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Extraction of bacaba (*Oenocarpus bacaba*) oil with supercritical CO_2: Global yield isotherms, fatty acid composition, functional quality, oxidative stability, spectroscopic profile and antioxidant activity

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SUMMARY: Bacaba is widely consumed by the Amazonian population, and is promising for the production of cooking oil. The objective of this research was to determine the parameters of bacaba oil extraction with supercritical CO_2: the fatty acid composition, functional quality, oxidative stability, spectroscopic profile and antioxidant activity of the extracted oil. Extractions of bacaba (*Oenocarpus bacaba*) oil were performed with supercritical CO_2 at temperatures of 40 and 60 ºC, with pressures varying from 120 to 420 bar. The highest mass yield was 60.39 ± 0.72% on a dry basis, obtained in the isotherm of 60 °C and 420 bar. Oleic acid was the major compound. The Infrared spectroscopic profile showed the predominance of unsaturated fatty acids. The results indicate that bacaba oil presents good functional quality.

***KEYWORDS**: Amazon; Bacaba; Bioactive Compounds; Functional Food; Supercritical CO_2*

RESUMEN: ***Extracción de aceite de bacaba (*Oenocarpus bacaba*) con CO_2 supercrítico: Isotermas de rendimiento global, composición de ácidos grasos, calidad funcional, estabilidad oxidativa, perfil espectroscópico y actividad antioxidante*.** La bacaba es muy consumida por la población amazónica, constituyendo una promesa para una producción de aceite de cocina. El objetivo de esta investigación es determinar parámetros de la extracción de aceite de bacaba con CO_2 supercrítico, la composición de ácidos grasos, evaluar su calidad funcional, la estabilidad oxidativa, el perfil espectroscópico y la actividad antioxidante del aceite. Las extracciones de aceite de bacaba (*Oenocarpus bacaba*) se realizaron con CO_2 supercrítico a temperaturas de 40 y 60 ºC y presiones de 120 a 420 bar. El mayor rendimiento en masa fue de 60.39 ± 0.72% en base seca, obtenido en la isoterma de 60 °C y 420 bar. El ácido oleico fue el compuesto mayoritario. El perfil espectroscópico infrarrojo mostró el predominio de ácidos grasos no saturados. Los resultados indicaron que el aceite de bacaba presenta buena calidad funcional.

***PALABRAS CLAVE**: Alimentos funcionales; Amazonas; Bacaba; CO_2 supercrítico; Compuestos bioactivos*

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1. INTRODUCTION

Bacaba (*Oenocarpus bacaba*) is a fruit widely consumed by the riverside populations of the Amazon region. The morphological characteristics of the bacaba tree were described by Mendonça and Araújo (1999). Its fruits are rich in oil and present a varied chemical composition. The bacaba fruits can be promising for the production of oil with similar quality to cooking oil, due to its content in fatty acids.

According to Gouveia *et al.,* (2007), a fixed oil, to be considered functional, must be rich in fatty acids and have biological activity. Some fatty acids such as linolenic acid may prevent cardiovascular diseases and may act as antihypertensive agents in patients with peripheral arterial disease (Caligiuri *et al.*, 2014). In addition to fatty acids, other compounds of higher polarity like phenolics can also be found in bacaba (Abadio Finco *et al*., 2012).

Oil quality depends on several factors such as oxidative stability, which, in turn, does not depend exclusively on the chemical composition, but also on other factors, such as the extraction conditions and the storage technique. Mechanical pressing or the use of organic solvents, for example, are characterized as processes that reduce the quality of lipid extracts (Li *et al.*, 2014; Anwar *et al*., 2013). Hydrolytic rancidity can be accelerated by the mechanical pressing system, while the use of organic solvents may increase the cytotoxicity of the extracts.

On the other hand, Extraction with supercritical CO_2 does not leave toxic residues in the extracts. This extraction technique is considered "green" and the carbon dioxide is inert and easily exits the extract by pressure difference. In addition, supercritical extraction makes it possible to obtain various fractions of oils, mainly in terms of mass yield and chemical composition (Gouveia *et al*., 2007; Carvalho Junior *et al*., 2005; de Melo *et al*., 2014).

