Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online

CHEMICAL AND BIOACTIVE PROPERTIES OF THE OILS FROM BRAZILIAN NUTS

Tainara Costa[1], Carolina Médici Veronezi[1]*, Neuza Jorge[1]

SAP 24152 Received: 01/03/2020 Accepted: 06/07/2020
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 19, n. 2, apr./jun., p. 180-186, 2020

ABSTRACT - This paper aims to determine the content of bioactive substances of lipid fractions extracted from *Bertholletia excelsa*, *Lecythis pisonis* and *Dipteryx lacunifera*, in by the interest of better identifying the quality of these raw materials. Proximate composition of nuts was determined by official methods and total carbohydrate was calculated by difference. The oils were extracted from the nuts by cold pressing and analyzed for fatty acid composition, tocopherols, phytosterols and total carotenoids and phenolics compounds. The fatty acid composition of oil extracted from *L. pisonis* was more unsaturated compared with others oils. *L. pisonis* oil showed to be richer in total tocopherol and γ-tocopherol, moreover showed considerable total phytosterol and carotenoid amounts, thus representing an important source of vitamins A and E. The oils showed significant content of phenolic compounds, with the exception of the oil extracted from *D. lacunifera*. The study revealed that the oils from Brazilian nuts contain bioactive compounds in relevant quantities, *L. pisonis* oil standing out. This fact favors their use for food and, as raw material in chemical, pharmaceutical and cosmetic industries, adding value to products derived from these oils, increasing the viable sources of raw materials.
Keywords: carotenoids, fatty acids, phenolic compounds, phytosterols, tocopherols.

PROPRIEDADES QUÍMICAS E BIOATIVAS DE ÓLEOS DE NOZES BRASILEIRAS

RESUMO - Este trabalho tem como objetivo determinar o teor de substâncias bioativas das frações lipídicas extraídas de *Bertholletia excelsa, Lecythis pisonis* e *Dipteryx lacunifera*, visando a melhor identificação da qualidade dessas matérias-primas. A composição imediata das nozes foi determinada por métodos oficiais e o carboidrato total foi calculado pela diferença. Os óleos foram extraídos das nozes por prensagem a frio e analisados quanto à composição de ácidos graxos, tocoferóis, fitosteróis, carotenoides e compostos fenólicos totais. A composição de ácidos graxos do óleo extraído de *L. pisonis* mostrou-se mais insaturada em comparação com os outros óleos. O óleo de *L. pisonis* também mostrou ser rico em tocoferóis totais e γ-tocoferol; além disso, apresentou quantidades consideráveis de fitosteróis e carotenoides, representando assim uma importante fonte de vitaminas A e E. Os óleos apresentaram um conteúdo significativo de compostos fenólicos, com exceção do óleo extraído de *D. lacunifera*. O estudo revelou que os óleos de castanha do Brasil contêm compostos bioativos em quantidades relevantes, destacando-se o óleo de *L. pisonis*. Esse fato favorece seu uso em alimentos e, como matéria-prima nas indústrias química, farmacêutica e de cosméticos, agregando valor aos produtos derivados desses óleos, e aumentando as fontes viáveis de matérias-primas.
Palavras-chave: carotenoides, ácidos graxos, compostos fenólicos, fitosteróis, tocoferóis.

INTRODUCTION

There is a large number of native plant species in Brazil and some of their fruits proved to be good sources of nutrients, for example, *L. Pisonis* (NOGUEIRA et al., 2010). Considering that, in recent years there has been an increase in the research and production of oleaginous seeds and fruits, both for the food industry, which employ most of the oils obtained from natural sources.

However, a growing interest in the study of foods that carry more than the purely nutritive function has also been observed, in other words, foods that have functional activities, such as preventing the action of free radicals, hypercholesterolemia and hypertension, among others. The composition of these foods contains bioactive compounds that, even in small amounts, may cause preventive effects in physiological disorders (EMAM, 2011).

Vegetable oils contain essential fatty acids and significant levels of other bioactive compounds such as phenolic compounds, tocopherols, phytosterols and carotenoids, contributing to the prevention of cardiovascular diseases through several mechanisms that may be attributed to their antioxidant effects that protect the biomolecules from the action of free (GHARRAS, 2009).

Foods from vegetable origin are a major source of biologically active compounds and polyunsaturated fatty acids. Among them, oleaginous seeds, especially nuts and walnuts, are targets for studies to elucidate the composition of their kernels and oils.

