Physicochemical and nutritional aspects of babassu coconut almond and oil (Orbignya phalerata Mart.)

Aspectos fisicoquímicos y nutricionales del almendrastro y aceite de coco de babassu (Orbignya phalerata Mart.)

ABSTRACT

The potential use of babassu (Orbignya phalerata Mart.) in several activities is large. In view of these facts, this study aimed to determine the physicochemical composition of the babassu almond (OpAM) and evaluate the chemical, physical and physicochemical aspects of babassu coconut oil isolated by different methods of extraction. Babassu nut oil was removed by extraction with a hot solvent (Soxhlet) (OpS), hydraulic pressure (OpHP) and cold extraction (Blight and Dyer) (OpBD). Two artisanal samples from the states of Pará (OpP) and Maranhão (OPM) were also tested. OpAM presented 2% protein, 49.5% fat, 42.4% carbohydrates and water activity of 0.670. No statistical differences were found between the babassu coconut extraction techniques which present saturated fatty acids as major oil fatty acids, especially lauric (41.6%), myristic (14.6%) and unsaturated oleic (15.7%). No samples tested positive in the thiobarbituric acid reactive substances test, and they also showed low levels of acidity. Babassu coconut oil showed good oxidative stability with a high induction period. The samples tended to green and yellow colors, and the babassu oil extracted by Soxhlet was less viscous than the others.

Keywords: Blight Dyer; Orbignya; Pressing and artisanal oils; Soxhlet.

INTRODUCTION

Babassu (Orbignya phalerata Mart.) is a native fruit...
found in Brazil and Colombia. The fruits are ellipsoidal, weighing between 90 and 280 g. The name babassu refers to three different species in the Palmae family: Scheelea, Attalea, and Orbignia, where babassu is usually referred to the name Orbignya phalerata. The fruits have a thin bark (the epicarp) that surrounds a layer of secondary starch (mesocarp) and there is a rigid wood in the center of the coconut (the endocarp) with 3 or 4 almonds, from which the oil is extracted.

All varieties of babassu are important because of their ecological, social, economic and environmental aspects. The fruit (coconuts) is much appreciated by both man and wildlife. Each crop can have between 3 and 5 bunches, and each bunch can produce 300 to 500 coconuts.

The main product of babassu is almond oil, constituting 65% of its weight, and is used in manufacturing soap, glycerine, and edible oil, and later transformed into margarine, in addition to cakes used in producing animal feed.

Babassu oil is obtained through mechanical extraction or through solvents, which is a more expensive chemical process, but also considered more efficient for extraction, since the residual content of oil is lower.

Barbosa et al. found results that suggest that unrefined babassu coconut oil reduces microvascular effusions and protects against histamine-induced effects in post-capillary venules in hamsters. In addition, both the almond and its oil are important sources of energy. Sousa et al. showed that babassu coconut oil can be considered a potential alternative for the treatment and prophylaxis of benign prostatic hyperplasia, and Alves et al. found that babassu fixed oil is a source of bioactive compounds with anti-Candida parapsilosis action.

Babassu almond artisanal oils present physicochemical characteristics such as an acidity test (oleic/lauric fatty acids) close to the limits established by the international norms of the Codex Alimentarius, indicating a quality factor of raw matter and a good conservation state of the oils. Saponification indices indicate that there is a low presence of carboxylic groups in these oils and that the chemical composition of these oils and lipid tricacylglycerols esterified with monokarboxylic fatty acids.

The physicochemical composition of babassu coconut oil removed by different methods of extraction (hot solvent, hydraulic pressure and cold extraction).

**MATERIALS AND METHODS**

**Material**

Babassu coconut almonds were collected through coconut breakers in the city of Iporanga, Ceara, Brazil, and were crushed using a Walita® 400W household mixer, freeze-dried, and stored in polyethylene bags protected from light and humidity.

The oils were obtained from the freeze-dried samples, and a completely randomized design was used for three different extraction methods (babassu coconut oil extracted by Blight and Dyer - OpBD, babassu coconut oil extracted by Soxhlet - OpS, and babassu coconut oil extracted by pressure - OpHP) in triplicate.

In addition to the oils obtained in the laboratory, oils from the popular market of Pará (OpP) and Intersectoral Movement of Coconut Babassu-MIQCB (MA) from Maranhão (OpM) were purchased and analyzed. Three packs (500 mL) of each of the commercial samples were evaluated.

**Extractions of babassu coconut oil with solvent (hexane) and cold pressure**

The babassu oil was extracted from freeze-dried almonds. Two extracts were obtained in the production of babassu oil: by Soxhlet and by cold pressure and carried out in triplicate.

For extraction by Blight and Dyer, fifty grams of the homogenized sample was weighed in a beaker to which 50 mL of chloroform and 100 mL of methanol were added. Subsequently, 50 mL of chloroform and 50 mL water were added. This mixture was stirred for 15 minutes using a magnetic stirrer. The material was filtered using a glass funnel with a filter paper containing anhydrous sodium sulphate into a separating funnel of 500 mL. After complete separation and clarification, the chloroform layer was collected in a flat-bottomed flask and then evaporated on a rotating evaporator until complete removal of the solvent.

