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Physicochemical characterization of the pulp oil of bacuri *Attalea phalerata* Mart. ex Spreng. (Arecaceae)

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Abstract

The aim of the study was to characterize the pulp oil of bacuri *Attalea phalerata* Mart. ex Spreng. (Arecaceae) according to official analytical methods. Total phenolic and carotenoids contents were evaluated by spectrophotometry, and tocopherols composition by high-performance liquid chromatography. The fatty acid profile was obtained through gas chromatography from samples transesterified with potassium hydroxide in methanol and n-hexane. According to the proximate composition, bacuri pulp contained 41.5 % carbohydrates and 39.2 % lipids. Regarding its physicochemical properties, the oil showed a free fatty acids content of 0.7 %, a peroxide value of 1.4 meq/kg, a refractive index of 1.463, an iodine number of 84.3 g I_2/100 g, a saponification number of 193.5 mg KOH/g, an unsaponifiable matter of 0.5 %, and 48.7 h of oxidative stability. Total phenolic, carotenoids, and tocopherols contents recorded values of 2.4 mg GAE/g, 243.0 µg/g, and 86.8 mg/kg, respectively. The bacuri oil showed a fatty acid composition similar to olive oil and a high percentage of unsaturation, finding 67.3 % of monounsaturated acids, and 11.3 % of polyunsaturated acids. The main fatty acids were oleic (67.3 %), palmitic (13.3 %), and linoleic (10.5 %). Due to its physicochemical characteristics, bacuri oil has a great potential to be used in food preparations, such as salad oil or in margarine formulation.

Keywords: bioactive compounds, phenolic content, physicochemical properties, plant oils, proximate composition

Caracterización fisicoquímica del aceite de pulpa de bacuri *Attalea phalerata* Mart. ex Spreng. (Arecaceae)

Resumen

El objetivo del estudio fue caracterizar el aceite de pulpa de bacuri *Attalea phalerata* Mart. ex Spreng. (Arecaceae) de acuerdo con métodos analíticos oficiales. Los contenidos totales de fenólicos y carotenoides se evaluaron mediante espectrofotometría, y la composición de tocoferoles, mediante cromatografía líquida de alta resolución. El perfil de ácidos grasos se realizó por cromatografía de gases a partir de las muestras transesterificadas con hidróxido de potasio en metanol y n-hexano. Según la composición proximal, la pulpa de bacuri registró un 41,5 % de carbohidratos y un 39,2 % de lípidos. En cuanto a las propiedades fisicoquímicas, el aceite presentó un contenido de ácidos grasos libres de 0,7 %, valor de peróxido de 1,4 meq/kg, índice de refracción de 1,463, índice de yodo de 84,3 g I_2/100 g, índice de saponificación de 193,5 mg KOH/g, materia insaponificable de 0,5 % y estabilidad oxidativa de 48,7 h. Los contenidos totales fenólicos, de carotenoides y de tocoferoles fueron de 2,4 mg EAG/g, 243,0 µg/g y 86,8 mg/kg, respectivamente. El aceite de bacuri mostró una composición de ácidos grasos similar a la del aceite de oliva y un alto porcentaje de insaturación, con un 67,3 % de ácidos monoinsaturados y un 11,3 % de poliinsaturados. Los principales ácidos grasos fueron el oleico (67,3 %), el palmítico (13,3 %) y el linoleico (10,5 %). Debido a sus características fisicoquímicas, el aceite de bacuri tiene un gran potencial para ser utilizado en preparaciones alimenticias como aceite de ensaladas o en formulación de margarinas.

Palabras clave: aceites vegetales, composición proximal, compuestos bioactivos, contenido fenólico, propiedades fisicoquímicas

Introduction

Bacuri, *Attalea phalerata* Mart. ex Spreng. is a palm that belongs to the Arecaceae family, and is also known as acuri or guacuri (Negrelle, 2015). It is widely distributed in the Brazilian states of Mato Grosso do Sul and Mato Grosso. The pulp has colors that range from yellow to orange due to the presence of carotenoids, and some of these are vitamin A precursors (Coimbra & Jorge, 2013). Its fruits are used cooked to prepare juices, jellies, and ice cream due to its high nutritional value and sensory attributes (Negrelle, 2015). The pulp oil is also rich in saturated fatty acids, as well as polyunsaturated and monounsaturated acids. It is also used by the local population to relieve joint pain and as a hair tonic (Lima et al., 2017).

