / g, peroxide index of 4.84 meq / kg, saponification index of 140.91 mg KOH / oil g, iodine index of 3.72 gI\(_2\) / 100 g, refractive index of 1.46, density of 0.92 g / mL, water content of 493.11 ppm and oxidation stability of 32.01 h. The results suggest that tucum-do-Pantanal almond as an important source of oil, calories and fibers, with potential use in the food industry.

Keywords: Food analysis; Fatty acids; Tucum-do-Pantanal; Pantanal.
INTRODUCTION

The introduction should briefly place the study in a broad context and highlight why it is important. It should define the purpose of the work and its significance. The current state of the research field should be reviewed carefully and key publications cited. Please highlight controversial and diverging hypotheses when necessary. Finally, briefly mention the main aim of the work. References should be numbered in order of appearance and indicated by a numeral or numerals in square brackets, e.g., [1] or [2,3], or [4–6]. See the end of the document for further details on references.

Brazil holds one of the most extensive collections of animal and plants species in the world. It stands out for the richness of native fruits that offer high nutritional, functional and biochemical value, as well as sensory attractions such as color, flavor and intense and peculiar aromas. This high diversity of species, especially in the Cerrado and Pantanal regions, has encouraged studies identifying the nutritional, sensorial and functional potential of native fruits, in order to explore commercial value and use of the fruits [1–3].

The tucum-do-Pantanal is a palm fruit found in the Pantanal wetlands. It is popularly known as tucum, jacum, tucum-bravo, tucum-do-brejo, tucum-de-espinho, uva-do-mato, tucum-amarelo and coco-de-natal [4]. This fruit is divided into peel, pulp and almond. It is found in bunches, with fibrous, succulent and sweet pulp. When mature, the tucum peel has a dark red or purple coloration due to the large amount of anthocyanins [5]. Duarte et al. [6] report the use of tucum almond in the manufacture of necklaces. Boeing et al. [7] indicate the presence of antioxidant compounds in the extract of this almond and suggest further studies to know and elucidate the potential of the tucum almond.

Most palm trees have oleaginous potential. Some of the palm tree fruits offer significant amounts of oil in the fruit pulp (mesocarp), others in the seed, or both. When it comes to almond oil, most are rich in lauric acid (saturated) [8]. Almonds can be used for oil extraction, a process that produces a residue known as press cake. This residue offers great industrial potential due to its high content of proteins and fibers. Thus, the press cake can be used in the formulation of concentrates and isolates of protein or fibers by adding value and favoring the development of new products [9,10].

Previous studies observed the potential use of by products of fruits [11,12]. Pimentel et al. [12] studied palm kernel cake in the diet of lactating crossbred cows in confinement and found economic gains in the production. Pinelli et al. [13] found high dietary fiber, calcium and
iron content, presence of polyphenols and antioxidant activity in partially defatted flour of Baru (*Dipteryx alata*), suggesting an alternative with good sensory acceptability and nutrient value in substitution of wheat flour in cookies. Bhise *et al* [14] used sunflower, soybean and flaxseed texturized defatted flour in noodles and observed improved taste, fiber and protein content, and better protein digestibility. In health studies, Chen *et al* [15] observed that mice treated with defatted walnut meal hydrolysate presented improvement in learning and memory. Carvalho *et al* [16] observed that partially defatted Brazil nut flour ameliorated the lipidemic profile in dyslipidemic and hypertensive patients.

To our knowledge, no studies were found about the characterization of the tucum-do-Pantanal almond and its by-products. Also, there is still no commercial use of the Tucum nut, except for the pulp. Presenting the potential use and socioeconomic importance of these species is the most rational strategy to guarantee the preservation of native species. Thus, studies that value the native fruits found in the Pantanal region are extremely important for the sustainable development of the region, by improving the source of income of family farmers and extractivists who market ‘in natura’ and processed fruits [11].

Taking into consideration all these potential benefits, this study aimed to provide informations about physicochemical characteristics of tucum-do-Pantanal almond and its by-products press cake and crude oil.