For extraction by Soxhlet, the freeze-dried sample (50 g) was subjected to the extraction process using a solvent reflux extractor (hexane), whose extraction is intermittent, avoiding the high boiling temperature of the solvent and consequently avoiding its decomposition as a hexane solvent and as equipment. The dried sample was immersed in 150 mL of solvent, and it remained in reflux equipment after boiling at 62 °C inside a flat bottom flask for eight hours.

Pressure extraction was carried out using a hydraulic press (Marconi model MA098/ACA20/EL) with a microwave sample (60 g) preheating system and heating of the press chamber base with temperature up to 200 °C, temperature controller, protection system with light, an electric hydraulic pump, hydraulic pressure and relief valve, with manual control.

Pressure of 100 kgf/cm² was used for 5 minutes at room temperature (about 30 °C).
After each process (with or without solvent), each material was weighed to calculate the yield of the obtained oils.

**Analysis of almond centesimal composition**

Almonds were submitted to centesimal composition analysis. Moisture analysis was performed by drying the sample in an oven according to AOAC\textsuperscript{12}. Water activity was performed by direct reading of the crushed samples using a 4TE Aqua Lab Dew Point Water Activity Meter (Decagon). Proteins were measured using the Bradford method\textsuperscript{13}, lipids by the cold solvent extraction method\textsuperscript{14}, ash by the dry ash method\textsuperscript{15} and the theoretical calorific value was calculated according to values provided by the MERRIL and WATT\textsuperscript{16}.

**Composition of fatty acids and physicochemical characterization of babassu coconut oil**

Lipid extraction was performed according to Bligh and Dyer (1959) and the Analytical Standards of the Adolfo Lutz Institute\textsuperscript{17}. The preparation of methyl esters was performed with the mixture of 100 mg of lipids extracted, 2 mL of n-hexane (chromatography grade), and 0.2 mL of hydroxide potassium 2 M solution in methanol (chromatography grade). This solution was stirred at room temperature in a vortex for 30 seconds. Next, 3 mL of saturated solution of sodium chloride was added. The upper phase was analyzed. Identification and quantification of fatty acids was performed using a Shimadzu GCMS QP2010 gas chromatograph equipped with mass selective detector and a DB-1 column (30 m long × 0.250 mm thickness × 0.250 mm internal diameter) using helium carrier gas. The chromatograph was programmed as follows: initial temperature of 25 ºC and an increase of 50 ºC/minute until 230 ºC. The temperature of the injector and column were set at 250 ºC and 110 ºC, respectively. The injector was operated with a split ratio of 10. A co-injection of the internal standard was performed in all injections. The internal standard used was methyl heptadecanoate at 0.200 µg/mL. This compound was purchased from Sigma.

The peaks were identified by comparison with those of authentic fatty acid standards. The percentage of individual fatty acids was calculated from the peak area using an external five-point calibration curve for each fatty acid studied.

**Test of thiobarbituric acid reactive substances (TBARS)**

For this analysis, 1 g of oil was initially added to 5 ml of 0.100% TCA. The mixture was centrifuged at 5000 rpm for 20 min at 4 ºC. For the peroxides analysis, a solution of 0.500% thiobarbituric acid diluted in 20% trichloroacetic acid solution was used. An equal volume of the crude extract and the TCA-TBA solution was added into 3 ml test tubes. These were mixed using a vortex and then heated for 30 min at 95 ºC. After the reaction time, they were transferred to an ice bath. Spectrophotometric readings of the supernatant were made at 532 and 600 nm. Calculations of the malondialdehyde content were expressed in nm of dry matter MDA.g⁻¹, using the molar coefficient of MDA: ε = i55 mM.cm⁻¹.

**Acidity level**

The acid number was expressed as the number of milligrams of potassium hydroxide needed to neutralize the free acids of one gram of sample. The free fatty acids were determined in a solution of oil or fat in ethanol by titration with sodium hydroxide solution and using phenolphthalein as an indicator\textsuperscript{18}.

The free fatty acid content was calculated based on the molecular weight of the predominant acid (lauric acid). Two grams of the sample was weighed in a 125 mL Erlenmeyer flask, then 25 mL of a neutral ethyl ether-ethanol (1:1) mixture was added and manually shaken. Two drops of 1.0% ethanolic solution of phenolphthalein was added to the mixture. Titration was done using 0.1 M NaOH solution or until pink coloration. Results for lauric acid were expressed as a percentage of free fatty acids, with a gram equivalent of 200 using the formula:

\[
V \times N \times 200 / P = \% \text{ lauric acid}
\]

where \(V=\) number of mL of KOH solution spent in titration; \(N=\) normality of the KOH solution, duly standardized; \(P=\) number of grams of the sample and 200= factor for lauric acid\textsuperscript{18}.

**Rancimat stability**

In a reaction tube (with care being taken not to smudge the walls), 3 g of each sample were submitted to the following conditions: 110 ºC temperature, 200 us/cm conductivity, and 10L/h⁻¹ air flow, during the necessary period to reach the end point (Metrohm 873 Rancimat stability equipment, Herisau, Switzerland).

**Color measurement**

The colorimetric measurements \(a^*\), \(b^*\) and \(L^*\) of babassu coconut oil samples were evaluated using a CR-400 Konika Minolta colorimeter and a CIELAB scale.

