

Extraction and Evaluation of Fatty Acid Composition of *Orbignya phalerata* Martius Oils (Arecaceae) from Maranhão State, Brazil

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A composição de ácidos graxos de seis amostras de *Orbignya phalerata* de diferentes cidades do estado do Maranhão foi estudada. Os óleos foram extraídos utilizando extrator Soxhlet por duas metodologias e a composição de ácidos graxos foi avaliada por cromatografia gasosa-espectrometria de massas (CG-EM). O teor da fração de lipídios revelou que o solvente usado influencia na extração, sendo a maior porcentagem obtida com hexano. O teor de lipídios variou de 62,46-67,45%, com predominância de ácidos graxos saturados (80,32-87,80%), principalmente ácido láurico (C12:0) com percentual de 44,86-52,15%. A análise multivariada mostrou a distribuição das amostras de *O. phalerata* em três regiões distintas e sugere que a composição química dos óleos pode estar associada com a sua localização geográfica. Estes dados mostram o conhecimento da biodiversidade de ácidos graxos de *O. phalerata* entre as diferentes regiões do estado do Maranhão.

The fatty acid composition of six *Orbignya phalerata* samples of different cities from Maranhão State (Brazil) was studied. The oils were extracted by two methods using Soxhlet extractor and the fatty acid composition was evaluated by gas chromatography-mass spectrometry (GC-MS) analysis. The lipid fraction content showed that the solvent used influences lipid extraction, the highest percent was obtained with hexane. Lipid content ranged from 62.46-67.45%, with predominance of saturated fatty acids (80.32-87.80%), mainly lauric acid (C12:0) with 44.86 to 52.15%. Multivariate analysis showed the distribution of *O. phalerata* samples into three distinct regions and suggests that the oil chemical composition may be associated with their geographic location. These data show knowledge of the biodiversity of *O. phalerata* fatty acids among the different regions of the Maranhão State (Brazil).

Keywords: babassu oil (*Orbignya phalerata* Martius), fatty acids, GC-MS, multivariate analysis

Introduction

The babassu palm, *Orbignya phalerata* Martius synonymy *O. martiana*, belongs to Arecaceae (Palmae)

family. It is the most widespread, morphologically variable and economically important species¹ distributed in some Brazilian states: Maranhão, Piauí, Goiás, Tocantins, Pará and Mato Grosso. Exploitation of *O. phalerata* palm tree is a well-established and secular activity in Brazil for use as food supply, production of household objects, raw material for building homes and biomass.²

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The babassu fruits are oval and elongated weighing 90-280 g. The fruit contains epicarp (11% in mass), mesocarp (23% in mass) and endocarp (59% in mass) with 3-4 nuts (7% in mass), which are rich in triacylglycerols (> 60% in mass), with predominance of lauric acid (C12:0) and minerals (Al, Ba, Ca, Cu, Fe, K, Mg, Mn, Sr and Zn).^{2,3} The babassu nut is one of the non-timber products that stood out the most out in production value, concentrating the total of extractive production in the Brazilian Northeast (99.4%), making the Maranhão State the largest producer of babassu nuts, corresponding to 54.6% of national output in 2010.⁴

According to the Brazilian Agricultural Research Corporation (EMBRAPA),⁵ the economic potential of babassu fruits, especially its nuts, as well as its oil, is largely used in pharmaceuticals, cosmetics, food and medicinal uses. Souza *et al.*⁶ reported that in the traditional medicine of Northeast Brazil, babassu-derived products are mainly used in some diseases, such as inflammation process. Although, babassu oil presents several industrial applications, for example biodiesel production,⁷ the chemical knowledge is necessary to ensure quality and better exploitation of biomass.

Previous articles describe the use of gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) for oil chemical constituent identification.⁸ This procedure has been successfully applied to the identification of substances of structures known, because in most cases, all data generated can be compared directly with the retention time values obtained in columns with different polarities and mass spectra of constituents published in computerized libraries. Advances in gas chromatography (GC) have promoted the study of lipids and provided knowledge of the fatty acid composition in a short period of time.^{9,10}

The objective of the present study was to evaluate the chemical composition of babassu nut oils from samples of *O. phalerata* Mart. collected from different cities of Maranhão State (Brazil). The fatty acid composition by GC-MS was evaluated using methods of principal component analysis (PCA) and hierarchical cluster analysis (HCA).