**MATERIAL AND METHODS**

**Fruit collection, identification and processing**

About 20 kg of mature fruits of tucum palm were collected at the Pantanal Study Base of the Federal University of Mato Grosso do Sul (UFMS) (18°34'35,6"S e 57°01'05,6"W). The transport to the UFMS food processing laboratory was carried out in polyethylene bags. For botanical fruit identification, specimens were deposited in the UFMS Herbarium under the CGMS identification number 48441 and SISGEN A23EE4B. The fruit selection for the processing obeyed the pattern of healthy fruits, no defects, free of parasites and presenting advanced maturation; then followed by washing in running tap water. The fruits were frozen at -18 °C in a standard freezer. Still frozen, fruits were manually depulped with the aid of a stainless steel knife. The yield of almond with endocarp was 41.59%.

**Physical analyses**

One hundred randomly selected almonds underwent physical analysis. The largest diameter, smallest diameter, and height were measured using a digital caliper (ZAA-1-0004, Zaas Precision®, Brazil). The almond and its endocarp were weighed on an analytical balance (Prix AS 220 R2, AND®, Japan).

**Almond processing, oil extraction and press cake**

The tucum-do-Pantanal has a dark and strong peel that covers the almond (endocarp) (Figure 1). Samples were dried in a ventilated greenhouse (TE-394/3, Lawes®, Brazil) at 40°C for 3 hours to facilitate peel removal and then, processed in an industrial multiprocessor (Super Cutter, Sire®, Brazil). The almond was milled with a knife mill (MA 340/A, Marconi®, Brazil) to form a flour. This flour was crushed again in a multipurpose mill (TE 631/1, Tecnal®, Brazil) and sieved in Tyler 28 tamis (Bertel®, Brazil) until obtaining a powder.

The almond flour of tucum-do-Pantanal underwent continuous oil extraction with hexane solvent PA (Vetec®) (1: 3 w / v) until sample exhaustion. The product was filtered and concentrated to remove the solvent on a rotary evaporator (802, Fisatom®, Brazil) at 40°C and then taken to the fume hood (CE0730, Permution®, Brazil) for complete solvent evaporation. The extracted oil was stored in amber glass at 4°C until further physicochemical analysis. The press cake also underwent evaporation. The material was then packed in polyethylene plastic and kept under refrigeration at 4°C until physicochemical analyses [17].
Characterization of tucum-do-Pantanal

Chemical properties of almond in natura and press cake

The following parameters were obtained in triplicate:

- Moisture - determined in an oven at 105°C until constant weight;
- Ash - the samples were charred and then calcined in a muffle furnace at 550°C;
- Total lipids - by the Soxhlet method with extraction by petroleum ether;
- Proteins - through the total nitrogen content of the sample by the Kjeldahl method and determined at the semimicro level [18]. The nitrogen to protein conversion factor of 5.18 was used (AOAC 950.48/1950);
- Dietary fiber - through the AOAC method 985.29 [18].
- Carbohydrates - by theoretical calculation (by difference) of the results of triplicates, according to the formula: % Carbohydrates = 100 - (% moisture + % protein + % lipids + % ashes +% dietary fiber);
- Total caloric value (kcal) - calculated by the following values: lipids (9.03 kcal/g), protein (4.27 kcal/g) and carbohydrates (3.82 kcal/g) [19].

Crude oil - chemical properties

The composition of fatty acids was determined by esterification through the method of Maia and Rodriguez-Amaya, [20] and followed by gas-liquid chromatography, a method recommended by AOCS [21].

Analyses were carried out on Shimadzu® (Brazil) gas chromatograph model GC 2010. A BPX-70 column 30m x 0.25mm i.d., 0.25µm with a stationary phase of 70% cyanopropyl polysilphenylene siloxane was used. A split injector was used at 250 °C with 50:1 split ratio. Analyses were performed with the FID type detector at 250°C. The temperature ramp was initially 80°C remaining for 3 min during analyses. Thereafter, the temperature ramp increased at a rate of 10°C/min until 140°C, continuing to increase at a rate of 5°C/min until 240°C, thereby remaining for 5min.