The nuts and walnuts are sources of fiber (1.75 g of soluble fiber per 100 g of walnuts) and bioactive compounds, including phenolic compounds (tannins,

[1]Universidade Estadual Paulista (UNESP), Departamento de Engenharia e Tecnologia de Alimentos, São José do Rio Preto, São Paulo, Brazil. E-mail: cveronezi@hotmail.com. *Correspondenting author.

ellagic acid and curcumin), flavonoids (luteolin, quercetin, myricetin, resveratrol and kampferol) isoflavones (genistein and daidzein), terpenoids, organosulfur compounds and tocopherols. Peanuts are rich in folate, resveratrol and several other flavonoids, while cashew nuts present alkylphenol in abundance (YANG et al., 2009). Moreover, the phenolic compounds in these oleaginous seeds are presented in larger quantities, while the carotenoids, in smaller quantities. The present quantity of phenolics and flavonoids is higher in pecan nuts and peanuts, while the isoflavones, lignans and phytoestrogens are present mostly in pistachio nuts, when compared to other oleaginous seeds (ALASALVAR and SHAHIDI, 2008).

Therefore, the study and characterization of oils extracted from little explored oleaginous seeds is very important, especially regarding the presence of bioactive compounds, favoring their use for food and pharmaceutical industries.

Thus, this study aimed to determine the composition of fatty acids, tocopherols contents, vitamin E activity, phytosterols analysis, total carotenoids, phenolic compounds and oxidative stability in oils extracted from *B. excelsa*, *L. pisonis* and *D. lacunifera*, aiming at a possible use for food or industry.

MATERIAL AND METHODS

The *Bertholletia excels* Humb. & Bonpl., *Lecythis pisonis* Cambess.and *Dipteryx lacunifera* Ducke, fruits were from North and Northeast regions of Brazil, tropical climate region. Immediately after receiving the samples, they were peeled, selected to remove dirt from the shells and those who suffered injuries were separated. They were, then, dried for approximately 72 h, in trays at room temperature to reduce the moisture content up to 10%, wich is recommended for oil extraction. The lots of nuts and walnuts were homogenized, vacuum packaged, properly labelled and stored under refrigeration. The oils were obtained by physical process of cold extraction by using hydraulic press (Tecnal, model TE-098, Piracicaba, Brazil) at room temperature. Then, they were packed in amber glass, inertised with nitrogen gas and stored in a freezer (-18°C) for further analyses.

The analytical determinations of moisture, lipids and ashes were performed according to the official methods of American Oil Chemists' Society (AOCS, 2009). The proteins were determined by the Kjeldahl method and fibers described by Association Official Analytical Chemists (AOAC, 2005) and total carbohydrates were quantified by the difference of the value obtained by the sum of moisture, lipids, ashes, proteins and fibers.

The fatty acid composition was conducted through gas-liquid chromatography from the esterified oils through the method which was AOCS (2009). A gas chromatographer (model 3900, Varian, Walnut Creek, CA, USA) equipped with a flame ionization detector, split injection system, and fused-silica capillary column was used (CP-Sil 88, Microsorb, Varian, Walnut Creek, CA, USA). The initial temperature of the oven was 90°C for 4 min., then it was heated at 10ºC min^{-1} until it reached 195°C, when it was kept at the same temperature for 16 min. The temperatures that were used in the injector and in the detector were 230 and 250°C, respectively. Samples of 1.0 mL were injected, adopting a 1:30 split ratio. Hydrogen was used as the carrier gas. The fatty acids were identified according to their retention times, by comparing them with standard 37 composed of methyl esters of fatty acids C4:0 to C24:1, with purity between 99.1 and 99.9% (Supelco, Bellefonte, USA).

The AOCS method was applied in order to determine the contents of tocopherols (AOCS, 2009). The analysis was performed in high performance liquid chromatograph (Varian Inc., 210-263 model, Walnut Creek, USA) with fluorescence detector, stainless steel column packed with silica (microsorb Si 100, Varian Inc., Walnut Creek, CA, USA) and wavelength excitation in 290 nm and emission at 330 nm. A mixture of 99.5% n-hexane and 0.5% isopropanol, HPLC purity, was used as mobile phase. Around 1 g of the oil sample was weighed in a 25 mL volumetric flask, and such volume was completed with n-hexane with a degree of purity for HPLC. The volumetric flask was covered with aluminum foil to prevent degradation of the isomers by the action of light. Then, the volumetric flask was agitated in the mechanical stirrer, for 1 min. After that, filtering was done in a 0.45 μm filter and injected (20 μL) into the chromatograph.