Vegetable oils rich in health-beneficial compounds are in great demand due to consumer interest in disease prevention and health promotion. These compounds include phenolics, carotenoids, tocopherols, antioxidants, and fatty acids with a high content of mono and polyunsaturated acids (Parry et al., 2005).

It is exceedingly beneficial to consume monounsaturated and polyunsaturated fatty acids through the diet. The omega-3 polyunsaturated fatty acids are precursors of prostaglandins, leukotrienes, and thromboxanes with anti-inflammatory, anticoagulant, antiplatelet, and vasodilatory activities (Calder, 2013). On the other hand, the omega-6 fatty acid group plays an important physiological role. It participates in cell membrane structure activities, influencing blood viscosity, blood vessels permeability, antiplatelet action, blood pressure, and platelet functions (Arima & Fukuda, 2011). The principal monounsaturated fatty acid is oleic acid. Studies show that oleic acid-rich diets act beneficially on the lipid profile and may reduce low-density lipoprotein (LDL)-cholesterol level and the incidence of heart disease (Lopez-Huertas, 2010).

Various health benefits have been attributed to the action of carotenoids. They act as antioxidants against cardiovascular diseases, certain cancers, neurological disorders, and macular degeneration related to age and cataracts; they also strengthen the immune system, and act in gene activation and inflammatory processes by modulating the lipoxygenase (Gama & Sylos, 2007).

It has been demonstrated that palm species are promising sources of bioactive compounds and unsaturated fatty acids. However, there is not much nutritional, chemical, and pharmacological information on the use of the bacuri palm *Attalea phalerata* pulp oil, especially concerning physicochemical properties, and tocopherol and phenolic composition. Therefore, it is essential to investigate and quantify such compounds in the oil extracted from the bacuri palm fruit, focusing on its food or industrial use potential. Accordingly, this study aimed to characterize the bacuri (*A. phalerata*) pulp through its composition and fatty acid profile, as well as by the physicochemical properties of its oil.

Materials and methods

Plant material

Composite samples comprised of three batches of bacuri fruits from the southeast and midwest regions of the São Paulo state, Brazil, were analyzed in triplicate. After harvesting, whole fruits were washed with distilled water and dried at 40 ºC for 3 h. Subsequently, the pulp was manually separated from the seed with a steel knife. Then, the pulp was dried once more at 40 °C to reduce its moisture content.

Proximate composition of the pulp

The proximate composition of the pulp was established through the following variables: moisture content by dehydration in a vacuum oven at 70 °C, according to method Ca 2d-25 of the American Oil Chemists' Society (AOCS, 2009); ash by calcination at 550 ºC, according to method Ba 5a-49 (AOCS, 2009); lipids by Soxhlet extraction with petroleum ether at 40-60 °C, according to method Bc 3-49 (AOCS, 2009); proteins employing the Kjeldahl method, according to method 984.13 of the Association of Official Analytical Chemists (AOAC, 2005), and total carbohydrates and fiber by difference.

Characterization of oil extracted from fruit pulp

The oil used for analysis was obtained from the fruit pulp through extraction with petroleum ether at 40 to 60 °C in the Soxhlet apparatus. The bacuri pulp oil was characterized according to the levels of the following variables: free fatty acid, peroxide value, refractive index at 40 °C, iodine value, saponification value, and oxidative stability, using the Rancimat method (Metrohm Ltd., Herisau, Switzerland) at 110 °C with an airflow rate of 20 L/h, according to method Cd 12b-92 (AOCS, 2009).

Total phenolic compounds

Total phenolic compounds were calculated using the Folin-Ciocalteu reagent and a standard curve of gallic acid, as described by Singleton and Rossi (1965). The blue color produced by the reduction of the Folin-Ciocalteu phenol was measured spectrophotometrically (Shimadzu, Kyoto, Japan) at a wavelength of 765 nm, and expressed as mg of gallic acid equivalents per gram of oil (mg GAE/g). The extraction of phenolic compounds was performed according to the method proposed by Parry et al. (2005).