In this context, supercritical CO_2 has been shown to be an important alternative tool to conventional extraction methods, and can be used to obtain functional compounds from bacaba (*Oenocarpus bacaba*). The objective of this research was to determine the parameters of bacaba oil extraction with supercritical CO_2, fatty acid composition, functional quality, oxidative stability, spectroscopic profile and antioxidant activity.

2. MATERIALS AND METHODS

2.1. Bacaba samples

The drupes of bacaba were collected at the Campus of the Federal University do Pará, latitude -01°72'50'', longitude -48 °86'18'', in the city of Abaetetuba, state of Pará, Brazil, in February, 2014. The fruits were processed on the same day of collection, with potable water in a pulp machine to obtain the bacaba pulp. The pulp was kept frozen for 7 months. This material was frozen and dried in a lyophilizer (model LJI015, JJ Científica, Brazil), with an initial dehydration temperature of -18 ºC and final temperature of 35 ºC, for 72 hours. The pulp was stored in polyethylene vacuum packages and kept in a refrigerator at 5 °C for 7 months. The pulp moisture was determined in triplicate using an infrared moisture analyzer (model SHI-MOC-120H, Shimadzu, Brazil). The water activity (aw) was determined in an analyzer (model 4TE, Aqualab, USA) and the true density of the sample was determined with a Helium pycnometer (Ultrapyc 1200e model, Quantachrome, USA) at the Chemistry Institute of the University of Campinas (Unicamp, São Paulo, Brazil). The apparent density was calculated as the ratio of the sample mass and the sample volume put in the extraction cell, which is shown in equation 1. The bed porosity was determined by the mathematical relationship between true and apparent densities, according to equation 2.

$$\rho_a = \frac{m}{v} \tag{1}$$

Where: ρ_a is the apparent density, m is the sample mass and V is the sample volume.

$$\varepsilon = 1 - \frac{\rho_a}{\rho_r} \tag{2}$$

Where: ε is the bed porosity and ρ_r is the true density of the sample.

2.2. Oil extraction with supercritical CO_2

The experiments were performed on a Spe-ed™ SFE extraction unit (model 7071 from Applied Separations, USA), equipped with a 100 mL cell, with the following dimensions: internal diameter of 0.0314m and 0.1244m height (see Figure 1). For the determination of the global yield isotherms, 20g of pulp were used in each assay, corresponding to 0.1005m height of the sample inside the cell. The global yield isotherms were performed in the following operating conditions: temperatures of 40 and 60 °C and pressures of 120, 170, 290, 190, 270 and 420 bar. The density values, for each condition, were calculated using the TermoDi software, developed by the laboratory of physical separations (LASEFI) of the State University of Campinas (UNICAMP), which uses the Peng-Robinson equation of state (Peng and Robinson, 1976). The solvent used was CO_2 (99.9% pure, White Martins, Pará, Brazil). The extraction time corresponded to a static period of 1,800s and a dynamic period of 10,800s. The CO_2 mass flow rate was 8.85×10^{-5} kg/s. The global yields were calculated as the mathematical ratio between the

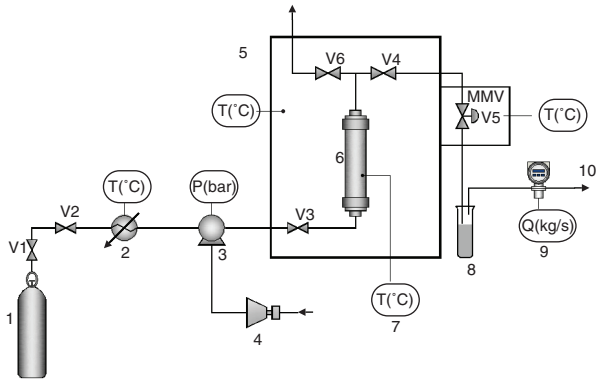

FIGURE 1. Supercritical carbon dioxide extraction apparatus. 1. CO_2 tank; 2. Cooling bath; 3. Pump; 4. Compressor; 5. Oven; 6. Extractor vessel; 7. Monitor; 8. Vial; 9. Flowmeter; 10. CO_2 Outlet; V1 – V6 Flow control valves; MMV Micrometric valve.

extracted oil mass and the sample mass (db), as shown in equation 3. Each assay was performed in triplicate. These experiments were performed in duplicate.

$$Y_{(\%b.s.)} = \left(\frac{m_0}{m_a\left(1-\frac{U_a}{100}\right)} \right) 100 \qquad (3)$$

Where: $Y_{(\%\ b.s.)}$ is the global yield (%); m_0 is the oil mass; m_a is the sample mass and U_a is the moisture of the sample.