The mixing of α-, β-, γ-, δ-tocopherol, with purity between 99.0 and 99.9%, was used as standard, containing all isomers; then, it was diluted from concentrated standards and injected. Results of injections were recorded in the computer software Galaxie. Concentration values were calculated based on the area of reading excitement peak and expressed in values of each separate counterpart, in terms of mg kg^{-1}. This activity, represented as the equivalent of α-tocopherol, was calculated by using the correction factor 1.0 for the α-tocopherol content, while the concentrations of β-and γ-tocopherol were multiplied by 0.25, and for the amount of δ-tocopherol the correction factor 0.01 was used. The isomers β-, γ-and δ-tocopherols were calculated with a lower correction factor, in order to avoid the overvaluation of the α-tocopherol equivalent (KORNSTEINER et al., 2006).

Phytosterols composition were determined by saponifying 50-100 mg of the oil extracted with ethanolic KOH solution (1 mL) at 70°C 50 min^{-1}. The internal standard (100 μL of β-cholestanol 3 mg L^{-1} in MTBE) was added to the sample before saponification. The unsaponifiable fraction was extracted using liquid-liquid partitioning into 1 mL of distilled water and 5 mL of n-hexane, according Duchateau et al. (2002). The organic phase was transferred to a test tube containing Na_2SO_4, and the extraction was repeated two times with 5 and 4 mL of n-hexane. All these three extracts were combined and homogenized before injection into a gas chromatograph. The gas chromatograph (Shimadzu, GC 2010 Plus model, Chiyoda-ku, Tokyo, Japan), equipped with a flame

ionization detector, split injection system, and a fused silica capillary column (Restek RTX 5, dimensions of 30 m x 0.25 mm internal diameter and 0.25 µm of film thickness, Shimadzu, Chiyoda-ku, Tokyo, Japan) was used. The carrier gas (high purity hydrogen) was set to a linear velocity of 45.6 cm s^{-1}. The GC oven program was as follows: start at 100°C, hold for 2 min and then heat to 260°C at 15°C min^{-1}, final hold time of 35 min. Phytosterols are identified accordingly with the retention times, comparing with standards of purity of 95-98% (Supelco, Bellefonte, Pennsylvania, USA) and analyzed under the same conditions of the samples. The quantification of each of the isomers was effected by internal standardization (cholestano-5α-3β-ol), based on the peak areas, and expressed in mg 100 g^{-1}.

Total carotenoids were measured spectrophotometrically (Shimadzu, Uv-Vis mini 1240 model, Chiyoda-ku, Tokyo, Japan), using the method described by Rodriguez-Amaya (2001) for the extraction of carotenoids. An aliquot of oil (0.5 g) was transferred to a 10 mL volumetric flask and volume was completed with petroleum ether. The reading of the samples was performed in a scanning spectrophotometer with a wavelength range of 300-550 nm and an A value of 2592 in petroleum ether. Carotenoids were expressed as β-carotene, in micrograms per gram of sample.

The extraction of phenolic compounds was performed according to the method proposed by Parry et al. (2005). Total phenolics were quantified spectrophotometrically (Shimadzu, Uv-Vis mini 1240 model, Chiyoda-ku, Tokyo, Japan), using the Folin-Ciocalteau reagent and gallic acid standard curve method as described by Singleton and Rossi (1965). The blue color produced by reduction of the Folin-Ciocalteau phenol was measured spectrophotometrically at a 765 nm wavelength and the results expressed in GAE mg g^{-1}.

The results of the analytical determinations, in triplicate, were subjected to analysis of variance and the differences between means were tested at 5% of probability by Tukey's test (GACULA JÚNIOR et al., 2008), through the ESTAT program - Statistical Analysis System, version 2.0.

RESULTS AND DISCUSSION

As expected, the nuts presented levels from 1.42 to 2.89% for moisture in their composition (Table 1). *Bertholletia excelsa* showed the lowest moisture content, lower than the one reported by Yang (2009). As for the protein content in the samples, it is noted that these species are rich sources of protein, and the highest content was found in *Lecythis pisonis*. However, in a study on the chemical composition of Spanish nut, a considerable variation in protein content was observed (1.4 to 9.6%), depending on local culture and cultivar (PEREIRA-LORENZO et al., 2006).