**Rheological behavior**

The rheological behavior of babassu oils was determined by a R/S plus SST 2000 Brookfield Searle cylindrical rotating rheometer. The measurements were done at 25 ºC, which was adjusted through a thermostatic bath coupled to the equipment. The equipment provided the shear stress and strain rate data through RHEO V 2.8 software. Rheological determinations were obtained with a variation of the deformation rate from 0 to 500 s⁻¹ (upward curve) and from 500 to 0 s⁻¹ (downward curve), every 1 minute and with 25 points recorded for each curve.

**Statistical Analysis**

Comparison of the samples by measured properties was accomplished with one-way analysis of variance (ANOVA), followed by Tukey's tests. Rheological analysis were done in triplicate and a new sample was used at each measurement. The data obtained were adjusted to the Casson and Newton
models (Table 1) by non-linear regression. Statistical analyses were performed using SAS software version 9.1⁹. The level of confidence for all statistical analyses was set at least 95%.

RESULTS

Centesimal composition

Analysis of the centesimal composition of the commercial coconut almond had a mean moisture content of 4.9% and water activity of 0.670. The sample had 2.1% protein, 49.5% lipids, 1.4% ash and 42.4% carbohydrates.

Table 1. Rheological models used to evaluate the rheological behavior of babassu oil.

| Model    | Equation |
|----------|----------|
| Casson   | \(\tau^{0.5} = K_{oc} + K_c \gamma^{0.5}\) |
| Newton   | \(\tau = \eta(\gamma)\) |

Where: \(\tau = \) shear stress (Pa), \(K_{oc} = \) consistency index (Pa.s), \(n = \) flow behavior index (dimensionless), \(\gamma = \) shear rate (s-1), \(K_c = \) initial tension of Casson (Pa), \(K = \) viscosity of Casson (Pa.s).

In 100 g of babassu coconut almonds, 49.5 g of lipids which corresponds to 446 kcal; 2.05g of proteins equivalent to 8.2 kcal; and 42.4 g of carbohydrates equivalent to 169 kcal were measured. Thus, a total of 623 kcal per 100 g was measured.

Babassu coconut oil yield

Using hot extraction with hexane (OpS), the average obtained yield was 58 ± 0.01% of lipids (Table 2). A yield of 55.6 ± 0.01% (OpHP) was obtained at the end of the pressing at room temperature (30 °C). For artisanal oils (OpM and OpP), it was not possible to calculate the yield because we did not have access to the preparation of the acquired oils.

Efficiency of extraction and composition of babassu coconut oil

OpHP, OpBD and OpS samples were analyzed. Fatty acid composition analysis results of the oil samples are shown in Table 2. Taking the result relative to the sample obtained by pressing at room temperature, it was observed that saturated fatty acids - SFA represented 78% of the sample; monounsaturated was (MUFA) 15.7%; and polyunsaturated (PUFA) was 2.3%.

Thiobarbituric acid reactive substances (TBARS) test, acid number and period of induction or oxidative stability

From the analyzed samples, two presented null results, characterizing the absence of malondialdehyde oil obtained in the laboratory by OpBD and OpM. OpP presented a small amount, while OpS and OpHP presented the largest amount. However, there was no statistical difference between the samples, meaning that even if present, malondialdehyde is only present in a low quantity.

The sample that presented the lowest endpoint (the onset time of oxidative deterioration signs) is the same as that obtained by cold extraction with solvents (OpBD) (Figure 1). The product obtained by pressing at room temperature (OpHP) presented the second lowest endpoint, followed by OpM samples (handmade), OpS (hot solvent) and the OpP-sample.

The OpS sample presented a duplicate whose endpoint was not reached during the final analysis period of the equipment, remaining without presenting indicative results of oxidation. It should be noted that the sample with the highest oxidative stability (OpP) was the one with the highest acidity indexes (Table 2), followed by OpS and OpM samples.

Considering the OpBD and OpHP samples with the lowest acidity indexes, it can be stated that they present high oxidative stability, for oxidative stability index using Rancimat.

Thus, the samples presented high oxidative stability, a fact that is related to the composition of fatty acids, acidity and the MDA content found within them. The major presence of saturated fatty acids and the low amount of peroxides explain the good results found by the Rancimat test.

Color measurement

As for luminosity (L), OpS samples (45) and OpM samples (44.6) were considered the clearest and not statistically different (Table 3). On the other hand, the manually-processed OpP sample (41) presented lower L, indicating greater proximity to the dark color. OpBD (44) and OpHP (44) presented intermediate results.

All samples presented negative results regarding parameter a, evidencing a tendency to green color, especially the OpM and OpP samples, however, these differed statistically from one another and from the others. The OpBD sample showed OpS and OpHP similarities. All the samples presented positive results for criterion b, showing a tendency to yellow coloration. The OpBD, OpS, and OpHP samples were not statistically different. The OpM and OpP samples were also similar, presenting the highest values found.

The Chroma parameter measures the color saturation. Samples obtained artisinally in the OpM and OpP presented higher intensity and were statistically similar, whereas the others (OpBD, OpS, and OpHP) had no statistical difference, showing smaller values. The OpBD and OpHP samples had statistically equal hue saturation angles. The OpS sample and the manually-processed OpM and OpP presented different angles between them, with the first being the most open and the last the shortest.