2.3. Fatty acid profile

The fatty acid profile was obtained by gas chromatography of the fatty acid methyl esters (FAMEs) according to the methodology described by Rodrigues, Darnet and Silva (2010). The FAMEs were prepared via saponification and esterification with a methanolic solution of potassium hydroxide (0.1 mol·L^{-1}) and a methanolic solution of hydrochloric acid (0.12 mol·L^{-1}). The FAMEs were extracted with hexane and inserted into a gas phase chromatograph (model Varian CP 3380), equipped with a CP-Sil 88 capillary column 60 m long, with 0.25 mm internal diameter, 0.25 µm film thickness (Varian Inc., USA) and flame ionization detector (FID). Helium gas was used as the mobile phase at a flow rate of 0.9 mL·min^{-1}. An aliquot of 1µL was injected with the injector set at 250 °C. The column temperature was programmed to 80 °C and then raised to 205 °C with a heating rate of 4 °C·min^{-1}. Peaks were identified based on the retention time, and compared to a standard sample of fatty acids (Nucheck prep Inc, USA). The quantification of the peak areas was carried out using the software Varian Star 3.4.1 and the results were expressed in percentages. These experiments were performed in duplicate.

2.4. Functional quality of bacaba oil

The function of the lipid fractions was determined by the proportions of fatty acids, determined in their respective lipid profiles, evaluated by three composition indexes: Atherogenicity Index (AI), equation 4; Thrombogenicity Index (TI), equation 5, defined according to Ulbricht and Southgate (1991); and the hypocholesterolemic/hypercholesterolemic (H/H) ratio, equation 6, defined by Santos-Silva *et al*., (2002).

$$AI = \frac{(C12:0)+4(C14:0)+(C16:0)}{(\sum MUFA)+(\sum\omega-6)+(\sum\omega-3)} \qquad (4)$$

$$I.T = \frac{(C14:0)+(C16:0)+(C18:0)}{0.5(\sum MUFA)+0.5(\sum\omega-6)+(\sum\omega-3)+\left(\frac{\sum\omega-3}{\sum\omega-6}\right)} \qquad (5)$$

$$H/H = \frac{\begin{array}{l}(C18:1\omega-9)+(C18:2\omega-6)\\+(C20:4\omega-6)+(C18:3\omega-3)\\+(C20:5\omega-3)+(C22:5\omega-3)\\+(C22:6\omega-3)\end{array}}{(C14:0)+(C16:0)} \qquad (6)$$

Where: C12:0 (lauric acid); C14:0 (myristic acid); C16:0 (palmitic acid); C18:0 (stearic acid); C18:1 ω-9 (oleic acid); C18:2 ω-6 (linoleic acid); C18:3 ω-3 (linolenic acid); C20:4 ω-6 (arachidonic acid); C20:5 ω-3 EPA (eicosapentaenoic acid); C22:5 DPA (docosapentaenoic acid); C22:6 DHA (docosahexaenoic acid); MUFA (Monounsaturated Fatty Acids).

2.5. Oxidative stability

The oxidative stability of the oil was analyzed using the Rancimat method (model 743, MetronHerisan, Switzerland), with the following parameters: temperature of 110 °C, air flow of 10 L·h^{-1}, and 5g of sample (AOCS, 2009). The induction period was determined by the conductivity measurement.

2.6. Infrared absorption spectroscopy

The absorption spectra of the samples were obtained by Fourier transform infrared spectroscopy on a spectrometer (Prestige 21 Cat. No. 206-73600-36, Shimadzu Corporation IR, Japan), with registers in the range of spectral frequency of absorption from 4000 to 400 cm^{-1}. Sample incorporation was performed on potassium bromide (KBr) tablets with Scan 100 and resolution of 4 cm^{-1}. All bands were analyzed by the software Origin 8.0.

2.7. Antioxidant capacity

The antioxidant capacity quantification of the bacaba extracts was performed based on the 2,2'-azino-bis (3-ethylbenz-thiazoline-6-sulfonic acid) (ABTS•+) radical method as described by Pellegrini *et al*., (2006). The oils were initially solubilized in n-hexane, depending on their presumed activity. In this case, 10 g of oil were solubilized in 10 mL of n-hexane. The points for obtaining the Trolox calibration curve were prepared.