Figure 1. Almond of tucum-do-Pantanal. (a) almond with endocarp; (b) whole almond; (c) almond with partially apparent endocarp; (d) cut almond.
For compounds identification, a standard with 37 FAMEs of the supelco was used, comparing the compound retention times with those of the samples. Quantification was performed by area normalization and expressed as a percentage.

**Crude oil - physicochemical properties**

Physical analyses of density were performed by direct reading in densimeter digital (DMA 4500, Anton Paar®, Austria) and refractive index by reading in Abbé refractometer (RL3, TecnaL®, Brazil). Physicochemical analyses of water content, peroxide index, acid index and saponification index were performed according to the procedure described by AOCS [21] official methods. The iodine index was determined by theoretical calculation by fatty acid determination. Oxidative stability was measured by the Metrohm® (Switzerland) Rancimat Biodiesel 873 equipment. The increase in water conductivity were continually measured, while air (10 L/h) was bubbled into each oil (5 g) heated to 110 ºC and their volatile compounds were collected in water. The time taken to reach the conductivity inflection time was recorded. The moisture content was measured by Karl Fischer Coulometric Titration (MKC-710B, KEM®, Japan).

**Statistical analysis**

All analyses were performed in triplicate and the data expressed as a mean ± standard deviation. The results between almond and press cake were compared using Student's t-test at 5% significance, GraphPad Prism ® software, version 6.

**RESULTS AND DISCUSSION**

Table 1 shows the results of the physical characterization of tucum-do-Pantanal, relevant aspects that contribute to the distinction of species of the same genus. In comparison with the tucum, the pyrene (*Bactris maraja* Mart.) weights almost three times less [22]. The almond weight of tucum-do-Pantanal corresponds to 60.32% and its endocarp to 39.68% (Figure 1). The almond percentage is higher than that of Brazil nut (48%) [23].

| Parameters        | Mean ± SD¹ |
|-------------------|------------|
| Total weight (g)  | 0.81±0.08  |
| Large diameter (mm)| 10.87±1.14 |
| Small diameter (mm)| 8.21±0.80  |
| Height (mm)       | 12.50±1.31 |
| Nut weight (g)    | 0.38       |
| Endocarp weight (g)| 0.25      |

¹ Mean of 100 analyzed units; SD: standard deviation.

The Arecaceae family has considerable heterogeneity due to the diversity of species, climate and soil type, considered the greatest predictor of floristic change, thus justifying differences in size, weight and fruit composition [23,24].

Chemical analyses of the almond flour and press cake are described in table 2. All parameters differed statistically (p <0.05). There is a low content of proteins in the almond (6.24%) and press cake (8.85%), unlike the pequi almond (29.65%), baru almond (29.92%), [25] peanut press cake (38.04%), [26] and bocaiuva press cake (17.58%) [27]. In this way, tucum-do-Pantanal press cake may not be feasible for preparing protein supplements.
Table 2. Chemical analysis of tucum-do-Pantanal press cake flour and almond flour.

| Parameters                  | Almond Mean ± SD | Press cake Mean ± SD¹ |
|-----------------------------|------------------|-----------------------|
| Moisture (g kg⁻¹)           | 93.22±1.44⁴      | 83.56±1.87⁵           |
| Ash (g kg⁻¹)                | 12.10±0.05⁵      | 17.11±0.28⁴           |
| Protein (g kg⁻¹)            | 51.73±1.64⁵      | 73.35±0.11⁴           |
| Lipid (g kg⁻¹)              | 278.48±0.23⁴     | 36.31±0.98⁵           |
| Carbohydrate (g kg⁻¹)       | 564.47±2.97⁴     | 789.68±2.65⁴          |
| Total energy value (kcal. g kg⁻¹) | 4891.83±5.65⁴ | 3657.60±8.36⁵         |
| Total fiber (g kg⁻¹)        | -                | 636.80±1.13           |

SD: standard deviation. Values are mean of three replicates. Distinct letters indicate significant difference by Student's t-test (p ≤ 0.05).