Experimental

Materials

The solvents and reagents used were of analytical grade. The reference standard of fatty acid methyl esters (FAME, C₄-C₂₄) for GC was purchased from Supelco (St. Louis, MO, USA). The thin layer chromatograms (TLC) were made on glass support with 0.25 mm thickness of stationary phase containing silica gel 60 G Sigma. The TLC plates were developed by iodine vapors.

Babassu nut samples

O. phalerata nut samples were collected in six cities of Maranhão State: São Luís (SL), Imperatriz (IMP), Penalva (PEN), Esperantinópolis (EPT), Fortuna (FOR) and Riachão (RIA), which corresponded to the ecological regions: Litoral, Pre-Amazon, Baixada, Cocais, Transition area (Cerrado/Cocais) and Cerrado, respectively (Table 1, Figure 1). The babassu fruit selection was aleatory. At the moment of

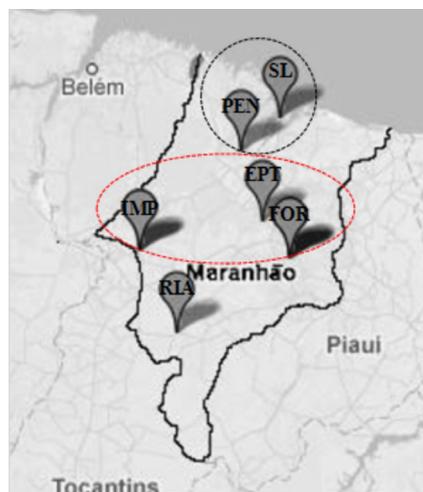


Figure 1. Distribution of six *O. phalerata* nuts from Maranhão State (Brazil) which originated the samples in Table 1. São Luís (SL), Esperantinópolis (EPT), Fortuna (FOR), Riachão (RIA), Penalva (PEN) and Imperatriz (IMP). The dash lines were marked on the basis of high correlation 3D PCA plot (Figure 3).

Table 1. Localization and geographical coordinates of *O. phalerata* nut sampling sites in Maranhão State, Brazil

City	Latitude S; Longitude W	Area / km ²	Climate	Region
São Luís	-02°31'47"; 44°18'10"	827.1	tropical, hot and humid	Litoral
Imperatriz	-05°31'35"; 47°29'30"	1367.9	tropical sub-humid	Pre-Amazon
Penalva	-03°17'39"; 45°10'25"	785.6	tropical humid	Baixada
Esperantinópolis	-04°52'00"; 44°42'30"	480.9	tropical sub-humid	Cocais
Fortuna	-05°44'00"; 44°09'30"	695.0	tropical, dry season	Transition Area (Cerrado/Cocais)
Riachão	-07°21'43"; 46°37'02"	6373.2	tropical, dry season	Cerrado

collection, the nuts were separated from babassu fruits and packed in hermetically sealed flasks under refrigeration.

Oil extraction

The babassu oils (5.0 g) were extracted using two methods. Method A:¹¹ extraction with petroleum ether, in accordance with the analytical protocol of Adolfo Lutz Institute (IAL). Method B:¹² extraction with *n*-hexane according the IUPAC procedure. The nuts were crushed in rotor mills (Tecnal model TE 651) and dried for 2 h at 105 °C. The dried samples were weighed on analytical balance and inserted in Soxhlet extraction system (Tecnal model TE-044-8/50) for determination of lipid contents. The solvent of lipid fraction was removed by evaporation under reduced pressure in a rotary evaporator. The oils obtained were weighed until constant weight in dessicator, and then the oil yield was calculated. Oil yield (%) was calculated by the followed equation:

$$\text{Oil yield} = \frac{\text{Oil weight}}{\text{Nut weight}} \times 100 \quad (1)$$

All procedures were performed in triplicate.