Total carotenoids analysis

Total carotenoids were determined spectrophotometrically (Shimadzu, Kyoto, Japan) using the method described by Rodriguez-Amaya (1999) for the extraction of carotenoids. Quantification was calculated using absorption values in the maximum absorption wavelength and an A value of 2,592 in petroleum ether. Carotenoids were expressed as β-carotene, in µg/g sample.

Tocopherols composition

The composition of tocopherols was established according to method Ce 8-86 (AOCS, 2009), using a high-performance liquid chromatography (HPLC) system (Varian Inc., Walnut Creek, USA) equipped with a fluorescence detector. The analysis conditions were the following: a silica column of 250 mm x 4.6 mm i.d. with a pore size of 0.5 μm (Varian Inc., Walnut Creek, USA). The system was operated isocratically at a flow rate of 1.2 mL/min. The operating conditions were an λ excitation of 290 nm and an λ emission of 330 nm, and a mobile phase comprised of the mixture of 99.5 % n-hexane and 0.5 % isopropanol. Values were calculated based on the excitation peak area of the reading and expressed in mg/100 g.

Fatty acids composition

Fatty acids composition was determined by chromatography employing a GC 3900 gas chromatographer (Varian Inc., Walnut Creek, USA) equipped with a flame ionization detector (GC-FID) with a split ratio of 1:30, a fused silica capillary column CP-Sil 88 of 60 m of width, an internal diameter of 0.25 mm, and a film thickness of 0.20 μm (Varian Inc., Walnut Creek, USA). The samples were transesterified into methyl esters using potassium hydroxide in methanol and n-hexane, according to method Ce 2-66 (AOCS, 2009).The initial column temperature was 90 °C for 4 min, increasing to 195 °C at 10 °C/min, and then an isothermal procedure was applied for 16 min. The injector temperature was 230 °C, and the detector was 240 °C. The carrier gas was hydrogen. Fatty acids were identified according to the retention times, and quantification was done through the normalized area (%) method. A mixture of 37 esters of fatty acids was used as a standard (Supelco, Bellefonte, USA) from C4:0 to C24:1, with purity between 99.1 and 99.9 %.

Statistical analysis

The results of the analytical determinations, in triplicate, were expressed as means ± SD (standard deviation).

Results and discussion

The major constituents of the bacuri pulp were total carbohydrates (41.5 %), lipids (39.2 ± 0.6 %), and proteins (8.5 ± 0.4 %) (table 1). The mineral content, represented by the ash fraction, was also relevant (2.7 ± 0.0 %). Studies carried out with pulps of other palm fruits, such as guariroba (*Syagrus oleracea* (Mart.) Becc.), macaúba (*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.), and inajá (*Maximiliana maripa* (Aubl.) Drude), also presented carbohydrates and lipids as the main constituents, showing their high energy potential (Coimbra & Jorge, 2011; Costa-Singh, 2015). The levels of nutrients from the bacuri pulp were very similar to those found in the freeze-dried açaí (*Euterpe oleracea*, Mart.) pulp. In a previous study, Menezes et al. (2008) found in açaí pulp, values of 42.53 % for total carbohydrates, 40.75 % for lipids, and 8.13 % for proteins.

Table 1. Proximate composition (%) of bacuri pulp

Components	Mean ± SD
Moisture	8.1±0.1
Ash	2.7±0.0
Lipids	39.2±0.6
Proteins	8.5±0.4
Total carbohydrates	41.5

SD: standard deviation.

Source: Elaborated by the authors

The physicochemical properties of bacuri oil are shown in table 2. The level of free fatty acids was 0.7 ± 0.2 %, and the peroxide value was 1.4 ± 0.0 meq/kg. The low acid and peroxide values recorded, verify the good quality of the bacuri oil related to the development of hydrolytic and oxidative reactions, respectively. The Codex Alimentarius Commission (2009) has defined a maximum acid value of 4.0 mg KOH/g for crude oils and maximum peroxide values of 10 and 15 meq/kg for crude and refined oils, respectively, as quality parameters. The values reported by the bacuri oil are well below these limits, indicating that it is a high-quality raw material and oil.