The concentration of 27.84% lipid in the tucum almond shows that this macronutrient is the main compound in the mesocarp of this fruit (Table 2). This feature contributes considerably to its high energy value.

The Food and Nutrition Board of the Institute of Medicine [28] recommends the adult daily intake of approximately 40 to 80g of lipids (20 to 35% of the energy of a 2000 calorie diet). Based on the average of 40g of lipids for adults, 100g of tucum-do-Pantanal almonds provide about 34.8% of the daily intake of lipids. On the other hand, the high lipid content may interfere with the shelf-life of this almond, due to the oxidation process that may cause the product to become rancid [29].

The fiber was the prominent macronutrient in the press cake. Each 100g of tucum-do-Pantanal almond press cake had approximately 64% of fibers (Table 2). From this result, one can state that the tucum-do-Pantanal almond press cake has high fiber content and potential for use in the food industry as a source of fibers. In this way, we suggest its addition in light products such as yogurts, ice creams, pastries, cakes and bread, since the percentage of lipids in the press cake is low and its flavor is similar to that of coconut. The use of the tucum almond press cake might produce good quality foods with high nutritional value and satisfactory sensory results [30]. In addition, the amount of fibers can contribute to protection against chronic non-communicable diseases and intestinal constipation [31].

The tucum almond oil showed 23 different fatty acids (Table 3). The crude oil of tucum-do-Pantanal presented 86.91% of saturated fatty acids, being 58.48% lauric acid. Lauric acid is also present in significant amounts in coconut (38.6%) and babassu (57.5%) [32].
**Table 3.** Fatty acid profile of tucum-do-Pantanal crude oil.

| Fatty acids/Carbon number       | Mean±SD (%) |
|--------------------------------|-------------|
| Caprylic Acid (C8:0)           | 2.40±0.10   |
| Capric Acid (C10:0)            | 4.57±0.15   |
| Lauric Acid (C12:0)            | 58.48±0.31  |
| Myristic Acid (C14:0)          | 12.59±0.23  |
| Palmitic Acid (C16:0)          | 5.86±0.05   |
| Stearic Acid (C18:0)           | 3.02±0.07   |
| Oleic Acid (C18:1n9c)          | 10.15±0.21  |
| Linoleic Acid (C18:2n6c)       | 2.53±0.01   |
| Saturated                      | 86.91±0.37  |
| Monounsaturated                | 10.15±0.21  |
| Polyunsaturated                | 2.53±0.01   |
| Not identified                 | 0.40±0.57   |

Values are mean of two replicates. SD: standard deviation

Lauric acid is a medium-chain fatty acid that has been shown to protect against obesity and osteoarthritis [33]. Moreover, it has been demonstrated its high antimicrobial activity against gram-positive bacteria and some viruses and fungi [34]. The tucum almond oil showed a 12.59% of myristic acid. Recently Takato *et al.* [35] reported that a 300 mg/kg oral administration of myristic acid in mice, improved congenital type 2 diabetes, by markedly improving hyperglycemia and insulin resistance.

Taking into consideration the increase in the search for fresh vegetable oils in cooking, mainly due to healthier eating habits, the consumption of tucum-do-Pantanal oil is promising. In addition, this almond oil can be applied in the production of fatty acids, glycerin, lubricants, fuels, biodiesel, and numerous other applications [36].

Table 4 shows the physicochemical characterization of tucum almond oil. Some parameters evaluated as acidity index and peroxide index are the gold standard in determining the quality of oils. On the other hand, the saponification index, refractive index, iodine index and relative density are related to the chain length and number of particular unsaturation of each vegetable oil [37].