Preparation of fatty acid methyl ester (FAME)

FAME was obtained according method described by Hartman and Lago¹³ with some modifications. An amount of 500.0 mg of babassu oil was added to 5.0 mL of 0.50 mol L⁻¹ NaOH in methanol and the mixture was heated under reflux for 5 min. Then, 15 mL of esterification reagent (2.0 g of ammonium chloride, 60.0 mL of methanol and 3.0 mL of concentrated sulfuric acid, a mixture previously prepared for ca. 15 min) were added, the mixture was heated under reflux for 15 min and next transferred to a separation funnel with 25.0 mL of hexane and 50.0 mL of deionized water. The procedure was repeated. After agitation and phase separation, the aqueous phase was discarded and organic phase was dried with anhydrous sodium sulfate. Then, it was performed filtration through Whatman No. 1 filter paper and the organic phase collected. The conversion of FAME was evaluated by TLC using silica gel as stationary phase and *n*-hexane/EtOAc (95:5) as eluent, the chromatographic plates were revealed by iodine vapors. FAME was analyzed by injection into a GC-MS system.

Analysis of FAME by gas chromatography-mass spectrometry (GC-MS)

FAME was analyzed with the Shimadzu GC-17A gas chromatograph coupled to a Shimadzu mass spectrometer

model QP5050A equipped with HP-1MS capillary column (100% methylpolysiloxane, 30 m long × 0.25 mm i.d × 0.25 μm film thickness), after injection of 1 μL of FAME hexane solution (5.0 mg mL⁻¹). Injector and auxiliary temperature was at 300 °C. Programming of the column was as follows: initial temperature 80.0 °C for 1 min, rate of 4.0 °C min⁻¹ up to 200 °C, held for 2 min, and heating rate of 12 °C min⁻¹ up to 300 °C, held for 8 min. The mass detector was run in scan mode, acquisition time of 41.33 min and solvent-delay time was 8 min, mass range 40-450 Da, electron ionization (EI) at 70 eV, voltage detector at 1.3 kV, quadrupole mass analyzer and 1.5 mL min⁻¹ helium carrier gas-flow.

FAME was identified by comparison of mass spectra of the total ion chromatogram with those of Wiley 229 library using similarity index (SI) and comparison of retention times of peaks with authentic FAME. Fatty acid methyl esters were quantified as percentages (%) of the total methyl ester peak areas.

Statistical analyses

The relationship between the samples and analyzed variables was established by application of multivariate exploratory analysis using HCA with dendrogram plot construction to visualize similarities between samples, and PCA to identify the variables that influence the group formation. The statistical procedures were performed using the software program SPSS 15.0 (Statistical Package for the Social Sciences).

Results and Discussion

In this study, babassu nut oils were extracted from *O. phalerata* fruits originated from six cities of Maranhão State. A list of localization and geographical coordinates of *O. phalerata* nuts was shown in Table 1. The oil contents of babassu nuts (*O. phalerata*) obtained from the extraction methods A and B (Table 2) per each 5.0 g sample ranged around the averages: 3.29-3.32 g and 2.56-2.82 g, which is related to the oil yields 62.46-67.45% and 46.79-61.16%, respectively. The selected methodologies were to yield a result within the related range of lipid yields, according to the literature, Gunstone and Norris,¹⁴ Peixoto,¹⁵ Soler *et al.*¹⁶ and Picciani,¹⁷ in which the oil yields from the babassu nuts were 60-65%, 65, 60-68%, 65-68%, respectively.

The oil yield obtained using method A with babassu nuts of the Imperatriz (IMP), Esperantinópolis (EPT), Riachão (RIA), São Luís (SL) and Fortuna (FOR) (65.17, 65.17, 65.81, 66.45 and 67.45%) are in accordance with Soler *et al.*¹⁶ and Picciani.¹⁷ The Penalva City (PEN) (62.46%) is within the range reported by Gunstone and Norris¹⁴ and Soler *et al.*¹⁶

Table 2. Oil contents (%) of babassu nuts (*Orbignya phalerata* Mart.) from Maranhão State (Brazil) obtained by the protocols of IAL (method A) and IUPAC (method B)

Sample	Method A	Method B
	Mean \pm SD / % (CV / %)	Mean \pm SD / % (CV / %)
São Luís	66.45 \pm 0.21 (0.31)	51.36 \pm 1.05 (2.03)
Imperatriz	65.17 \pm 0.44 (0.67)	61.16 \pm 2.43 (3.97)
Fortuna	67.45 \pm 0.04 (0.06)	55.94 \pm 2.66 (4.75)
Esperantinópolis	65.17 \pm 0.44 (0.67)	58.80 \pm 1.16 (1.97)
Penalva	62.46 \pm 1.36 (2.17)	46.79 \pm 5.02 (10.72)
Riachão	65.81 \pm 1.03 (1.56)	56.38 \pm 0.11 (0.20)

SD: standard deviation; CV: coefficient of variation.