Bertholletia excelsa and *Lecythis pisonis* showed high percentages of ashes. As the present ashes content indicates the amount of minerals that there is in a sample it can be implied that the nuts studied in the present work are important sources of these micronutrients. The nuts studied were important sources of lipids for food, and the *Bertholletia excelsa* stood out with 65.03%. Other nuts, such as pecans, also have large amounts of lipids (62.17%) (MACIEL et al., 2020). According Gong & Pegg (2015) the mechanical pressing, depending on equipment design, can result in oil extraction yields of between 70 and 80% (for hydraulic press) and 80-90% (screw pressing).

TABLE 1 - Proximate composition of Brazilian nuts.

Composition (%)	*B. excelsa*	*L. pisonis*	*D. lacunifera*
Moisture	$1.42 \pm 0.02^{c*}$	2.89 ± 0.02^{a}	2.11 ± 0.06^{b}
Protein	16.67 ± 0.01^{b}	22.75 ± 0.05^{a}	13.92 ± 0.02^{c}
Ash	3.89 ± 0.02^{a}	3.88 ± 0.01^{a}	2.42 ± 0.01^{b}
Lipids	65.03 ± 0.30^{a}	58.62 ± 0.09^{b}	35.74 ± 0.06^{c}
Fibers	7.25 ± 0.19^{b}	5.98 ± 0.06^{c}	12.94 ± 0.13^{a}
Carbohydrates total*	5.74	5.87	32.87
Calories (kcal/100 g)	674.91	642.06	508.82

*Mean values followed by different letter within a line are significant different ($p < 0.05$). Mean ± SD ($n = 3$), calculated by difference.

Dietary fiber has been identified as an important component of a healthy diet. It is defined as plant cells components that are resistant to digestion by human digestive enzymes. Its consumption has been associated to reduced risk of chronic diseases (LIU, 2007; DHINGRA et al., 2012). Among the nuts, *Dipteryx lacunifera* showed higher percentage of fibers (12.94%), followed by *Bertholletia excelsa* and *Lecythis pisonis*. The total dietary fiber found in nuts and seeds by Dhingra et al. (2012) ranged from 6.0 to 11.2% for cashew nut and almonds, respectively.

To calculate the amount of total carbohydrates, the percentages of moisture, protein, ash, fat and fiber were 100% excluded. *Dipteryx lacunifera* showed the highest percentage of 32.87%, proving to be an important source of macronutrients when included in the diet. The total carbohydrates content of nuts and walnuts varies considerably, depending on growing conditions, ripeness, cultivar and growing location for the nuts. Maskan & Karatas (1999) found 13.5% of sugar in Gazientep pistachio nuts grown in Turkey.

The nuts analyzed can be important energy intake, once included in the diet. Using the correction factor of

kcal g^{-1} for protein and carbohydrates and 9 kcal g^{-1} for lipids, it was possible to estimate the caloric value of nuts. The *Bertholletia excelsa* was the one that provided higher caloric intake, followed by *Lecythis pisonis*.

The physical process of cold extraction produces oil of high quality since the use of solvent and high temperatures can lead to the darkening of the oil, as well as the degradation of thermosensitive minor components (UITTERHAEGEN & EVON, 2017). According to Table 2, higher amounts of unsaturated fatty acids were found in all oils analyzed, highlighting *L. pisonis* with 79.25%. Santos et al. (2019) studying *L. pisonis Camb* oil also found a predominance of unsaturated fatty acids, regardless of the extraction method used, but from 75.05 to 76.65%. Differences in fatty acid composition are due to several reasons, such as differences between harvesting times, sample processing and preparation, collection time or collection site, edaphoclimatic characteristics, etc. Predominance of monounsaturated acid were found in *D. lacunifera* oil.

Comparing the ratio of total saturated and unsaturated fatty acids analyzed in this study to those reported by Borges et al. (2007) for common oils such as peanut, corn and soybeans, it was found that *B. excelsa* (1/3.05), *L. pisonis* (1/3.82) and *D. lacunifera* (1/3.45) oils were closer to the peanut oil (1/2.8). On the other hand, Costa-Singh et al. (2012). studying the *Couepia edulis* oil found a ratio of 1/1.39.

The amount of α-tocopherol found ranged between 2.80 and 32.13 mg kg^{-1} in *D. lacunifera* and *B. excelsa* oils, respectively (Table 2). From oils extracted by solvent, cashew nut, pecan nut, walnut and common pistachio nut, Yang (2009) obtained α-tocopherol levels of 3.6, 12.2, 20.6 and 15.6 μg g^{-1}, respectively. However, in other vegetable oils, α-tocopherol values of 9-352 mg kg^{-1} for soybean oil and 16-38 mg kg^{-1} for grape seed oil are observed (CODEX, 2009).