**Table 4.** Physicochemical characterization of tucum-do-Pantanal crude oil.

| Parameters                                    | Mean±SD     |
|-----------------------------------------------|-------------|
| Acid index (KOH/g)                            | 3.01±0.21   |
| Peroxide index (meq/kg)                       | 4.84±0.63   |
| Saponification index (mg KOH/g of oil)        | 140.91±0.00 |
| Iodine index (gI2/100g)                       | 3.72±0.18   |
| Refractive index (20°C)                       | 1.46±0.00   |
| Density (g/mL)                                | 0.92±0.04   |
| Water content (ppm)                           | 493.11±10.19|
| Oxidation stability (h)                       | 32.01±1.24  |

Values are mean of three replicates. SD: standard deviation
The acidity index indicates the oil deterioration through the presence of free fatty acids released through the triacylglycerols hydrolysis, which may occur through heating or exposure to light, giving the product rancid appearance [37,38]. Tucum-do-Pantanal oil showed lower acidity index (3.01 KOH/g) than that of tucumã fruit (5.47 KOH/g), [39] belonging to the same family. A high acidity index indicates the oil is suffering breaks in its chain, releasing fatty acids. Therefore, one can state this oil was not in the process of deterioration [38].

The beginning of rancidification process of oils and fats produces peroxides. Thus, the quantification of these compounds enables to identify products that are not suitable for consumption [40]. The Codex Alimentarius [41] recommends the peroxide index of less than 15meq/kg for cold pressed and unrefined oils, such as tucum-do-Pantanal almond oil, which meets this recommendation.

The saponification index allows us to verify the properties of oils and vegetable fats, as well as to determine their degree of deterioration [42]. The value found in this study (140mgKOH/g) meets the thresholds recommended for coconut oil (248-265mgKOH/g) and babassu (245-256mgKOH/g) [41].

The Iodine Index is a parameter related to the measure of unsaturation of an oil or a fat [37]. The higher the degree of unsaturation in the carbon chain, the more susceptible the oxidative rancidity [43]. The value found in this study was lower (3.72gI2/100g) than that recommended by the Codex Alimentarius [41] for babassu oil (10-18gI2/100g) and coconut oil (6.3-10.6gI2/100g). Thus, the tucum almond oil has less unsaturation than the oils mentioned above.

The refractive index measures the degree of saturation of oils and fats by the ratio of the speed of light in the vacuum to the speed of light in the analyzed substance, while the density determines the mass/volume ratio of oils and fats [44]. The refractive index and density of the tucum almond oil (Table 4) were similar to those found by Ferreira et al [39] when studying tucumã: 1.46 and 0.91 g/mL, respectively. In addition, these findings are close to the values specified for coconut oil (1.44-1.45 and 0.90-0.92 g/mL) [41].

Some analyses are necessary for using vegetable oils in the production of biodiesel, including the water content. This parameter is related to biodiesel hydrolysis that results in free fatty acids, the proliferation of microorganisms and corrosion in storage tanks. The limit of water content allowed by the Brazilian National Agency for Petroleum, Natural Gas and Biofuels [45] is 500ppm and the tucum-do-Pantanal almond oil is in compliance (493,11ppm) with those parameters.

Oxidative stability is related to the degree of oil unsaturation, which justifies the long time (32.01 h) spent with tucum-do-Pantanal almond oil (Table 4) due to the various saturated bonds. Corsini and Jorge, [43] found even higher values for palm oil (141.34 h at 100ºC), while the findings for cotton oil (26.17 h at 100ºC) were similar to the present study. Buriti (Mauritia flexuosa), other brazilian native fruit, also had a high oxidative stability oil of 69.26 h at 100ºC [46].

**CONCLUSION**

The tucum-do-Pantanal almond showed a high content of lipids and calories, while the press cake showed high fiber content, but low protein content. The crude oil of...
tucum-do-Pantanal almond has a high amount of saturated fatty acids; mainly lauric acid that can aid in the treatment of diseases and microbial inhibition. Furthermore, the tucum-do-Pantanal almond has high applicability in the elaboration of products and as an ingredient in the food and biodiesel industries. These findings highlight the importance of studies on native fruits and show new food options sources of essential nutrients for health.

**Funding:** "This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001"

**Conflicts of Interest:** The authors declare no conflict of interest.

**REFERENCES**

1. da Cunha MSB, Arruda SF. Tucum-do-Cerrado (Bactris setosa Mart.) may promote anti-aging effect by upregulating sirt1-nrf2 pathway and attenuating oxidative stress and inflammation. Nutrients. 2017;9:1-17. doi:10.3390/nu9111243.