Rheological behavior

The results regarding rheological behavior are presented in Table 4. For the Casson model, the babassu oil extracted by BD presented lower initial stress and lower plastic viscosity of Casson, thus being considered more fluid (less viscous) than the other samples.
Table 2. Characteristics of babassu oils.

| AG | OpHP | OpM | OpP | OpBD | OpS |
|----|------|-----|-----|------|-----|
| **Lipid extraction by technique (%)** | 55.6±0.01%a | - | - | 49.5±0.006%a | 58.3±0.01%a |
| **Fatty acids** | | | | | |
| C6:0 | 0.410a | 0.440a | 0.550a | 0.370a | 0.460a |
| C8:0 | 5.64a | 5.76a | 5.99a | 5.02a | 6.04ª |
| C10:0 | 5.12a | 5.00a | 4.76a | 4.56a | 5.24ª |
| C12:0 | 41.6a | 42.4a | 41.2a | 37.00a | 44.4ª |
| C14:0 | 14.6qb | 14.8ab | 14.4ab | 13a | 15.5b |
| C16:0 | 7.67ab | 7.72ab | 7.68ab | 6.83a | 8.10b |
| C18:0 | 2.64a | 2.85a | 3.09a | 2.35a | 2.99ª |
| C18:1 | 15.7a | 14.2a | 15.5a | 14.0a | 15.0a |
| C18:2 | 2.26a | 2.50 | 2.54a | 2.01a | 2.62a |
| **Values of malondialdehyde –MDA (µM)** | 0.620a | 0.000a | 0.130ª | 0.000ª | 0.400ª |
| **Acidity (mg KOH/g)** | 0.010ª | 0.010b | - | - | - |
| **Acidity (oleic acid-%)** | - | - | 0.010ª | - | - |
| **Acidity (lauric acid-%)** | 0.420ª | 0.460ª | 1.300ª | 0.190c | 0.320ªc |

Repeat letters indicate that there is no statistical difference between the samples.

OpHP - Babassu coconut oil extracted by hydraulic pressing
OpM - Commercial oil of the Intersectoral Movement of the Babaçu Coco Breakers
OpP - handmade babassu coconut oil from Pará
OpBD - sample of babassu coconut oil by Blight and Dyer
OpS - babassu coconut oil extracted by Soxhlet

Figure 1: Period of induction or oxidative stability of babassu coconut oil samples at 100oC.

OpP – Manually processed babassu coconut oil from Pará
OpM - Commercial oil of the Intersectoral Movement of the Babaçu Coco Breakers
OpHP - Babassu coconut oil extracted by pressing
OpS - Babassu coconut oil extracted by Soxhlet
OpBD - Babassu coconut oil sample extracted by Blight and Dyer
In relation to the Newton model, the samples showed similar values for Newtonian viscosity. All samples presented a good fit of the data to the rheological model, presenting a high coefficient of determination and low mean square error for the two models tested.

Commercially available babassu oil showed a rheological behavior similar to babassu oil obtained through the press, followed by the oil obtained by Soxhlet.

**DISCUSSION**

In this research, we determined the physicochemical composition of babassu almond (OpAM) and evaluated the chemical, physical and physicochemical aspects of babassu coconut oil removed by different methods of extraction.

The water activity found for samples analyzed was close to the levels necessary for developing molds and yeasts, which, depending on the conditions of product manipulation and storage, would influence the deterioration rate of the food. Thus, the use of good manipulation practices is fundamental for the conservation of this product, as well as the correct processing and storage.

Protein levels were lower than other Brazilian vegetables oil sources. Ferrari and Soler (2015) found 1.2 to 9.4 % of protein investigating babassu oil composition, Ferreira et al. found 15.6% protein using the method by Kjeldahl. Using the same method, Dessimoni-Pinto et al. found 12.3% protein in macaúba. Lima, Garcia and Lima found 24.5% protein for cashew nuts using the method described by AOCS.

### Table 3. Colorimetric parameters of babassu coconut oils.

| Samples   | L       | a       | B       | Croma   | Hue     |
|-----------|---------|---------|---------|---------|---------|
| OpS       | 45.1a   | -3.29b  | 3.11b   | 4.53b   | 136.a   |
| OpM       | 44.6ab  | -3.95d  | 6.65a   | 7.74a   | 120c    |
| OpBD      | 44.1b   | -3.27ab | 4.02b   | 5.18b   | 129b    |
| OpHP      | 43.9b   | -3.18a  | 3.65b   | 4.85b   | 131b    |
| OpP       | 41.4c   | -3.68c  | 7.57a   | 8.42a   | 115.1d  |

Repeat letters indicate that there is no statistical difference between the samples.