TABLE 2 - Fatty acids composition and bioactive compounds of Brazilian nuts oils.

Fatty acids (%)	*B. excelsa*	*L. pisonis*	*D. lacunifera*
Saturated	24.66[a*]	20.76[c]	22.45[b]
Monounsaturated	31.12[c]	39.07[b]	65.77[a]
Polyunsaturated	44.22[a]	40.18[b]	11.78[c]
Sat/Unsat[**]	1/3.05	1/3.82	1/3.45
Bioactive compounds			
Tocopherols (mg kg^{-1})			
Alpha	32.13 ± 0.11[a]	6.97 ± 0.16[b]	2.80 ± 0.27[c]
Beta	1.30 ± 0.07[a]	0.97 ± 0.04[b]	0.80 ± 0.00[b]
Gamma	81.23 ± 0.38[b]	155.57 ± 2.42[a]	nd
Delta	8.00 ± 0.07[a]	8.50 ± 0.13[a]	7.87 ± 0.04[a]
Total	122.67 ± 0.49[b]	172.00 ± 2.60[a]	11.47 ± 0.31[c]
Vitamin E[***]	52.85 ± 0.13[a]	46.19 ± 0.77[b]	3.08 ± 0.27[c]
Phytosterols (mg 100 g^{-1})			
β-sitosterol	51.07 ± 0.03[a]	35.51 ± 0.01[c]	37.43 ± 0.02[b]
Stigmasterol	2.29 ± 0.01[b]	2.21 ± 0.01[c]	14.08 ± 0.02[a]
Stigmastanol	2.12 ± 0.01[b]	195.38 ± 0.02[a]	nd
Total	55.47 ± 0.03[b]	233.10 ± 0.01[a]	51.51 ± 0.03[c]
Total carotenoids (μg g^{-1})	8.01 ± 0.15[b]	10.08 ± 0.23[a]	7.75 ± 0.19[b]
Total phenolic (mg g^{-1})[****]	0.70 ± 0.05[a]	0.67 ± 0.05[a]	0.34 ± 0.05[b]

*Mean values followed by different letter within a line are significant different ($p < 0.05$) Mean ± SD (n = 3) nd: not detected [**]Relationship between the total of saturated and unsaturated. [***]Activity of vitamin E expressed as the equivalent of α-tocopherol. [****]Milligram of gallic acid equivalents per gram of sample.

According to Alasalvar and Shahidi (2008), the levels of β-tocopherol found in oils extracted from nuts and walnuts are negligible, with values ranging from 0.0 to 4.0 mg kg^{-1}. This value range corroborates the one found in this study, which ranged from 0.80 to 1.30 mg kg^{-1}.

The γ-tocopherol is the isomer of higher antioxidant activity, since it protects the unsaturated fatty acids in lipid oxidation; therefore, it was the predominant isomer in all analyzed oils, with emphasis on the *L. pisonis* oil (155.57 mg kg^{-1}). It was not detected in *D. lacunifera* oil, though. Yang (2009) reported concentrations of γ-tocopherol in oils extracted oils from nuts and walnuts, such as almonds, Brazil nuts, cashew nuts, hazelnuts, macadamia nuts, peanuts, pine nuts, pecan nuts and walnuts, whose values were 12.5, 116.2, 57.2, 61.2, traces, 60.3, 105.2, 168.5 and 300.5 mg kg^{-1}, respectively. Moreover, the Codex (2009) reports amounts of γ-tocopherol of 138-746 mg kg^{-1} in cotton seed oils, value not detected to 526 mg kg^{-1} in oil palm and to 212 mg kg^{-1} rice oils.

The oil extracted from *D. lacunifera* presented δ-tocopherol as a major isomer. Although δ-tocopherol is found naturally in small amounts in lipids, it was quantified in all analyzed oils concentrations (7.87 to 14.37 mg kg^{-1}), similar or superior to those found, for example, in peanut oil (13.4 mg kg^{-1}), sunflower oil (9.2 mg kg^{-1}) and canola oil (6.1 mg kg^{-1}) (TUBEROSO et

al., 2007) . Concentrations of total tocopherols ranged from 11.47 to 180.10 mg kg^{-1} in the analyzed oils.