The ABTS•+ radical was prepared by reacting ABTS•+ 7mM with potassium persulfate 2.45 mM, maintained at room temperature and stored in the dark for 16 hours. After this time, the solution was diluted in ethyl alcohol until a solution with the absorbance of 0.70 (± 0.05) at 734 nm was obtained.

Five points were prepared to obtain the Trolox calibration curve. The volumes of the radical were 0.5 mL; 2.5 mL; 5 mL; 7.5 mL and 10 mL, diluted in 10 mL of ethyl alcohol and compared to the standard. Still using these volumes, the sample extract was prepared to react with ABTS•+, and then the volumetric flasks were completed with distilled water.

In a dark environment, a 30 µL aliquot of each extract reacted with 3 mL of ABTS•+ solution. After homogenization, the reading (734 nm) was done after 6 minutes of stirring and ethyl alcohol was used as standard to calibrate the spectrophotometer.

Continuing the analysis, the data were plotted on an absorbance versus concentration (in µM of Trolox) plot. To calculate the antioxidant capacity, the line equation was replaced by the absorbance equivalent to 1,000 µM of the Trolox standard. The value obtained for the term *x* corresponded to the sample dilution (mg/L) equivalent to 1,000 µM of Trolox. This analysis was performed in triplicate.

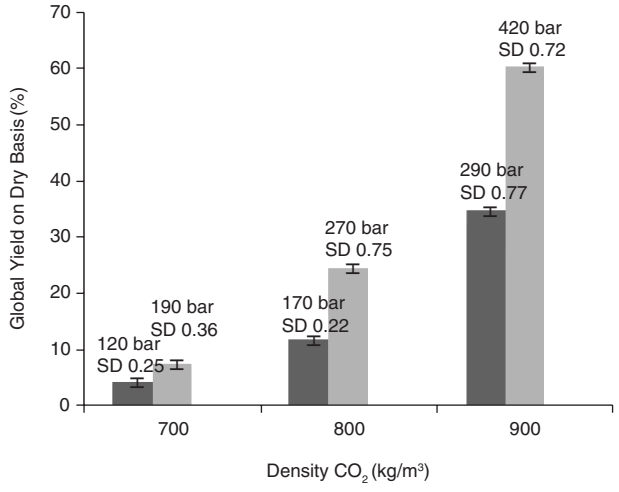

FIGURE 2. Supercritical CO_2 extraction isotherms yield on dry basis versus density of bacaba (*Oenocarpus bacaba*) oil. (■) 40 ºC and (■) 60 ºC isotherms. SD correspond to values of standard deviation of the yields.

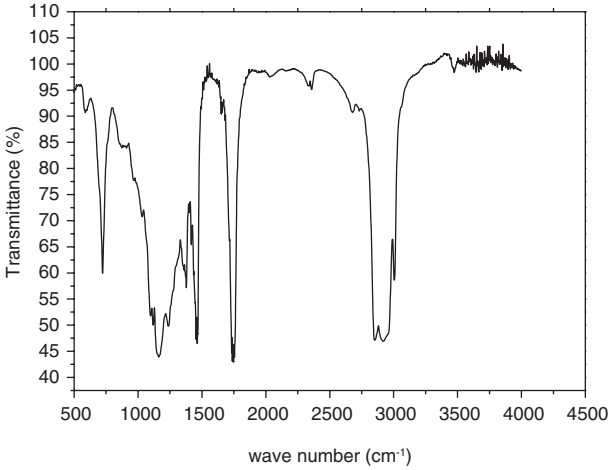

FIGURE 3. Spectrometric profile of bacaba (*Oenocarpus bacaba*) oil obtained in the experimental condition of 60 ºC and 420 bar.

3. RESULTS

3.1. Sample characterization

The mean moisture of the sample was 4.20 ± 0.1% on dry basis (db). The true pulp density was 1,130 ± 10 kg·m^{-3}. The apparent density was 291 ± 10 kg·m^{-3}. The bed porosity was 0.74 ± 0.01. The CO_2 densities calculated were 700, 800 and 900 kg·m^{-3} for each operating condition. The water activity (aw) of the pulp was 0.49 ± 0.01.