OpS - Babassu coconut oil extracted by Soxhlet
OpM - Commercial oil of the Intersectoral Movement of the Babaçu Coco Breakers
OpBD - Babassu coconut oil sample extracted by Blight and Dyer
OpHP - Babassu coconut oil extracted by pressing
OpP – Manually processed babassu coconut oil from Pará

### Table 4. Parameters of the Casson and Newton rheological models.

| Model   | Parameters | OpHP | OpBD | OpS | OpP |
|---------|------------|------|------|-----|-----|
| Casson  | Koc (Pa)   | 0.055 ± 0.012 | -0.009 ± 0.012 | 0.022 ± 0.044 | 0.032 ± 0.036 |
|         | Kc (Pa.s^n) | 0.212 ± 0.000 | 0.209 ± 0.000 | 0.213 ± 0.002 | 0.216 ± 0.002 |
|         | R²         | 0.999 | 0.999 | 0.995 | 0.996 |
|         | MSE        | 0.026 | 0.016 | 0.247 | 0.180 |
| Newton  | η (Pa.s^n) | 0.046 ± 0.000 | 0.043 ± 0.000 | 0.046 ± 0.000 | 0.047 ± 0.000 |
|         | R²         | 0.999 | 0.999 | 0.995 | 0.996 |
|         | MSE        | 0.031 | 0.016 | 0.245 | 0.179 |

Koc= Initial Casson tension, Kc= Casson plastic viscosity, η = Newtonian viscosity, R²= coefficient of determination, MSE= Mean squared error.
OpHP - Babassu coconut oil extracted by pressing
OpBD - Babassu coconut oil sample extracted by Blight and Dyer.
OpS - Babassu coconut oil extracted by Soxhlet.
OpP – Manually processed babassu coconut oil from Pará.
We observed that the babassu almond presented much lower protein content than that found in other almonds. The different results found for the percentage of cocoa babassu can be explained by the methodology used, since most of the studies with almonds were carried out using the Kjeldahl method, which counts organic nitrogen and ammonia; whereas the Bradford method is based on the interaction between BG-250 dye and protein macromolecules containing basic or aromatic amino acids.

Regarding lipid content, the results found are in agreement with the value found by Vieira\textsuperscript{21} through centrifugation with ethyl and petroleum ethers. The oil removed during this analysis was separated and constitutes the OpBD sample. The ash was close to that reported by Vieira\textsuperscript{21}, who found an average of 1.2% ashes in babassu coconut almonds. Ferreira et al.\textsuperscript{22} found 3.1% for ash in their work with Brazilian nuts. Carvalho et al.\textsuperscript{23} found ash values of 3.2% for chicha, 2.5% for gurguéia nuts, and 3.1% for sapucaia through gravimetry after incineration in a muffle oven at 550 °C. Lima, Garcia and Lima\textsuperscript{24} found about 2.5% ash in cashew nuts. Thus, it is possible to observe that the babassu coconut has the lowest percentage of ash compared to other studies.

Regarding carbohydrates, Vieira\textsuperscript{21} found about 23.6% of carbohydrates through the difference in the values of other constituents of almonds. These variations are due to the results found for protein and ash, which differed from the values found in this study.

The calorific value of 567 kcal in 100 g of babassu coconut almonds is close to another quantified for Brazilian nuts. Ferreira et al.\textsuperscript{22} found a calorific value of 680 kcal per 100 g of Brazilian nuts. It can be observed that babassu coconut almonds have a large amount of carbohydrates and lipids, being important nutrients for food as energy sources, as well as having a high calorific value (623 Kcal).

Fats and oils are recognized as essential nutrients for human health and provide the most concentrated source of energy available. Babassu coconut almonds can be used in preparations in order to enrich total caloric value and to stimulate the ingestion of carbohydrates and lipids when necessary.

The lipid yield by hot extraction was higher than other extractions. Using hexane as a solvent under a temperature above its boiling point, this type of extraction obtains triglycerides, free fatty acids, lecithins, waxes, carotenoids, chlorophyll and other pigments, as well as sterols, phosphatides, vitamins and essential oils\textsuperscript{17}. The presence of these other compounds must be considered within the total obtained.

The yield for samples obtained by pressing at room temperature (30 °C) is very approximate to that obtained by extraction with a hot solvent, without any damage that could be caused by the presence of hexane residues and subjecting the raw material to high temperatures. Ferreira et al.\textsuperscript{22} obtained a yield of 61 ± 1.32% for Pará nuts via cold pressing by pressing the Marconi brand ME 998 at room temperature (31 °C) with an initial pressure of 3 tons and a final pressure of 12 tons. In extracting cashew nut oil by pressing the pre-crushed nuts (classified as xerem) previously heated to 60 °C in a domestic microwave oven and using a force of 50 tons, Lima\textsuperscript{25} found an average extraction ratio yield of 45.7%, considering that cashew nut almonds have an average of 45% oil.

In comparing the oil content found in babassu coconut almonds with cashew and Brazilian nuts, we obtained intermediate values for the production of babassu coconut oil, characterizing it as a food with a large amount of lipids, which is an important nutrient in human food.

The fatty acid composition for OpHP, OpM and OpP samples were close to results reported by Vieira, Lima and Nascimento\textsuperscript{28}, that found 62.7 ± 1.13% of SFA, 12.36 ± 1.47% of MUFA and 2.5 ± 0.59% of PUFA. The Food Composition Table - TACO\textsuperscript{29} found 50.9% of AGS, 18.6% of AGM and 30.2% of AGP. Ferreira et al.\textsuperscript{30} found 93.4% of AGS and 6.5% of AGM, failing to determine AGP values.

Regarding the lauric acid content (C12: 0) in oil (about 41%), the assay was higher than what was quantified by Vieira\textsuperscript{21}, who found 31.57 ± 1.03%. Also noteworthy was the presence of 15.73% oleic acid (C18: 1n9c) and 14.6% myristic acid (C14: 0).