It was found that the activity of vitamin E expressed as equivalents of α-tocopherol ranged from 3.08 for *D. lacunifera* oil to 52.85 for the *B. excelsa* oil. In a study of nuts and walnuts as to the activity of vitamin E, it was possible to determine levels ranging from a not detected value, for macadamia nut oil, to 33.1 equivalent of α-tocopherol, for hazelnut oil. Towards food, low levels of vitamin E may be associated with increased risk of developing degenerative diseases such as atherosclerosis. Adequate intake of this vitamin exerts cardioprotective effect by inhibiting the oxidation of fraction of cholesterol in low density lipoprotein (LDLc), which is a key role in the atherogenic process. Moreover, the α-tocopherol is considered to be the most active form in human beings, but γ-tocopherol is the most prevalent in plant seeds, especially in oil (KORNSTEINER et al., 2006).

As seen in Table 2, the total phytosterol concentration was found in the range of 51.51-233.10 mg 100 g^{-1}. There is approximately a 5-fold difference in phytosterol content between the highest and the lowest ranked nuts and walnuts. *L. pisonis* showed the highest concentrations of total phytosterols. This level can be compared to almond, soybean, pistachio nut, cashew nut, peanut, peanut oil, olive oil, and soybean oil contents, as mentioned by Normén et al. (2007). All the samples presented β-sitosterol + stigmasterol as the major phytosterols, except for the *L. pisonis* as that presented the stigmastanol as the predominant phytosterol with 83.8%

According to Yang (2009), the pistachio had the highest phytosterol content, averaging 558.6 mg 100 g^{-1} oil, while the lowest content was measured in hazelnut, averaging 109.6 mg 100 g^{-1} oil. The decreasing order of total phytosterol content was pistachio > pinenut > almond > cashew > pecan > Brazil nut > peanut > macadamia > walnut > hazelnut. β-sitosterol was the most abundant sterol, ranging from 99.12 in the hazelnut to 468.6 mg 100 g^{-1} oil in the pistachio. In addition, β-sitosterol was found in much higher concentrations than campesterol and stigmasterol in all ten nuts. The β-sitosterol, campesterol, and stigmasterol contents present in Brazil nut were 132.5, 2.6, and 57.7 mg 100 g^{-1} oil, respectively.

Costa et al. (2010) analyzed the composition of phytosterols in pulps and nuts of Brazilian fruits. Mucajá (179-243 mg 100 g^{-1}) and Jenipapo (233 mg 100 g^{-1}) nuts presented the highest concentrations of total phytosterols while Brazil nut presented 47-148 mg 100 g^{-1} oil. The amount of total carotenoids, expressed as β-carotene, was significantly higher in the *L. pisonis* oils than in the others oils (Table 2). Visually, the oils showed no difference in coloring.

By comparison, other studies have found a β-carotene content of 2.16 μg g^{-1} in jerivá kernel oil, 1.82 μg g^{-1} in macaúba kernel oil and 0.81 μg g^{-1} in guariroba oil (COIMBRA and JORGE, 2012). Lima et al. (2007) analyzed pequi kernel, finding levels of carotenoids from 2.95 μg g^{-1}. Costa-Singh and Jorge (2015) evaluating the oils of *Carya illinoiensis* and *Juglans regia* extracted by cold pressing found 5.13 and 4.84 μg g^{-1} of total carotenoids, respectively.

Regarding the yields of phenolic compounds, it is possible that the concentrations have ranged from 0.34 mg GAE g^{-1} for *D. lacunifera* oil, to 0.70 mg GAE g^{-1} for *B. excelsa* oil (Table 2). The extraction solvent has a strong influence on the determination of total phenolic compounds, since the polarity of the solvent interferes with the types of compounds extracted, in others words, the higher the polarity of the solvent extraction the greater the amount of total phenolic compounds extracted. In soybean, sunflower, corn, canola and rice oils, cold extracted, the amount of total phenolics ranged from 1.26 to 1.48 mg GAE 100 g^{-1} (SIGER et al., 2008).

In oils extracted by solvents from Brazil nuts, cashew nuts and macadamia nuts, the concentration of total phenolic compounds was 3.10, 2.74, 1.56 and 0.68 mg of GAE g^{-1}, respectively (ALASALVAR and SHAHIDI, 2009). In a study by Kornsteiner et al. (2006) with oils extracted from nuts and walnuts, using Soxhlet and petroleum ether as solvent, levels of total phenolic compounds in almonds, hazelnuts, Brazil nuts, cashew nuts, macadamia nuts and pinion of 0.47, 2.91, 1.12, 1.37, 0.46 and 0.32 mg GAE g^{-1}, were found, respectively. Costa-Singh and Jorge (2015) evaluating the oils of *Carya illinoiensis* and *Juglans regia* extracted by cold pressing found 0.74 and 0.88 mg GAE g^{-1} of total phenolic compounds, respectively. These values were different from the present study, probably due to the type of extraction, raw material, cultivation conditions, climate, etc.