2. Vieira PAZ, Scheidt RV, Santos MMR, Cândido CJ, Santos EF, Novello D. Cupcakes added bocaiuva flour: characterization physico-chemical and sensory evaluation among children. Revista da Universidade Vale do Rio Verde. 2017;15:501-13. doi:10.5892/ruvrd.v15i2.2943.

3. Cunha FC, Siqueira I, Pelegrin JO, Souza AVOM, Vasconcelos MP, Candido CJ, Santos EF, Hiane PA, Sanches FLFZ. Development of cereal bars using bacuri pulp flour for spostsmen: nutritional composition and sensory acceptability. IJDR. 2018;8:18947-53.

4. Leitman P, Soares, K, Henderson A, Noblick L, Martins RC. Arecaaceae in Lista de Espécies da Flora do Brasil [Internet]. Rio de Janeiro: Instituto de Pesquisas Jardim Botânico de Curitiba. [updated 2015 Jan 27; cited 2018 Nov 6]. Available from: http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB15698.

5. Rosa FR, Arruda AF, Siqueira EM, Arruda SF. Phytochemical compounds and antioxidant capacity of tucum-do-cerrado (Bactris setosa Mart), Brazil's native fruit. Nutrients. 2016;8:110-27. doi:10.3390/nu8030110.

6. Duarte AYS, Queiroz RS, Sanches RA, Garcia CR, Dedini FG. Ethnobotany of Natural Fibres – Bactris setosa (tucum) in a Traditional Rural Community. Fibres & Textiles in Eastern Europe. 2012;20:18-20.

7. Boeing JS, Ribeiro D, Chisté RC, Visentainer JV, Costa VM, Freitas M, Fernandes E. Chemical characterization and protective effect of the Bactris setosa Mart. Fruit against oxidative/nitrosative stress. Food Chem. 2017;1:427-37. doi:10.1016/j.foodchem.2016.09.188.

8. Clement CR, Lleras E, Van Leeuwen J. The potential of tropical palm trees in Brazil: The successes and failures of the last decades. Agrociencia. 2005;1:67-71.

9. Glória MM, Regitano-D’Arce MAB. Brazil nut protein concentrate and isolate production: chemical and functional properties. Ciência Tecnol Alim. 2000;2:240-5. doi:10.1590/S0101-20612000000200019.

10. Nunes AA, Favaro SP, Miranda CHB, Neves VA. Preparation and characterization of baru (Dipteryx alata Vog) nut protein isolate and comparison of its physico-chemical properties with commercial animal and plant protein isolates. J Sci Food Agric. 2016;97:151-7. doi:10.1002/jsfa.7702.

11. Negri TC, Berni PRA, Brazaca SGC. Nutritional value of native and exotic fruits from Brazil. Biosãude. 2016;18:82-96.
12. Pimentel LR, Silva FF, Silva RR, Schio AR, Rodrigues ESO, Costa LT. Economic viability of including palm kernel cake in diets for feedlot lactating cows. Acta Scientiarum. 2016;38:319-25. doi:10.4025/actascianimsci.v38i3.31150.

13. Pineli LLO, Carvalho MV, Aguiar LA, Oliveira GT, Celestino SMC, Botelho RBA, Chiarello MD. Use of baru (Brazilian almond) waste from physical extraction of oil to produce flour and cookies. LWT. 2015;60:50-5. doi:10.1016/j.lwt.2014.09.035.

14. Bhise S, Kaur A, Aggarwal P. Development of protein enriched noodles using texturized defatted meal from sunflower, flaxseed and soybean. J Food Sci Technol. 2015.52:5882–9. doi:10.1007/s13197-014-1630-1.

15. Chen H, Zhao M, Lin L, Wang J, Sun-Waterhouse D, Dong Y, Zhuang M, Su G. Identification of antioxidative peptides from defatted walnut meal hydrolysate with potential for improving learning and memory. Food Research International. 2015;78:216-23. doi:10.1016/j.foodres.2015.10.008

16. Carvalho RF, Huguenin GVB, Luiz RR, Moreira ASB, Oliveira GMM, Rosa G. Intake of partially defatted Brazil nut flour reduces serum cholesterol in hypercholesterolemic patients - a randomized controlled trial. Nutrition Journal. 2015.14:1-9. doi:10.1186/s12937-015-0036-x.