In method B, the oil yield of babassu nuts from Imperatriz presented a percentage equal to 61.16%, which is consistent with Gunstone and Norris¹⁴ and Soler *et al.*¹⁶ However, the babassu nut oil yield from other cities when method B was employed showed lower values than those reported in the literature.¹⁴⁻¹⁷

The extraction methods A and B of the babassu nut samples were reproducible with coefficient of variation (CV) less than 5%, except extraction of the Penalva sample by Method B which presented highest CV 10.72% (Table 2). Moreover, the method A showed the highest oil contents when compared to method B. The lipid concentrations were statistically different ($p < 0.05$) between the methods.

The oil yield from the nuts depends on the nature of the solvent, the temperature of extraction, seed particle, among other factors. The larger amount of lipid extracted from babassu nuts by Soxhlet extraction with hexane (method A) in contrast with petroleum ether (method B) was due to a better solubility of non-polar lipids in hexane.^{18,19} Therefore, the extraction method A was the most appropriate methodology for obtainment of triacylglycerols from babassu nuts.

The lipid fraction extracted using method A was subjected to hydrolysis reaction to free fatty acids (FFA). Then, FFA was submitted to esterification reaction using H_2SO_4/NH_4Cl /methanol resulting in their respective fatty acid methyl esters. Typical chromatogram obtained from GC-MS analysis of FAMES from babassu nuts are presented in Figure 2. As it can be observed, the chromatographic profile showed smooth base line and good reproducibility due to less variation to retention time.

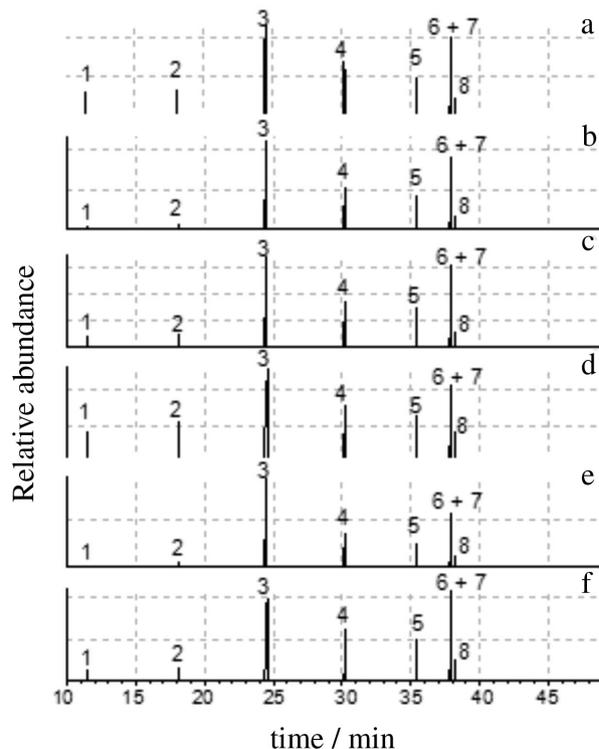


Figure 2. GC-MS chromatograms using HP-1MS capillary column of the fatty acid methyl ester composition of babassu nut oils from Cities of the Maranhão State (Brazil): (a) São Luís (SL), (b) Esperantinópolis (EPT), (c) Fortuna (FOR), (d) Riachão (RIA), (e) Penalva (PEN) and (f) Imperatriz (IMP). Fatty acid methyl esters: 1- methyl caprylate (C8:0), 2- methyl capricate (C10:0), 3- methyl laurate (C12:0), 4- methyl myristate (C14:0), 5- methyl palmitate (C16:0), 6- methyl linoleate (C18:2), 7- methyl oleate (C18:1) and 8- methyl stearate (C18:0).