CONCLUSIONS

The consumption of nuts provides significant amounts of all macronutrients, necessary for human diet, and they are a good energy source.

The high fiber content indicates that the studied nuts have the potential to be used in the formulation of bakery products to enrich their texture, flavor and nutritional value.

High percentages of unsaturated fatty acids were detected in all oils with predominance of monounsaturated acid in *D. lacunifera* oil. *L. pisonis* oil showed to be richer in total tocopherol and γ-tocopherol compounds, moreover showed considerable total phytosterol and carotenoid amounts, thus representing an important source of vitamins A and E.

The oils showed significant content of phenolic compounds, with the exception of the oil extracted from *D. lacunifera*.

ACKNOWLEDGMENTS

To FAPESP (São Paulo Research Foundation), for the concession of the research assistance, to CNPq (National Council for Scientific and Technological Development), for the Masters and Research Productivity scholarship.

REFERENCES

ALASALVAR, C.; SHAHIDI, F. **Tree nuts:** composition, phytochemicals and health effects. Boca Raton: CRC Press, 2008. 340p.

ALASALVAR, C.; SHAHIDI, F. Natural antioxidants in tree nuts. **European Journal of Lipid Science Technology**, v.111, n.11, p.1056-1062, 2009.

AOAC. ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. **Official and tentative methods of the AOAC International.** 18a. ed. Maryland: AOAC International, 2005. 771p.

AOCS. AMERICAN OIL CHEMITS SOCIETY. **Official and tentative methods of the American Oil Chemists' Society:** including additions and revisions. 6a. ed. Champaign: AOCS, 2009. 500p.

BORGES, O.; CARVALHO, J.S.; CORREIA, P.R.; SILVA, A.P. Chemical composition of umbu (*Spondias Tuberosa* Arr. Cam) seeds. **Química Nova**, v.30, n.1, p.49-52, 2007.

CODEX. CODEX ALIMENTARIUS COMMISSION. **Codex-Stan 210:** codex standard for named vegetable oils. Rome: Codex alimentarius Commission, 2009. 300p.

COIMBRA, M.C.; JORGE, N. Fatty acids and bioactive compounds of the pulps and kernels of Brazilian palm species, guariroba (*Syagrus oleraces*), jerivá (*Syagrus romanzoffiana*) and macaúba (*Acrocomia aculeata*) fruits. **Journal of the Science of Food and Agriculture**, v.92, n.3, p.679-684, 2012.

COSTA, P.A.; BALLUS, C.A.; TEIXEIRA-FILHO, J.; GODOY, H.T. Phytosterols and tocopherols content of pulps and nuts of Brazilian fruits. **Food Research International**, v.43, n.6, p.1603-1606, 2010.

COSTA-SINGH, T.; BITENCOURT, T.B.; JORGE, N. Caracterização e compostos bioativos do óleo da castanha de Cotia (*Couepia edulis*). **Revista do Instituto Adolfo Lutz**, v.71, n.1, p.61-68, 2012.

COSTA-SINGH, T.; JORGE, N. Characterization of *Carya illinoiensis* and *Juglans regia* oils obtained by different extraction systems. **Acta Scientarium Technology**, v.37, n.2, p.279-285, 2015.

DHINGRA, D.; MICHAEL, M.; RAJPUT, H.; PATIL, R.T. Dietary fibre in foods: a review. **Journal of Food Science and Technology**, v.49, n.3, p.255-266, 2012.

DUCHATEAU, G.S.M.J.E.; BAUER-PLANK, C.G.; LOUTER, A.J.H.; VAN DER HAM, M.; BOERMA, J.A.; VAN ROOIJEN, J.J.M.; ZANDBELT, P.A. Fast and accurate method for total 4-desmethyl sterol(s) content in spreads, fat-blends, and raw materials. **Journal of the American Oil Chemists Society**, v.79, n.3, p.273-278, 2002.

EMAM, S.S. Bioactive constituents of *Atriplex halimus* plant. **Journal of Natural Products**, v.4, n.1, p.25-41, 2011.

GACULA JÚNIOR, M.; SINGH, J.; BI, J.; ALTAN, S. **Statistical methods in food and consumer research.** London: Academic Press, 2008. 888p.

GHARRAS, H.E. Polyphenols: food sources, properties and applications - a review. **International Journal of Food Science & Technology**, v.44, n.12, p.2512-2518, 2009.