3.2. Global yield isotherms

The extraction efficiency and the global oil yields (db) are shown in Figure 2. The highest yield, 60.39 ± 0.72% (db), was obtained under the experimental conditions at 60 °C and 420 bar, while the lowest yield, 4.32 ± 0.25% (db), was observed under the conditions of 40 °C and 120 bar. The results for the bacaba oil + supercritical CO_2 system showed the direct relationship among the global yield, the pressure and the CO_2 density. It was observed that the solvent density directly affected the mass yield during the extraction process. This can also be observed in the work of Batista *et al*., (2015). It is reported in the literature (Carvalho Junior RN *et al*., 2005) that the solvation power of CO_2 over the oil can increase with increasing pressure, since the distances between the molecules decrease. Hence, there is a greater solubility of the solute, which results in an increased global mass yield at the end of the supercritical fluid extraction process. The highest global yields of bacaba oil were observed under conditions of higher CO_2 pressures

Table 1. Total fatty acid contents of bacaba (*Oenocarpus bacaba*) extracts.

	Concentration of fatty acids in % (g/100g)					
	40 ºC	**40 ºC**	**40 ºC**	**60 ºC**	**60ºC**	**60ºC**
	120 bar	**170 bar**	**290 bar**	**190 bar**	**270 bar**	**420 bar**
Fatty Acids	**700 kg·m^{-3}**	**800 kg·m^{-3}**	**900 kg·m^{-3}**	**700 kg·m^{-3}**	**800 kg·m^{-3}**	**900 kg·m^{-3}**
C8:0	0.01	0.03	0.06	0.03	0.08	0.01
C10:0	0.05	0.03	0.01	0.01	0.01	0.02
C12:0	0.12	0.29	0.15	0.05	0.32	0.21
C13:0	0.18	0.10	0.06	0.21	0.05	0.03
C14:0	0.89	0.41	0.40	1.20	0.35	0.22
C15:0	0.07	0.08	0.06	0.07	0.07	0.07
C16:0	22.71	23.15	22.12	23.30	22.47	22.05
C16:1 (ω-7)	0.45	0.61	0.43	0.58	0.46	0.02
C17:0	0.08	0.05	0.09	0.10	0.06	0.09
C18:0	3.02	2.48	3.39	2.43	2.71	2.68
C18:1 (Cis ω-9)	59.96	57.90	61.16	57.93	60.13	60.52
C18:2 (Cis ω-6)	11.85	14.04	11.48	13.33	12.66	13.37
C18:3 (ω-3)	0.08	0.06	0.11	0.06	0.06	0.06
C20:0	0.54	0.76	0.48	0.70	0.56	0.64
SFA	27.66	27.39	26.82	28.10	26.69	26.03
UFA	72.34	72.61	73.18	71.90	73.31	73.97
MUFA	60.41	58.51	61.59	58.52	60.59	60.54
PUFA	11.93	14.10	11.58	13.38	12.72	13.43

Where: C8:0 (caprylic acid); C10:0 (capric acid); C12:0 (lauric acid); C13:0 (tridecanoic acid); C14:0 (myristic acid); C15:0 (pentadecanoic acid); C16:0 (palmitic acid); C16:1 ω-7 (palmitoleic acid); C17:0 (margaric acid); C18:0 (stearic acid); C18:1Cis ω-9 (oleic acid); C18:2Cis ω-6 (linoleic acid); C18:3 ω-3 (linolenic acid); C20:0 (arachidic acid); C22:0 (behenic acid); SFA (Saturated Fatty Acids); UFA (Unsaturated Fatty Acids); MUFA (Monounsaturated Fatty Acids); PUFA (Polyunsaturated Fatty Acids). The standard deviations for all fatty acids were lower than 1.8%.

and densities, with no inflection points between the isotherms. Also, the solute vapor pressure did not predominate in the CO_2 + bacaba oil system, due to the difference in yields between 40 and 60 ºC when supercritical CO_2 density values were fixed.