The characteristic fragment ions of mass spectra by electron ionization (EI, 70 eV) of fatty acid methyl esters (FAME) are: (1) methyl caprylate (C8:0) EIMS: $[M^+]$: 158 (0.34%), 87 (36%), 74 (100%), 55 (29%) and 41 (42%); (2) methyl capricate (C10:0) EIMS: $[M^+]$: 186 (0.51%), 143 (9%), 87 (43%), 74 (100%), 55 (31%) and 41 (51%); (3) methyl laurate (C12:0) EIMS: $[M^+]$: 214 (2.5%), 143 (18%), 87 (84%), 74 (100%), 55 (67%) and 41 (78%); (4) methyl myristate (C14:0) EIMS: $[M^+]$: 242 (1.4%), 87 (34%), 74 (100%), 55 (60%) and 41 (43%); (5) methyl palmitate (C16:0) EIMS: $[M^+]$: 270 (2.0%), 87 (65%), 74 (100%), 55 (44%) and 41 (60%); (6) methyl linoleate (C18:2) EIMS: $[M^+]$: 294 (1.5%), 81 (100%), 67 (83%), 55 (75%) and 41 (60%); (7) methyl oleate (C18:1) EIMS: $[M^+]$: 296 (1.5%), 264 (5%), 110 (10%), 55 (100%) and 41 (95%); (8) methyl stearate (C18:0) EIMS: $[M^+]$: 294 (1.5%), 255 (5%), 143 (11%), 87 (67%), 74 (100%), 55 (53%) and 41 (69%). The typical fragmentation of methyl esters (the McLafferty rearrangement ion is characterized by bond cleavage of β linkage at carbon 2 and 3 from carbonyl and migration of H for the carbo-methoxy group) presents m/z 74 $[H_3COCOHCH_2^+]$ in the mass spectra.²⁰

However, the McLafferty ions (m/z 74) are only abundant in fragmentation of methyl esters of saturated fatty acids. In contrast, the mass spectrum of methyl esters of unsaturated fatty acids shows hydrocarbon ions with m/z 55 ($[C_nH_{2n-3}]^+$) to methyl esters of monoenoic fatty acids as the base peak and hydrocarbon ions (m/z 67, 81, 95, 109, etc.) of general formula ($[C_nH_{2n-3}]^+$) are predominant in the lower mass range to methyl esters of dienoic fatty acids.

In the chromatographic analysis, it was identified eight fatty acid methyl esters in *O. phalerata* nuts from Maranhão State, as can be seen in the Table 3. The results were expressed as fatty acid composition (%) determined by GC-MS peak integration, and for chemical constituent identification, it was used the similarity index (Wiley 229 library) and retention time of methyl esters of the FAME standard mixture.

The babassu oil (*O. phalerata*) showed a high percent of saturated fatty acids, ranging from 80.32 to 87.80%. The results also showed that there was no difference in types and/or classification of fatty acids among the cities in the study. All samples presented the same chromatographic profiles of fatty acids with an even number of carbon atoms,

with the presence of three medium chain saturated fatty acids (C8:0, C10:0 and C12:0), three long chain saturated fatty acids (C14:0, C16:0 and C18:0) and two unsaturated fatty acids: a monoenoic acid, oleic acid (C18:1) and a dienoic acid, linoleic acid (C18:2).

The results obtained for fatty acid profiles of the babassu oils are in accordance with data reported in the literature,²¹⁻²⁶ in particular the lauric acid (C12:0) contents which showed variation from 44.86 to 52.15% and highest predominance in *Orbignya* sp oils. The salts prepared from lauric acid have a chemical structure that favors a balance of hydrophilic-lipophilic action, suitable for use in the detergent industry.²⁷ Table 4 shows fatty acid chemical composition of babassu nuts (*Orbignya* sp) reported in the literature.²¹⁻²⁶

The Codex Alimentarius, an international standard for food and drugs, shows the main quality parameters of babassu oils from *Orbignya* sp., a standardized species. The Resolution RDC 270 No. 482 (September 23, 1999) from the Brazilian National Health Surveillance Agency (Agência Nacional de Vigilância Sanitária, ANVISA),²⁸ which regulates the quality and authenticity of babassu oil, also adopts this standard. These parameters, compared

Table 3. Fatty acid composition (%) of babassu oils from different cities of Maranhão State (Brazil)