17. Lima FF, Traesel GK, Menegati SEMT, Santos AC, Souza RIS, Oliveira VS, Sanjinez-Arqandoa EJ, Cardoso CAL, Oesterreich SA, Vieira MC. Acute and subacute oral toxicity assessment of the oil extracted from Attalea phalerata Mart ex Spreng. pulp fruit in rats. Food Res Int. 2017;91:11-7. doi:10.1016/j.foodres.2016.11.019.

18. AOAC International. Official Methods of Analysis of AOAC International. 18 ed. 4 rev. Washington: Gaithersburg; 2011.

19. Merrill Al, Watt BK. Energy values of foods: basis and derivation. Washington: USDA, 1973.

20. Maia EL, Rodriguez-Amaya DB. Evaluation of a simple and economical method for the methylation of fatty acids with lipids of several species of fish. Rev Inst Adolfo Lutz. 1993;53:27-35.

21. AOCs. American Oil Chemists’ Society. Official and Tentative Methods of American Oil Chemists’ Society. 3rd ed. Champaig, IL (USA); 1980.

22. Rodrigues JK, Mendonça MS, Gentil DFO. Morphoanatomical, histochemical and biometric aspects of pyrene of Bactris maraja (Arecaceae). Rodrigüesia. 2015;66:75-85. doi:10.1590/2175-7860201566105.

23. Ferreira ES, Silveira CS, Lucien VG, Amaral AS. Physicochemical characterization of Brazil nut nuts (Bertholletia excelsa H.B.K), almond, pie and composition of major fatty acids. Alim Nutr Araraquara. 2006;17:203-8.

24. Costa FRC, Guillaumet J, Lima AP, Pereira OS. Gradients within gradients: The mesoscale distribution patterns of palms in a central Amazonian forest. Journal of Vegetation Science. 2009;20:69-78. doi:1111/j.1654-1103.2009.05314.x.

25. Sousa AGO, Fernandes DC, Alves AM, Freitas JB, Naves MMV. Nutritional quality and protein value of exotic almonds and nut from the Brazilian Savanna compared to peanut. Food Research International. 2011;44:2319-25. doi:10.1016/j.foodres.2011.02.013.

26. Gayol MF, Pramparo MC, Nepote V, Fernandez H, Grosso NR. Optimization of the protein concentration process from residual peanut oil-cake. Grasas y Aceites. 2013;64:489-96. doi:10.3989/gya.133112.
27. Galvani F, Juliano RS, Borghesi R, Oliveira DG. Centesimal composition of bocaiuva almond pie obtained after mechanical extraction of oil. In: Gonçalves WJ, editor. Proceedings of II Symposium of native and exotic fruits; 2017 Sept 27-29; Campo Grande, MS. Campo Grande: Federal University of Mato Grosso do Sul; 2017. p. 11-14.

28. Institute of Medicine. Dietary Reference Intakes (DRI) Dietary reference intakes for: energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids (macronutrients) [Internet]. [place unknown: publisher unknown]; [cited 2018 Feb 20]. Available from: https://www.nal.usda.gov/sites/default/files/fnic/uploads/energy_full_report.pdf.

29. Damiani C, Almeida TL, Costa NV, Medeiros NX, Silva AGM, Silva FA, Lage ME, Becker FS. Fatty acids profile and anti-nutritional factors of raw and roasted Caryocar brasiliense almonds. Pesq Agropec Trop. 2013;43:71-8. doi:10.1590/S1983-40632013000100004.

30. Saueressig ALC, Kaminski TA, Escobar TD. Inclusion of dietary fiber in gluten-free breads. Brazilian Journal of Food Technology 2016;19:1-8. doi:10.1590/1981-6723.4514.