The main fatty acids present in the babassu oil evaluated by Ferreira et al.\textsuperscript{30} were lauric acid (54.7), myristic acid (11.8%), caprylic acid (9.6%), and capric acid (9.2%). Total unsaturated fatty acids represent 9.5% of babassu oil.

Among other palm oils similar results have been found in fruits such as sour coke (Butia capitata var capitata), which has high levels of lauric acid (42.1%), followed by oleic acid (16.9%) and myristic acid (10.5%), with predominantly saturated fatty acids (78.9%)\textsuperscript{31}.

Similar amounts of lauric acid can be found in other fruits. In the case of the guabiroba pulp and almond, a typical fruit of the Cerrado, Nosaki et al.\textsuperscript{32} found a high concentration of saturated fatty acids (89.2%), mainly lauric acid (48.3%), followed by myristic acid (14.3%) and caprylic acid (10.3%).

Several authors have analyzed fatty acids from food and associated consumption of these substances with health benefits\textsuperscript{33,34,35,36}. Malondialdehyde was only present in low quantities. Peroxides are primary oxidation products and are unstable intermediates. In the course of their decomposition, compounds of a very diverse nature are generated, which are designated as by-products. The parameter generally used to measure the extent of oxidation at this stage is the number of TBARS\textsuperscript{37}. Due to the interference of the factors external to the oxidation process (eg light, temperature, etc.), it is important to apply the TBARS methodology, since it allows the verification of the oxidative stability in the samples, as other methods require extraction for analytical determination.

It is known that the main fatty acid found in babassu coconut oil is lauric acid. Thus, if we consider this fatty acid as a parameter and compare it with RDC No. 482,
dated September 23, 1999, we find results (Table 2) that show that OpBD and OpS samples presented the lowest values of acidity by lauric acid. OpHP and OpM presented similar values. OpP presented the highest index, being above the minimum value established by the Regulador de Identidad y Calidad de Aceites y Grasas (RDC No. 270) dated September 22, 2005. The acidity index for cold pressed and unrefined vegetable oils, all the analyzed oils were below the value established by the legislation. They are still lower than the maximum allowed by law for refined oils and fats.

Machado, Chaves and Antoniassi evaluated the physical and chemical characteristics of hydrogenated cocoa bean oils at two melting points (28 °C and 34 °C) to compare the effects of hydrogenation processes on fatty acid composition, physical characteristics, and chemical properties of the oils, finding acidity indexes within the limit of RDC No. 270, dated September 22, 2005, with 0.092% lauric acid for the first sample, 0.096% lauric acid for the second, and a maximum value of 0.3% lauric acid.

Hydrogenation, together with the great presence of lauric acid, can increase the oxidative stability of the product, causing it to have an acidity index within those recommended by the regulators of Identity and Quality of Oils and Fats.

The sample with the highest oxidative stability (OpP) was the one with the highest acidity indexes. All samples were subjected to processes involving heat to obtain them, a factor that affects the stability of an oil. The OpP and OpM samples were also kept in their original sales packaging, which did not have specific light protection barriers. In its manufacturing, it is assumed that processing conditions are under the minimum control of contact with water and air, which are other factors that cause product deterioration. On the other hand, the OpBD sample, which presented the most rapid oxidation signals, was obtained in a non-heat process and kept under refrigeration in opaque glass bottles. Its acid number is the smallest of the samples.

Determination of the oxidative stability index using Rancimat occurs when there is a formic acid formation that solubilizes, increasing the electrical conductivity of the water, a trend quickly observed in the OpS and OpHP samples, and better preserved from the previous pro-oxidant factor analysis. Regarding the other samples, they probably underwent initial stages of lipid oxidation, and as the latter progressed, the primary products of lipid oxidation decomposed faster than they were formed, a fact observed in rancid oils that have very low lipid concentrations. The high oxidative stability can be attributed to the predominant composition of saturated fatty acids, followed by oleic and monounsaturated acid.

Using the same methodology used in the present study, Melo et al. show that the babassu oil does not present an induction period, characterizing itself as having high oxidative stability. According to this study, even after 30h of analysis, there were no sudden changes in water conductivity caused by the presence of volatile compounds resulting from oxidation processes. Souza et al. suggest that antioxidant substances, possibly phenolic compounds, may contribute to the longer induction time presented by oils.

Regarding the colorimetric measurement of babassu coconut oil, RDC No. 270, dated September 22, 2005, we determined that these have a characteristic color and did not indicate parameters for their evaluation.

Determination of lipids in foods by solvent extraction in a Soxhlet-type apparatus provided results consisting not only of lipids but also of free fatty acids, fatty acid esters, lecithins, waxes, carotenoids, chlorophyll and other pigments; also, sterols, phosphatides, vitamins A and D and essential oils, which can lead to the highest luminosity presented by this sample. The artisanal extraction processes of babassu coconut oil involve the use of heat, with temperatures that do not present judicious control. Heat could be responsible for differences in color parameters between hot (Soxhlet and artisan) and cold- (Blight and Dyer and cold pressing) processed oils.

For the Casson model, babassu oil extracted by BD was considered more fluid (less viscous) than the other samples. The oil extracted through the press presented higher initial tension, followed by the commercial oil and the oil extracted by Soxhlet.

Babassu oil extracted by BD presented lower results for Newtonian viscosity. All samples presented Newtonian behavior. The increase of the rate of deformation applied in the samples, which means that an increase of the shear stress occurs and this relation is close to linearity, characteristic of Newtonian behavior.