3.3. Fatty acid profile

The chemical composition of the fatty acids in the different bacaba oil fractions did not change in qualitative terms. However, in a quantitative scope, the presence of some compounds such as oleic acid was significant, equal to 61.16% (Table 1). The predominance of unsaturated fatty acids is notably a characteristic of this oil (around 73%), regardless of the parameters applied in the extraction conditions. Oleic acid showed predominant concentrations over all other fatty acids, ranging from 57.90 to 61.16%, corresponding to the conditions of 40 ºC, 170 bar and 800 kg·m^{-3} and 40 ºC, 290 bar and 900 kg·m^{-3}, respectively. Evaluating the quantitative and qualitative aspects of unsaturated fatty acids, oleic acid predominated in all conditions.

Regarding the class of saturated fatty acids, palmitic acid had the highest concentration, varying from 22.05 to 23.30 (conditions of 60 ºC, 420 bar and 900 kg·m^{-3} and 60 ºC, 190 bar and 700 kg·m^{-3}, respectively). In descending order, stearic acid was found in all six conditions, with the highest concentration in the condition of 40 °C, 290 bar and 900 kg·m^{-3} and the lowest concentration in the condition of 60 °C, 190 bar and 700 kg·m^{-3}. In general, the mean percentage of saturated fatty acids present in the chromatographic profile was around 27%.

By analyzing the aspects related to the variations in the extraction parameters, it is possible to compare the results with the studies of Santos *et al*., (2012) and Santos *et al*., (2013). In their research, they varied the conditions of temperature, pressure and CO_2 density and obtained proportionally higher yields with the progressive increase in these parameters.

The importance of the aspects evaluated by gas chromatography and by analysis of its resulting profile shows the nutritional and functional relevance of the consumption of this Amazonian fruit and the possibilities of applications in several industrial segments, being guided, among other aspects, by its great presence of fatty acids compared to other

Amazonian oleaginous plants (Santos *et al*., 2012; Oliveira *et al*., 2017).

The relevance of the presence of these compounds and their proportional relations reinforce the potentialities of this oil. Oleic (ω-9) and linoleic (ω-6) acids are part of the modulatory components of the immune system and of the organic responses to inflammatory processes (Montillet *et al.*, 2013). These compounds are important to living beings, due to the structural role of cell membranes and for being a source of metabolic energy (da Costa *et al*., 2017).

ω-6 and ω-3 ratios influence the metabolism of eicosanoids, gene expression and intercellular communication. These two classes are metabolically different and have opposite physiological functions; thus, nutritional balance is important to achieve homeostasis and normal development of the organism. A diet with ω-6 and ω-3 is essential for proper metabolism of the human body functions, and aids in preventing cardiovascular and chronic degenerative diseases (Gupta and Prakash, 2014; Sales-Campos *et al*., 2013).

3.4. Functional quality

The prevalence of essential fatty acids and nutritional properties includes functions in the prevention of pathological diseases, which characterize the bacaba fruits as functional food, since their indexes are related to organic functions. The results showed that the ratio of polyunsaturated/saturated fatty acids was 0.43. The atherogenicity index (AI) of the oil was 0.30, the thrombogenicity index (TI) was 0.67 and the hypocholesterolemic/hypercholesterolemic ratio (H/H) found was 3.32.

The ratio of polyunsaturated/saturated fatty acids is considered a highly relevant factor for vegetable oils, and expresses the lipid functionality of the material and the potentiality of the oil. When observed under the nutritional and functional perspective in the different phases of life, this ratio is related to the development of nerve cells, neurons and glial cells in the intrauterine phase, and later, its effects can be seen in several physiological processes, including the prevention and treatment of cardiovascular diseases, arteriosclerosis, thrombosis, hypertriglyceridemia, hypertension, diabetes, arthritis and cancer (Gupta and Prakash, 2014).

The results of the equations, expressed as AI and TI, in reduced values, in the composition of foods and diets are one of the most desired factors. Since they reveal better nutritional and functional composition, they can act in the prevention of cardiovascular diseases. In contrast, the results of the H/H ratio should be evaluated inversely to AI and TI, since their high values are directly related to the benefit offered to the metabolism of cholesterol and the formation of high density lipoproteins (HDL). Thus, the higher its value, the more suitable the oil will be for human consumption (Ulbricht and Southgate 1991; Santos-Silva *et al*., 2002).

The profile of fatty acids and their correlations exert considerable influence on human organic functions, linked to the constitution and maintenance of cell membranes, composition of the human immune system, the pro and anti-inflammatory system, among other antioxidant functions and oxidative protection (Cândido *et al*., 2015; Gawlik-Dziki, 2012). According to Arab-Tehrany *et al*., (2012), polyunsaturated fatty acids, as is the case of ω-3, exert a strong positive influence on human health.

