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

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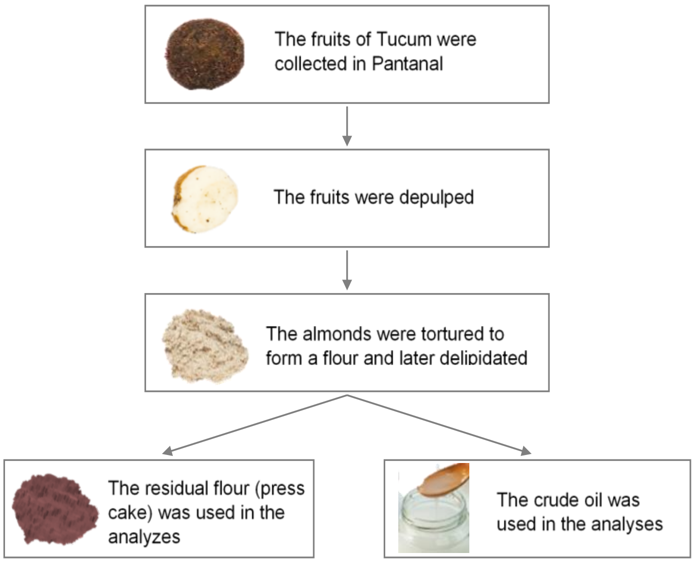
HIGHLIGHTS

- 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, lager 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 gI2 / 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.

GRAPHICAL ABSTRACT



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 6. 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. Pineli *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].

(**a**) (**b**)

(**c**) (**d**)

Figure 1. Almond of tucum-do-Pantanal. (a) almond with endocarp; (b) whole almond; (c) almond with partially apparent endocarp; (d) cut almond.

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 polysilfenylene 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.

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 conductivitie 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].

Table 1. Physical characterization of tucum-do-Pantanal almond.

Parameters	Mean ± SD[1]
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.

	Almond	**Press cake**
Parameters	Mean ± SD	Mean ± SD[1]
Moisture (g kg^{-1})	93.22±1.44^{a}	83.56±1.87^{b}
Ash (g kg^{-1})	12.10±0.05^{b}	17.11±0.28^{a}
Protein (g kg^{-1})	51.73±1.64^{b}	73.35±0.11^{a}
Lipid (g kg^{-1})	278.48±0.23^{a}	36.31±0.98^{b}
Carbohydrate (g kg^{-1})	564.47±2.97^{b}	789.68±2.65^{a}
Total energy value (kcal. g kg^{-1})	4891.83±5.65^{a}	3657.60±8.36^{b}
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 ($p \leq 0.05$).

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(gI_2/100g)	3.72±0.18
Refractive index (20ºC)	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 brasilian 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.

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