Fatty acid	t_r / min	SI / %	City					
			SL	EPT	FOR	RIA	PEN	IMP
Caprylic (C8:0)	11.47 ± 0.11	92	5.03	0.97	2.65	4.54	0.52	2.32
Capric (C10:0)	9.18 ± 0.09	91	5.89	2.54	3.35	7.99	2.32	3.03
Lauric (C12:0)	24.53 ± 0.19	91	46.89	46.96	46.53	48.93	52.15	44.86
Myristic (C14:0)	30.21 ± 0.09	91	16.95	16.89	16.91	15.64	16.58	17.57
Palmitic (C16:0)	35.42 ± 0.05	93	7.98	9.86	9.13	7.46	8.63	9.44
Linoleic (C18:2)	37.82 ± 0.03	94	1.34	1.86	1.72	1.65	1.53	1.67
Oleic (C18:1)	37.95 ± 0.04	95	13.54	17.82	16.51	10.55	15.13	17.96
Stearic (C18:0)	38.23 ± 0.02	93	2.38	3.10	3.20	3.24	3.14	3.15
ΣSaturated			85.12	80.32	81.77	87.80	83.34	80.37
ΣUnsaturated			14.88	19.68	18.23	12.20	16.66	19.63
Total			100	100	100	100	100	100

t_r : retention time; SI: similarity index; ΣSaturated: sum of saturated fatty acids; ΣUnsaturated: sum of unsaturated fatty acids; SL: São Luís; EPT: Esperantinópolis; FOR: Fortuna; RIA: Riachão; PEN: Penalba; IMP: Imperatriz.

Table 4. Typical fatty acid composition (%) of babassu oils²¹⁻²⁶

Fatty acid	Fatty acid composition / %					
	Martin and Guichard ²¹	Chow ²²	Rossell ²³	Ferreira <i>et al.</i> ²⁴	Codex Alimentarius ²⁵	Lima <i>et al.</i> ²⁶
Caproic(C6:0)	nd	0.4	nd	3.3	nd	nd
Caprylic(C8:0)	nd	5.3	5.5	9.2	2.6-7.3	6.0
Capric(C10:0)	nd	5.9	5.5	9.6	1.2-7.6	5.0
Lauric(C12:0)	44-47	44.2	43.0	54.7	40.0-55.0	44.0
Myristic(C14:0)	15-18	15.8	16.0	11.8	11.0-27.0	17.0
Palmitic(C16:0)	6.9	8.6	9.0	4.8	5.2-11.0	8.0
Stearic(C18:0)	3.5	2.9	3.5	2.05	1.8-7.4	4-5
Oleic(C18:1)	12-16	15.1	15.0	6.5	9.0-20.0	14.0
Linoleic(C18:2)	1-2	1.7	2.6	0.9	1.4-6.6	2.0

nd: not detected.

with the results obtained in this work for the species of *O. phalerata*, show that the percentage (%) of caprylic acid C8:0 of the samples from Esperantinópolis, Imperatriz and Penalva, was lower than the Codex Alimentarius values,²⁵ while the babassu nut sample from Riachão presented a percentage of capric acid C10:0 higher than the Codex Alimentarius, and the samples from São Luís and Fortuna cities were in agreement.

The classification of *O. phalerata* nuts from different regions of Maranhão State was performed using fatty acid composition by exploratory data analysis. The multivariate analysis of PCA and HCA are used for pattern recognition non-supervised. The chemical information subserves a better visualization of similarity between samples and infers about possible differences promoted by the variables in the study.²⁹⁻³¹

The fatty acid contents found on different samples of babassu oils obtained by chromatographic analysis were submitted to the PCA method. Initially, the numbers of principal components (PCs) that describe the original data were selected based on the percentage of variance explained. PCA demonstrated that a small number of variables dominates the total data variability, as the three first PCs accounted for 97.35% of the total variability. The first component is responsible for 56.99%, the second accounts for 25.28%, and the third explains 15.09% of the total information.

The PCA plot (Figure 3), considering the contribution or weight for each measurement, shows that PC1 separates the babassu nut oils according to the content of palmitic (0.986), oleic (0.972) and capric (-0.916); caprylic (-0.803) and myristic (0.709) fatty acids. In PC2, the samples were grouped in relation to the content of stearic (0.792), myristic (-0.670) and lauric (0.674) acids, while in PC3, the samples were divided as to lesser or greater amount of lauric acid (-0.664) and linoleic acid (0.574).