**CONCLUSIONS**

The babassu coconut almond has a predominance of carbohydrates and lipids. Of these, the saturated fatty acids stand out in nutritional composition. The almond also has a small percentage of proteins. It is a food with a high energy value that can be consumed in situations that demand higher caloric intake. The value of water activity indicates that it is necessary to guarantee conditions that prevent the development of molds and yeasts in its processing and storage. No statistical differences were found between extraction methods. Among the methods employed, the best procedure to preserve the sensorial and nutritional characteristics was pressing at room temperature, which in addition to not requiring heat, does not use solvent.

The analyzed oils did not present statistical differences regarding fatty acids. Among the saturated fatty acids, lauric acid was present in the greatest quantity, followed by myristic acid. Also, the presence of oleic monounsaturated fatty acid is noteworthy. Tests that evaluate oxidative stability have found favorable results for the use of babassu coconut oil. The particularities of laboratory and artisanal extraction processes such as temperature, pressure, and the use of solvents explain the differences between the 21 colorimetric patterns of each sample.

The samples presented Newtonian behavior. The babassu
oil extracted by Blight and Dyer was less viscous than the others, presenting lower Casson viscosity, lower initial stress and lower Newtonian viscosity than the other samples.

REFERENCES

1. Teixeira MA. Babassu – A new approach for an ancient Brazilian biomass. Biomass Bioenergy 2008; 32(9): 857-864.
2. Carrazza LR, Silva ML, Ávila JCC (2012) Technological Manual for Integral Utilization of Babacu Fruit. Brasilia DF. Institute for Society, Population and Nature. (ISPN). Brasil. ISBN: 978-85-63288-06-6
3. Carvalho JDV (2013) Technical Dossier- Babassu Cultivation and Oil Extraction. Center for Support to Technological Development of the University of Brasília – CDT/UnB. 2007. Available: <http://www.sbrt.ibict.br/dossies-tecnicos >. Acesso em novembro de 2013.
4. Barbosa MCL, Bouskela E, Cyriño FZGA, Azevedo APS, Costa MCP, Souza MGC, Santos DS, Barbosa FL, Guerra FLA, Nascimento MDSB. Effects of babassu nut oil on ischemia/ reperfusion-induced leukocyte adhesion and macromolecular leakage in the microcirculation: Observation in the hamster cheek pouch. Lipids Health Dis 2012; 11:158.
5. Sousa VP, Crean J, Borges VRA, Rodrigues CR, Tajber L, Boylan F, Cabral LM (2013) Nanostructured systems containing babassu (Orbignya speciosa) oil as a potential alternative therapy for benign prostatic hyperplasia. Int J Nanomed 2013; 8: 3129-3139.
6. Alves JD, Lima MRC, Silva DSJ, Silva AG, Silva MV. Óleo fixo de attalea speciosa (arecaceae) como agente anti-candida. Blucher Biophy Proc 2017; 1(1): 73-74.
7. Codex Alimentarius Commission, and Joint FAO/WHO Food Standards Programme. Codex alimentarius: fats, oils and related products. Vol. 8. Food & Agric Org., 2001.
8. Costa CL, França ETR, Santos DS, Costa MCP, Barbosa MCL, Nascimento MDSB. Physicochemical characterization of handmade fixed oils from the Babassu coconut (Orbignya phalerata) from ecological regions of the state of Maranhão, Brazil. Pesq Foco 2015; 20(1): 27-38.
9. BRASIL Ministry of Health. National Sanitary Surveillance Agency. Resolution RDC No. 482 of September 23, 1999. Approves the Technical Regulation for Identity and Quality Fixation of Vegetable Oils and Fats. Official Gazette of the Federative Republic of Brazil. Brasilia, September 23, 1999.
10. BRASIL. Ministry of Health. National Sanitary Surveillance Agency. Resolution RDC No. 270 of September 22, 2005. Technical Regulation for Vegetable Oils, Vegetable Fats and Vegetable Cream. Official Gazette of the Federative Republic of Brazil. Brasilia, September 22, 2005a.
11. Cecchi HM (2003) Theoretical and practical foundations in food analysis. 2a Ed. Campinas, SP. Publisher of UNICAMP.
12. AOAC (1997).Official methods of analysis. (16th ed., 3rd rev). Gaithersburg, MD: Association of Official Analytical Chemists.
13. Bradford MM. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Anal Biochem 1976; 72: 248-254.
14. Bligh EC, Dyer WJ. A rapid method of total lipid. Extraction and purification. Can J Biochem Phys 1959; 37: 911-17.
15. AOAC. Official Methods of Analysis of AOAC International, 17th edn. Association of Official Analytical Chemists, Washington, 2000.