GONG, Y.; PEGG, R.B. **Tree nut oils:** properties and processing for use in food. In: TALBOT, G. (Ed). Specialty Oils and Fats in Food and Nutrition, Cambridge: Woodhead Publishing Ltd, 2015. p.65-86.

KORNSTEINER, M.; WAGNER, K.H.; ELMADFA, I. Tocopherols and total phenolics in 10 different nut types. **Food Chemistry**, v.98, n.2, p.381-387, 2006.

LIMA, A.; SILVA, A.M.O.; TRINDADE, R.A.; TORRES, R.P.; MANCINI-FILHO, J. Composição química e compostos bioativos presentes na polpa e na amêndoa do pequi (*Caryocar brasiliense Camb*.). **Revista Brasileira de Fruticultura**, v.29, n.3, p.695-698, 2007.

LIU, R.H. Whole grain phytochemicals and health. **Journal of Cereal Science**, v.46, n.3, p.207-219, 2007.

MACIEL, L.G.; RIBEIRO, F.L.; TEIXEIRA, G.L.; MOLOGNONI, L.; SANTOS, J.N.; NUNES, I.L.; BLOCK, J.M. The potential of the pecan nut cake as an ingredient for the food industry. **Food Research International**, v.127, n.1, p.1-10, 2020.

MASKAN, M.; KARATAS, S. Storage stability of whole-split pistachio nuts (*Pistachia vera* L.) at various conditions. **Food Chemistry**, v.66, n.2, p.227-233, 1999.

NOGUEIRA, R.C.; CERQUEIRA, H.F.; SOARES, M.B.P. Patenting bioactive molecules from biodiversity: the Brazilian experience. **Expert Opinion on Therapeutic Patents**, v.20, n.2, p.1-13, 2010.

NORMÉN, L.; ELLEGARD, L.; BRANTS, H.; DUTTA, P.; ANDERSSON, H. A phytosterol database: fatty foods consumed in Sweden and the Netherlands. **Journal of Food Composition Analysis**, v.20, n.3-4, p.193-201, 2007.

PARRY, J.W.; SU, L.; LUTHER, M.; ZHOU, K.; YURAWECS, M.P.; WHITTAKER, P.; YU, L. Fatty acid composition and antioxidant properties of cold-pressed marionberry, boysenberry, red raspberry, and blueberry seed oils. **Journal of Agricultural and Food Chemistry**, v.53, n.3, p.566-573, 2005.

PEREIRA-LORENZO, S.; RAMOS-CABRER, A.M.; DÍAZ-HERNÁNDEZ, M.B.; CIORDIA-ARA, M.; RÍOS-MESA, D. Chemical composition of chestnut cultivars from Spain. **Scientia Horticulturae**, v.107, n.3, p.306-314, 2006.

RODRIGUEZ-AMAYA, D.B. **A guide to carotenoids analysis in food.** Washington: ILSI Press, 2001. 71p.

SANTOS, O.V.; CARVALHO JUNIOR, R.N.; COSTA, C.E.F.; LANNES, S.C.S. Chemical, chromatographic-functional, thermogravimetric-differential and spetrsocopic parameters of the sapucaia oil obtained by different extraction methods. **Industrial Crops and Products**, v.132, n.1, p.487-496, 2019.

SIGER, A.; NOGALA-KALUCKA, M.; LAMPART-SZCZAPA, E. The content and antioxidant activity of phenolic compounds in cold-pressed plant oils. **Journal of Food Lipids**, v.15, n.2, p.137-149, 2008.

SINGLETON, V.L.; ROSSI, J.A. Colorimetry of total phenolics with phosphomolybdic and phosphotungstic acid reagents. **American Journal of Enology and Viticulture**, v.16, n.3, p.144-158, 1965.

TUBEROSO, C.I.G.; KOWALEZYK, A.; SARRITZU, E.; CABRAS, P. Determination of antioxidant compounds and antioxidant activity in commercial oilseeds for food use. **Food Chemistry**, v.103, n.4, p.1494-1501, 2007.

UITTERHAEGEN, E.; EVON, P. Twin-screw extrusion technology for vegetable oil extraction: a review. **Journal of Food Engineering**, v.212, n.1, p.190-200, 2017.

YANG, J. Brazil nuts and associated health benefits: a review. **LWT - Food Science and Technology**, v.42, n.10, p.1573-1580, 2009.

YANG, J.; LIU, R.H.; HALIM, L. Antioxidant and antiproliferative activities of common edible nut seeds. **Food Science and Technology**, v.42, n.1, p.1-8, 2009.