The babassu oil samples from Fortuna (FOR), Esperantinópolis (EPT) and Imperatriz (IMP) showed similar chemical composition, considering the major and minor fatty acids, as shown in the graph PCA scores (Figure 3). The oil sample from São Luís (SL) differs from the others due to its higher content of minor fatty acids, caprylic (C8:0) and capric (C10:0) and lower content of oleic acid (C18:1). In turn, the babassu oil from Riachão (RIA) showed a higher content of caprylic acid (C8:0) and the lowest content of palmitic (C16:0) and oleic (C18:1) acids.

Figure 4 shows the PCA plot of the first three principal components: a three dimensional representation of the PCA analysis. In this representation, the similarity of the oil samples promotes a clear division of the Maranhão State in three regions: Penalva and São Luís in the North;

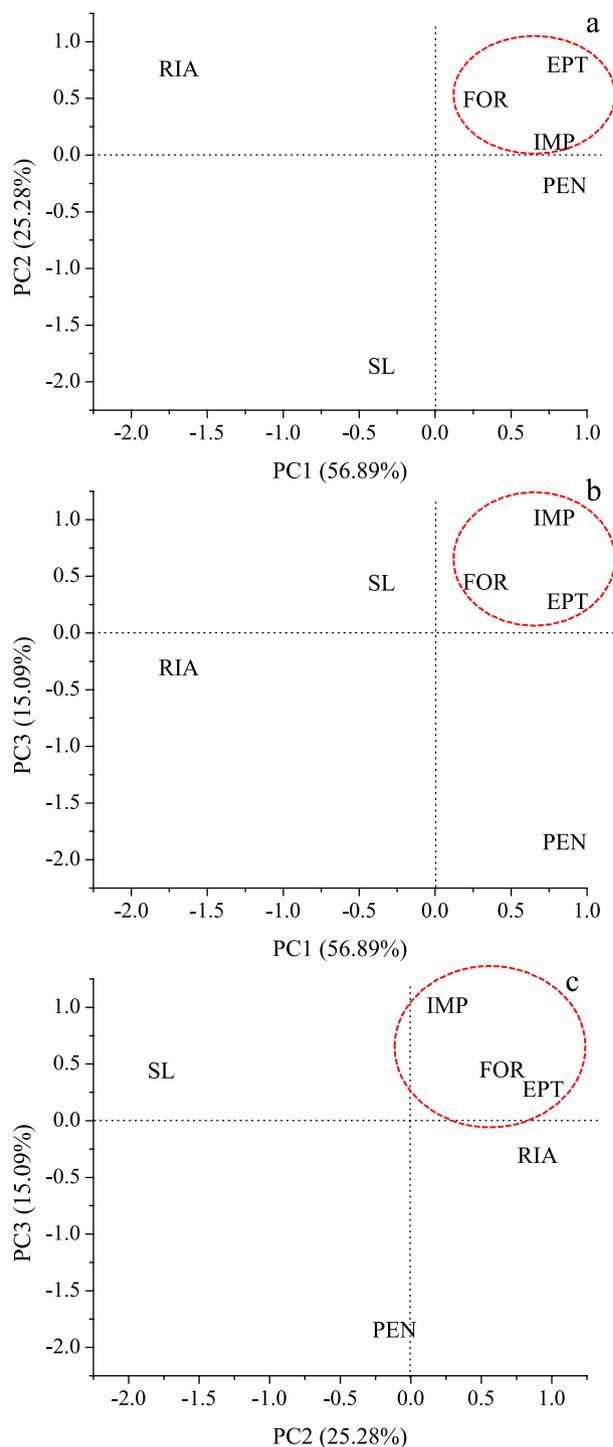


Figure 3. PCA score plot of babassu nuts: (a) PC1 vs. PC2, (b) PC1 vs. PC3 and (c) PC2 vs. PC3. Esperantinópolis (EPT), Fortuna (FOR), Imperatriz (IMP), Penalva (PEN), Riachão (RIA) and São Luís (SL).

Imperatriz, Fortuna and Esperantinópolis in the Central region; and Riachão in the South. The division observed in the 3D PCA plot (Figure 4) is comparable to Figure 1, map of the distribution of six *O. phalerata* samples in Maranhão State, which indicates that the chemical composition of the oils is associated with their geographic location.