16. Merrill AL, Watt BK. Energy value of foods: basis and derivation. Washington, DC: United States Department of Agriculture (Agriculture handbook, 74), 1973.
17. Instituto Adolfo Lutz. Analytical Standards of the Adolfo Lutz Institute. V. 1: Chemical and physical methods for food analysis. São Paulo: IMESP, 4. ed., 1st Digital Edition, 2008.
18. IUPAC Standard methods for the analysis of oils, fats and derivatives. International Union Of Pure And Aplied Chemistry, Oxford, 1997.
19. SAS Institute, Inc. SAS User’s Guide: version 9.1, Cary, NC: SAS Institute, 2006.
20. Deman JM. Principles of Food Chemistry. 3.Ed. Gaithersburg, Maryland, 1999, 395 p.
21. Ferrari RA, Soler MP. Obtention and characterization of coconut babassu derivatives. Scient Agric 2015; 72(4): 291-296.
22. Ferreira ES, Silveira CS, Lucien VG, Amaral AS. Physicochemical characterization of the nut, pie and composition of the major fatty acids of Brazil nut crude oil (Bertholletia excelsa H.B.K). Alim Nutr 2006; 17: 203-208.
23. Ferreira BS, Almeida CG, Faza LP, Almeida A, Diniz CG, Silva VL, Grazul RM, Le Hyaric M. Comparative properties of Amazonian oils obtained by different extraction methods. Molecules 2011; 16: 5875-5885.
24. Dessimoni-Pinto NAV, Silva VM, Batista AG, Vieira G, Souza CR, Dumont PV, Santos GKM Physicochemical characteristics of macaúba almond and its use in the elaboration of cereal bars. Alim Nutr 2010; 21 (1): 77-84.
25. Lima AC, García NHP, Lima JR. Collection and characterization of the main cashew products. Bol CEPPA 2004; 22 (1): 134-144.
26. AOCS (1993) Official methods and recommended practices, 4th edn. American Oil Chemists Society, Illionsos.
27. Carvalho MG, Costa JMC, Souza VAB, Maia GA. Evaluation of the physical and nutritional parameters of chichá, sapucaia and gurguéia chestnut almonds. Rev Ciência Agron 2008; 39 (12): 517-523.
28. Vieira LM, Lima A, AMCB Nascimento. (2013). Fatty acid composition of babassu coconut almond (Orbignya speciosa): In: III BRAZILIAN CONGRESS OF PROCESSING OF FRUITS AND VEGETABLES, 2013, Ilhéus. Annals. Ilhéus: Magistra, 2013. CR-ROM.
29. TACO. Brazilian Food Composition Table. Nucleus of Studies and Research in Food- NEPA. University of Campinas-UNICAMP, 4. ed. rev. e ampl. Campinas: 2011.
30. Ferreira BS, Faza LP, Hyaric ML. A comparison of the physicochemical properties and fatty acid composition of indaiá (Attalea dubia) and babassu (Orbignya phalerata) oils. Sci World J 2012; 1-4.
31. Faria JP, Arellano DB, Grimaldi R, Silva LCR Chemical characterization of sour coconut (Butia capitata var capitata), Rev Bras Frutic 2008; 30(2): 549-552.
32. Nosaki, VT, Munhoz CL, Guimaraes RCA, Hiane PA, Andreu MP, Viana LH, Macedo MLG. Lipid profile of pulp and guariruba almond. Ciência Rural 2012; 42(8): 1518-1523.
33. Valenzuela A., & Valenzuela R. (2014). Ácidos grasos omega-3 en la nutrición ¿ como aportarlos? Rev Chil Nutr 2014; 41(2): 205-211.
34. Valenzuela R, Morales J, Sanhueza J, Valenzuela A. Ácido docosahexaenoico (DHA), un ácido graso esencial a nivel cerebral. Rev Chil Nutr 2013; 40(4): 383-390.
35. Tapia A E. La suplementación con ácidos grasos omega-3 disminuye la agresividad, hostilidad y el comportamiento antisocial. Rev Chil Nutr 2005; 32(2): 95-101.
36. Jorge N, Luzia DMM, Bertanha BJ. Eugenia dysenterica DC.: actividad antioxidante, perfil de ácidos grasos y determinación de tocoferoles. Rev Chil Nutr 2010; 37(2): 208-2014.
37. BRAZIL. Ministry of Health. National Sanitary Surveillance Agency. Resolution RDC No. 270 of September 22, 2005. Technical regulation for vegetable oils, vegetable fats and vegetable cream. Official Gazette of the Federative Republic of Brazil. Brasilia, September 22, 2005.
38. BERTOLIN, T.E. et al. Natural Antioxidants in Prevention of lipid oxidation in beef jerky. Braz J Food Techn 2010; 13(2): 83-90.
39. Machado GC, Chaves JBP, Antoniassi, R. Composition in fatty acids and physical characterization and chemistry of hydrogenated oils of babassu coconut. Rev Ceres 2006; 53 (308): 463-470.
40. Lobo IP, Ferreira SLC, Cruz RS. Biodiesel: Quality Parameters and Analytical Methods. Quim Nova 2009; 32 (6): 1596-1608.
41. S. Damodaran, KL. Parkin, OR. Fennema. Fennema Química dos Alimentos. 4. Ed. Zaragoza, España: Acribia 2010; p 1154.
42. Melo MAMF, Melo MAR, Pontes ASCC, Farias AFF, Dantas MB, Calixto CD, Souza AG, Filho JRC. Non-conventional oils for biodiesel production: a study of thermal and oxidative stability. J Therm Anal Calorim 2014; 117: 845-849.
43. Souza DFS, Antoniassi R, Freitas SC, Bizzo HR. Oxidative stability of macadamia and pistachio oils. Boletim CEPPA 2007; 25(1): 141-156.