Table 2. Physicochemical properties of bacuri pulp oil

Components	Mean ± SD
Free fatty acids (%)	0.7±0.2
Peroxide value (meq/kg)	1.4±0.0
Refractive index (40 ºC)	1.463±0.0
Iodine number (g I_2/100 g)	84.3±1.2
Saponification number (mg KOH/g)	193.5±1.7
Unsaponifiable matter (%)	0.50±0.0
Oxidative stability (h)	48.7±0.1
Phenolic compounds (mg GAE/g)	2.4±0.4
Total carotenoids (µg/g)	243.0±2.8

SD: standard deviation.

Source: Elaborated by the authors

The refractive index and iodine number related to the unsaturation degree of the oil, were 1.463 ± 0.0 and 84.3 ± 1.2 g I_2/100 g, respectively. The refractive index and iodine number presented by the bacuri oil are higher than the values of other oils also extracted from palm fruits, including guariroba *Syagrus oleracea* (1.453 and 70 g I_2/100 g, respectively), jerivá, *Syagrus romanzoffiana* (Cham.) Glassman (1.446 and 69 g I_2/100 g, respectively), and macaúba, *Acrocomia aculeata* (1.455 and 80 g I_2/100 g, respectively) (Coimbra

& Jorge, 2011). These findings suggest that bacuri pulp oil is more unsaturated than the oils mentioned above.

The saponification number of the bacuri oil was 193.5 ± 1.7 mg KOH/g, similar to most vegetable oils, which have a saponification number between 181 and 265 mg KOH/g. The bacuri pulp oil obtained an unsaponifiable matter content value of 0.50 ± 0.0 %, i.e., below the limit of 1.5 % fixed for cotton, sunflower, soybean, coconut, and olive oils (Codex Alimentarius Commission, 2009).

The oxidative stability index is often a mandatory criterion within the purchasing specifications of food companies while procuring large shipments of oils for food production (Sarkar et al., 2015). The oxidative stability of bacuri pulp oil at 110 °C was 48.7 ± 0.1 h, revealing a high induction period. This value was higher than the one recorded for olive oil, which was 20.9 h (Koprivnjak et al., 2008), as well as compared to other oils also used for cooking, such as soybean and sunflower oils, showing oxidative stability values at 110 °C of 5.85 and 18.83 h, respectively (Sarkar et al., 2015).

Concerning the total phenolic compounds content, bacuri pulp oil recorded 2.4 ± 0.4 mg GAE/g, considered a high value compared with those found in other oils such as soybean, sunflower, corn, canola, and rice, which had total phenolic compound levels ranging from 1.26 to 1.48 mg/100 g (Siger et al., 2008). The levels of total phenolic compounds in guariroba, jerivá, and macaúba pulp oils, were close to the one recorded for the bacuri pulp oil, with values of 2.68, 3.26, and 2.21 mg GAE/g, respectively (Coimbra & Jorge, 2012).

The amount of carotenoids present in the bacuri pulp oil, expressed as β-carotene, was 243.0 ± 2.8 μg/g (table 2). This amount was much higher than those seen in raspberry, blueberry, and blackberry seed oils, ranging from 7.07 to 16.82 μg/g (Parry et al., 2005). Another study showed that the content in corn germ and fiber oils were also lower than the total carotenoids found in the current study, i.e., 5 and 80.1 μg/g, respectively; on the contrary, the value for corn seed oil (324.5 μg/g) was higher (Moreau et al., 2007).

The bacuri pulp oil included only α- and δ-tocopherol (table 3) with a total value of 86.8 ± 0.6 mg/kg, being α-tocopherol the predominant type (86 %). Masson et al. (2008) found similar total tocopherol content (84 mg/kg) in the seed oil of the Chilean palm *Jubaea chilensis* (Molina) Baill. (Arecaceae), being α-tocopherol also the predominant type, accounting for 45 % of the total value. Generally, higher tocopherol amounts are associated with the unsaturated fatty content in oils (Tuberoso et al., 2007). In this line, some more saturated palm oils showed lower total tocopherol contents than the bacuri pulp oil, including guariroba pulp oil (45.13 mg/kg), guariroba and jerivá kernel oils (19 mg/kg), and macaúba pulp oil (23.10 mg/kg) (Coimbra & Jorge, 2012).

Table 3. Tocopherols (mg/kg) found in bacuri pulp oil

Tocopherols	Mean ± SD
Alpha	74.7 ± 0.5
Delta	12.1 ± 0.1
Total	86.8 ± 0.6

SD: standard deviation.