3.5. Oxidative stability

Based on its constitution of fatty acids and antioxidant functions, the oxidative stability of bacaba oil showed an induction period of 339 minutes. The time of oxidative resistance is directly related to its high degree of unsaturated compounds, promoting a lower stability of the material against the simulation of real working conditions, such as air atmosphere and high temperature (Pardauil *et al*., 2011). For Frankel (2010), oils that present high contents of oleic acid have relatively higher oxidative stability. It has been reported that lipid oxidation has detrimental effects on food quality and human health, and efforts should be made to minimize oxidation and improve the oxidative stability of lipid products (Shahidi and Zhong, 2010).

3.6. Infrared absorption spectroscopy

The data presented by the fatty acid profile and the oxidative stability of the oil can be monitored and ratified by the presence or absence of spectral bands and their respective intensities in Fourier transform infrared spectroscopy, as shown in Fig. 3.

The characterization of the spectral bands presented by bacaba oil shows the prevalence of vibrational spectra from 3000 cm^{-1} to 2750 cm^{-1}, typical of bands of methyl groups (CH_3, CH_2 and CH). This is similar to the spectral bands of buriti oils (Santos *et al*., 2012; Albuquerque *et al*., 2003). A spectrum in the range of 1750 cm^{-1} of high intensity is observed, which is characteristic of the carbonyl group, methyl esters, ketones and frequent aldehydes present in long chain fatty acids, as found in the fatty acid profile of this oil (Pardauil *et al*., 2011; Silverstein and Webster, 2005). Minor spectral bands in the range of 1500 cm^{-1}, 1250 cm^{-1} and 1000 cm^{-1} are observed with strong intensity, characteristic of the functional groups that contain aromatic rings, alcohols, esters, ethers and carboxylic acids (Silverstein and Webster, 2005). The lowest values of spectra observed are in the range of 750 cm^{-1} and may be linked to sequences of aliphatic fatty acid chains.

3.7. Antioxidant capacity

The antioxidant capacity values obtained for the bacaba oil extracted under the conditions of 60 ºC, 420 bar and 900 $kg \cdot m^{-3}$, by the ABTS•+ radical sequestration method, were 20.69 µmol TE/100g oil. This result is lower than that found by Abadio Finco *et al*., (2012), who obtained results of 3294.55 µmol TE/100 g of *Oenocarpus bacaba* pulp. These results may be related to compounds of higher polarity that are present in the bacaba pulp, such as the anthocyanins cyanidin-3-glycoside and cyanidin-3-rutinoside. Such compounds are not extracted with supercritical CO_2 alone once this solvent has high affinity for lipophilic compounds.

Antioxidants are necessary for the maintenance of human health, since they prevent the formation of reactive oxygen species (ROS) and reactive nitrogen species (RNS) which are constantly formed in the human body. Free radicals can facilitate the appearance of diseases such as cancer, Alzheimer's, Parkinson's, autoimmune and cardiovascular diseases, cataracts, rheumatoid arthritis and many other neural disorders (da Costa *et al*., 2017).

Thus, studies that seek natural antioxidants become increasingly necessary, since the human body does not effectively combat the imbalance of the reactive species of oxygen and nitrogen and diseases caused by these radicals. The fractionation of plant materials with supercritical fluids may represent an alternative in the search for promising new secondary metabolites (bioactive molecules) with functional activities for the maintenance of human health.

4. CONCLUSIONS

The increase in temperature and pressure favored the increase in the mass yield in the process of bacaba oil extraction with supercritical CO_2. The fatty acid, thermogravimetric, oxidative and spectroscopic profiles indicate that bacaba oil has satisfactory functional quality due to the predominance of lipid bioactive compounds responsible for the prevention of chronic-degenerative diseases. The atherogenicity and thrombogenicity indexes, as well as the hypocholesterolemic / hypercholesterolemic ratio suggest that the oil may have cardioprotective action. These results indicate that bacaba oil can be used in the human diet, as table oil, similar to olive oil, besides the possibility of acting in the synthesis and application of phytotherapic compounds for the treatment of cardiovascular diseases based on ω-3, ω-6 and ω-9 compounds.

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