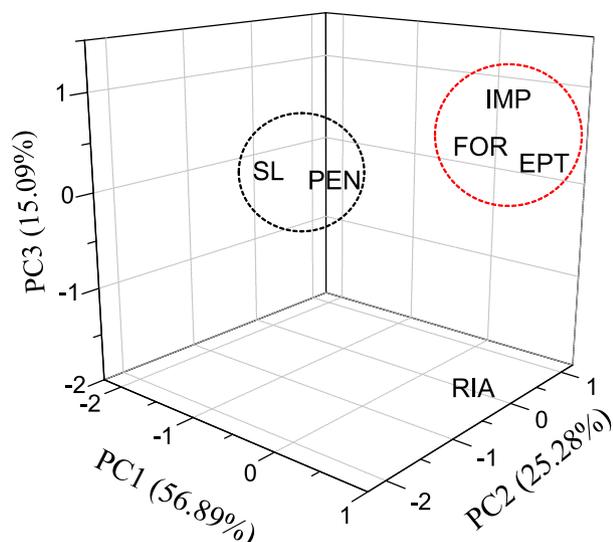


Figure 4. 3D PCA plot, correlation and principal components (PC1 vs. PC2 vs. PC3). Esperantinópolis (EPT), Fortuna (FOR), Imperatriz (IMP), Penalva (PEN), Riachão (RIA) and São Luís (SL).

HCA makes the distinction among babassu oil samples, considering the similarity in the fatty acid contents: the smaller Euclidean distance, the greater the similarity between samples. The HCA dendrogram correlates with the results obtained by PCA plot, PC1 vs. PC2 (Figure 3a), improving visualization of the formed groups. As shown in Figure 5, the babassu oils were classified into three groups, group I containing the samples from Imperatriz (IMP), Fortuna (FOR) and Esperantinópolis (EPT), group II consisting of Penalva (PEN) and São Luís (SL), while the group III is constituted only of Riachão (RIA) sample. These results show that babassu oils of the same geographical region in the Maranhão State (Brazil) have similarities in the fatty acid contents, which may provide useful criteria for geographical origin authentication of babassu nuts.³¹

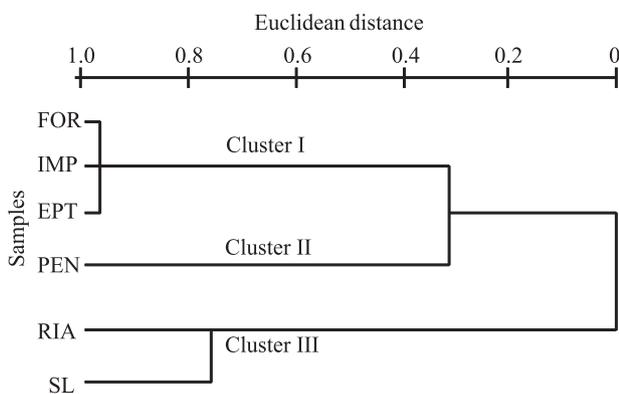


Figure 5. Dendrogram of hierarchical cluster analysis (HCA), Esperantinópolis (EPT), Fortuna (FOR), Imperatriz (IMP), Penalva (PEN), Riachão (RIA) and São Luís (SL).

Conclusions

The extraction of lipids from babassu nuts (*O. phalerata*) using the Adolfo Lutz Institute method was the most appropriate methodology for triacylglycerol obtainment. The analyses by GC-MS showed the predominance of saturated fatty acids, with a high lauric acid percentage, the Penalva nuts presented higher content of lauric acid 52.15%. The multivariate analysis methods, PCA combined with HCA, evidenced the similarity of the fatty acid composition of babassu oils from different regions in the Maranhão State, showing the importance of the exploratory data analysis to extract new information from the chemical data. The exploratory data analysis by PCA and HCA allowed to infer that the oils of the same territorial range have similar chemical composition, regardless of the biome. These data indicate knowledge of biodiversity of fatty acids of *O. phalerata* among the regions of the Maranhão State.

Acknowledgments

The authors thank Coordination for the Improvement of Higher Education Personnel (CAPES, Brazil), National Council for Scientific and Technological Development (CNPq, Brazil) and the Maranhão State Research Foundation (FAPEMA, Brazil) for financial support and research scholarships.

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Submitted: December 12, 2012

Published online: February 28, 2013