Source: Elaborated by the authors

The fatty acid composition of bacuri pulp is presented in table 4. The oil proved to be composed mainly of unsaturated fatty acids (78.6 ± 0.1 %), of which 67.3 ± 0.1 % are mono, and 11.3 ± 0.1 % polyunsaturated. Oleic acid was the predominant fatty acid, leading to being classified as monounsaturated with a high content of oleic acid.

Table 4. Fatty acids composition (%) of bacuri pulp oil

Fatty acids	Mean ± SD
C8: 0 (caprylic)	0.3 ± 0.0
C10: 0 (capric)	0.2 ± 0.0
C12: 0 (lauric)	2.1 ± 0.0
C14: 0 (myristic)	1.1 ± 0.0
C16: 0 (palmitic)	13.3 ± 0.1
C18: 0 (stearic)	3.7 ± 0.4
C20: 0 (arachidic)	0.2 ± 0.0
C22: 0 (behenic)	0.5 ± 0.1
Σ saturated fats	21.4 ± 0.2
C18: 1 (oleic)	67.3 ± 0.1
Σ monounsaturated fats	67.3 ± 0.1
C18: 2 (linoleic)	10.5 ± 0.1
C18: 3 (α-linolenic)	0.8 ± 0.0
Σ polyunsaturated fats	11.3 ± 0.1
Saturated/unsaturated	1/3.7
Oleic/linolenic	1/0.2

SD: standard deviation.

Source: Elaborated by the authors

Among the polyunsaturated fatty acids, linoleic (10.5 ± 0.1 %) and linolenic acids (0.8 ± 0.0 %) stood out; both are considered essential fatty acids. The rate between oleic and linoleic acids was 1/0.2. Among the saturated fatty acids, palmitic was the predominant type (13.3 ± 0.1 %). According to Lima et al. (2017),

A. phalerata oil is mainly composed of saturated (20.69 %) and unsaturated fatty acids (78.53%), of which 57.66 % are monounsaturated, and 20.87 % are polyunsaturated. Oleic, linoleic, and palmitic acids are the predominant types.

According to McDonald and Eskin (2007), a good frying oil should have a profile very similar to the one presented by bacuri pulp oil, i.e., low in saturated fatty acids, low in linoleic acid, very low in linolenic acid, and very high in oleic acid. New vegetable oils containing high levels of oleic acid would provide an alternative to the traditional oils commonly used, and ideal as frying oil considering health and stability issues.

Coimbra and Jorge (2012) analyzed the composition of macaúba pulp oil, finding similar results with a predominance of fatty acids, such as oleic (52.5 %), palmitic (24.6 %), and linoleic (13.80 %) acids. In a study carried out by Luzia and Jorge (2013), the main unsaturated fatty acids of *Annona crassiflora* Mart. (Annonaceae) seed oil were also oleic (49.75 %) and linoleic (16.29 %) acids, while the predominant saturated fatty acid was palmitic acid (18.07 %). According to these authors, this result is consistent with the fact that palmitic acid is the most abundant saturated fatty acid in vegetable lipids.

Comparing the rate between the total saturated and unsaturated fatty acids analyzed in this study with those cited by Borges et al. (2007) for common edible oils such as peanuts, corn, and soybeans, bacuri pulp oil (1/3.7) approached the value found in peanut oil (1/2.8), whereas for soybean oil, this rate was 1/5.7, and for maize, the ratio was 1/6.7.

The composition shown by the bacuri oil (table 4) was very similar to olive oil, providing levels of oleic acid between 55 and 83 %, linoleic acid between 3.5 and 21 %, and linolenic acid of 0.9 % (Codex Alimentarius Commission, 2009). Studies suggest that the beneficial effects of olive oil come from its unique fatty acid profile, characterized by a relatively low level of polyunsaturated and a high level of monounsaturated fatty acids, mainly oleic acid, i.e., the same features recorded for the bacuri oil. Monounsaturated fatty acids, combined with bioactive compounds, can reduce the levels of total and LDL cholesterol, and may protect against the cognitive decline related to age (Schwingshackl & Hoffmann, 2014). A diet rich in monounsaturated fatty acids acts on the resistance to LDL oxidation, metabolic control, and improves the lipid profile (Pérez-Jiménez et al., 2007).