31. Lottenberg AMP, Fan PLT, Buonacorso V. Effects of dietary fiber intake on inflammation in chronic diseases. Einstein. 2010;8:254-8. doi:10.1590/s1679-45082010md1310.

32. Da Ponte FAF, Rodrigues JS, Malveira JK, Ramos Filho JAS, Albuquerque MCG. Physical-chemical evaluation of babassu oil (Orbinya speciosa) and coconut oil (Cocos nucife) with high acidity and fatty acids (C6 to C16). Sci Plena. 2017;13:1-8. doi:10.14808/sci.plena.2017.085301.

33. Sekar S, Shafie SR, Prasadam I, Crawford R, Panchal SK, Brown L, Xiao Y. Saturated fatty acids induce development of both metabolic syndrome and osteoarthritis in rats. Sci Rep. 2017;7:1-11. doi:10.1038/srep46457.

34. Dayrit FM. The Properties of Lauric Acid and Their Significance in Coconut Oil. J Am Oil Chem Soc. 2015;92:1-15. doi:10.1007/s11746-014-2562-7.

35. Takato T, Iwata K, Murakami C, Wada Y, Sakane F. Chronic administration of myristic acid improves hyperglycaemia in the Nagoya-Shibata-Yasuda mouse model of congenital type 2 diabetes. Diabetologia. 2017;60:2076–83. doi:10.1007/s00125-017-4366-4.

36. Reda SY, Carneiro PIB. Oils and fats: applications and implications. Revista Analytica. 2007;27:60-7.

37. Instituto Adolfo Lutz. Chemical and physical methods for food analysis. 4th ed. São Paulo: IMESP; 2008.

38. Santos DS, Silva IG, Barbosa MCL, Nascimento MDSB, Costa MCP. Physico-chemical quality parameters of oils and morphometric analysis of fruits and seeds of the Orbignya phalerata Martius species by ecological region. Eclética Química Journal. 2016;41:74-84. doi:10.26850/1678-4618eqj.v41.1.2016.p74-84.

39. Ferreira, ES, Lucien, VG, Amaral AS, Silveira CS. Physico-chemical characterization of fruit and oil extracted from tucumá (Astrocaryum vulgare Mart). Alim Nutr, Araraquara. 2008;19:427-33.

40. Barroso AKM, Torres AG, Castelo-Branco VN, Ferreira A, Finotelli PV, Freitas SP, Rocha-Leão MHM. Brown and golden flaxseed: chemical and functional properties of the seeds and the cold-pressed oils. Ciência Rural. 2014;44:181-7. doi:10.1590/S0103-84782014000100029.

41. Codex Alimentarius. Codex standard for named vegetable oils CX-STAN 210 - 1999 [Internet]. [place unknown: publisher unknown]; [updated 2001; cited 2018 Feb 20]. Available from: https://mvo.nl/media/voedselveiligheid/codex_standard_named_vegetable_oils.pdf.
42. Ribeiro EP, Seravalli EAG. Food Chemistry. 2nd ed. São Paulo: Mauá; 2007.
43. Corsini MS, Jorge N. Oxidative stability of vegetable oils used in frozen cassava chips frying. Ciênc Tecnol Aliment. 2006;26:27-32. doi:10.1590/S0101-20612006000100005.
44. Jorge N, Lopes MRV. Evaluation of fry oils and fats collected in the São José do Rio Preto-SP trade. Alim Nutr Araraquara. 2003;14:149-56.
45. Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP). Resolução ANP Nº 7 de 19 de março de 2008 [Internet]. [updated 2017 Feb 3; cited 2018 Feb 20]. Available from: http://www.udop.com.br/download/legislacao/comercializacao/juridico_legiscalcao/res_7_comercializacao_biodiesel.pdf.
46. Pardaul JJ, Souza LK, Molfetta FA, Zamian JR, Rocha Filho GN, da Costa CE. Determination of the oxidative stability by DSC of vegetable oils from the Amazonian area. Bioresour Technol. 2011;102:5873-7. doi:10.1016/j.biortech.2011.02.022.

© 2018 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY NC) license (https://creativecommons.org/licenses/by-nc/4.0/).