Conclusions

It can be concluded that bacuri pulp is an important source of nutrients, especially carbohydrates and lipids. The bacuri oil was very similar to olive oil with physicochemical properties within the rules stated by the current legislation for vegetable oils. Furthermore, it has good oxidative stability and high contents of phenolic compounds, carotenoids, and monounsaturated fatty acids, mainly oleic acid, demonstrating its potential to become a new source of 'high oleic' oil and bioactive compounds to be used in food preparations, such as salad oil or in margarine formulation.

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Disclaimers

The authors declare no conflict of interest.

References

Association of Official Analytical Chemists [AOAC]. (2005). *Official Methods of Analysis of AOAC International* (18th ed.). AOAC International.

American Oil Chemists' Society [AOCS]. (2009). Official Methods and Recommended Practices of the AOCS. AOCS Press.

Arima, M., & Fukuda, T. (2011). Prostaglandin D. and T.2 inflammation in the pathogenesis of bronchial asthma. *The Korean Journal of Internal Medicine, 26*(1), 8-18. https://doi.org/10.3904/kjim.2011.26.1.8

Borges, S. V., Maia, M. C., Gomes, R. C., & Cavalcanti, N. B. (2007). Chemical composition of umbu (*Spondias tuberosa* Arr. Cam) seeds. *Química Nova, 30*(1), 49-52. https://doi.org/10.1590/S0100-40422007000100011

Calder, P. C. (2013). Omega-3 polyunsaturated fatty acids and inflammatory processes: nutrition or pharmacology? *British Journal of Clinical Pharmacology, 75*(3), 645-662. https://doi.org/10.1111/j.1365-2125.2012.04374.x

Codex Alimentarius Commission. (2009). Standard for Named Vegetable Oils. CXS 210-1999. Food and Agriculture Organization of the United States; World Health Organization. https://bit.ly/35xkVSS

Coimbra, M. C., & Jorge, N. (2011). Characterization of the pulp and kernel oils from *Syagrus oleracea, Syagrus romanzoffiana*, and *Acrocomia aculeata. Journal of Food Science, 76(8), 1156-1161.* https://doi.org/10.1111/j.1750-3841.2011.02358.x

Coimbra, M. C., & Jorge, N. (2012). Fatty acids and bioactive compounds of the pulps and kernels of Brazilian palm species, guariroba (*Syagrus oleraces*), jerivá (*Syagrus romanzoffiana*) and macaúba (*Acrocomia aculeata*). *Journal of the Science of Food and Agriculture, 92*(3), 679-684. https://doi.org/10.1002/jsfa.4630

Coimbra, M. C., & Jorge, N. (2013). Phenolic compounds, carotenoids, tocopherols and fatty acids present in oils extracted from palm fruits. *Boletim do Centro de Pesquisa de Processamento de Alimentos, 31*(2), 309-320. http://dx.doi.org/10.5380/cep.v31i2.34854

Costa-Singh, T. (2015). Avaliação dos parâmetros físico-químicos e estabilidade de compostos bioativos em óleos de polpa e amêndoa de frutos amazônicos. [PhD thesis, Universidade Estadual Paulista "Júlio de Mesquita Filho"]. Institutional repository UNESP. https://repositorio.unesp.br/handle/11449/127931

Gama, J. J., & Sylos, C. M. (2007). Effect of thermal pasteurization and concentration on carotenoid composition of Brazilian Valencia orange juice. *Food Chemistry, 100*(4), 1686-1690. https://doi.org/10.1016/j.foodchem.2005.01.062

Koprivnjak, O., Škevin, D., Valić, S., Majetić, V., Petričević, S., & Ljubenkov, I. (2008). The antioxidant capacity and oxidative stability of virgin olive oil enriched with phospholipids. *Food Chemistry, 111*(1), 121-126. https://doi.org/10.1016/j.foodchem.2008.03.045

Lima, F. F., Traesel, G. K., Menegati, S. E., Dos Santos, A. C., Souza, R. I., Oliveira, V. S., Sanjinez-Argandoña, J., Cardoso, C. A., Oesterreich, S. A., & Vieira, M. C. (2017). Acute and subacute oral toxicity assessment of the oil extracted from *Attalea phalerata* Mart ex Spreng. pulp fruit in rats. *Food Research International, 91*, 11-17. https://doi.org/10.1016/j.foodres.2016.11.019

Lopez-Huertas, E. (2010). Health effects of oleic acid and long chain omega-3 fatty acids (EPA and DHA) enriched milks. A review of intervention studies. *Pharmacological Research, 61*(3), 200-207. https://doi.org/10.1016/j.phrs.2009.10.007

Luzia, D. M., & Jorge, N. (2013). Bioactive substance contents and antioxidant capacity of the lipid fraction of *Annona crassiflora* Mart. seeds. *Industrial Crops and Products, 42*(1), 231-235. https://doi.org/10.1016/j.indcrop.2012.05.027

Masson, L., Camilo, C., & Torija, M. E. (2008). Caracterización del aceite de coquito de palma chilena (*Jubaea chilensis*). *Grasas y Aceites, 59*(1), 33-38. https://doi.org/10.3989/GYA.2008.V59.I1.487

McDonald, B. E., & Eskin, M. N. A. (2007). Role of fat in the diet. In M. D. Erickson (Ed.), *Deep frying; chemistry, nutrition, and practical applications* (2nd ed, pp. 167-171). Elsevier. https://doi.org/10.1016/B978-1-893997-92-9.50014-1

Menezes, E. M., Torres, A. T., & Srur, A. U. (2008). Valor nutricional da polpa de açaí (*Euterpe oleracea*, Mart.) liofilizada. *Acta Amazonica, 38*(2), 311-316. https://doi.org/10.1590/S0044-59672008000200014

Moreau, R. A., Johnston, D. B., & Hicks, K. B. (2007). A comparison of the levels of lutein and zeaxanthin in corn germ oil, corn fiber oil and corn kernel oil. *Journal of the American Oil Chemists' Society, 84*, 1039-1044. https://doi.org/10.1007/s11746-007-1137-2

Negrelle, R. R. B. (2015). *Attalea phalerata* Mart. ex spreng.: aspectos botânicos, ecológicos, etnobotânicos e agronômicos. *Ciência Florestal, 25*(4), 1061-1066. https://doi.org/10.5902/1980509820669

Parry, J., Su, L., Luther, M., Zhou, K., Yurawecz, M. P., Whittaker, P., & Yu, L. (2005). Fatty acid composition and antioxidant properties of cold-pressed marionberry, boysenberry, red raspberry, and blueberry seed oils. *Journal of Agricultural and Food Chemistry, 53*(3), 566-573. https://doi.org/10.1021/jf048615t

Pérez-Jiménez, F., Ruano, J., Pérez-Martínez, P., López-Segura, F., & López-Miranda, J. (2007). The influence of olive oil on human health: not a question of fat alone. *Molecular Nutrition & Food Research, 51*(10), 1199-1208. https://doi.org/10.1002/mnfr.200600273

Rodriguez-Amaya, D. B. (1999). *A guide to carotenoids analysis in food*. ILSI Press.

Sarkar, A., Golay, P., Acquistapace, S., & Craft, B. D. (2015). Increasing the oxidative stability of soybean oil through fortification with antioxidants. *International Journal of Food Science and Technology, 50*(3), 666-673. https://doi.org/10.1111/ijfs.12671

Schwingshackl, L., & Hoffmann, G. (2014). Monounsaturated fatty acids, olive oil and health status: a systematic review and meta-analysis of cohort studies. *Lipids in Health and Disease, 13*, 154. https://doi.org/10.1186/1476-511X-13-154

Siger, A., Nogala-Kalucka, M., & Lampart-Szczapa, E. (2008). The content and antioxidant activity of phenolic compounds in cold-pressed plant oils. *Journal of Food Lipids, 15*(2), 137-149. https://doi.org/10.1111/j.1745-4522.2007.00107.x

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture, 16*(3), 144-158.

Tuberoso, C. I., Kowalczyk, A., Sarritzu, E., & Cabras, P. (2007). Determination of antioxidant compounds and antioxidant activity in commercial oilseeds for food use. *Food Chemistry, 103*(4), 1494-1501. https://doi.org/10.1016/j.foodchem.2006.08.014