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AMAZONIAN ELIXIRS: INVESTIGATING THE NUTRITIONAL AND MEDICINAL PROPERTIES OF FRUIT SEEDS

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Abstract: Brazil stands as a global powerhouse in fruit production, boasting abundant resources, favorable climatic conditions, and substantial investments in infrastructure and logistics innovation. This paper explores Brazil's prominent position in the fruit industry, delving into key factors driving its success as one of the largest fruit-producing countries worldwide. Drawing upon data from the Brazilian Institute of Fruit Growing (IBRAF), the study highlights Brazil's remarkable fruit output, reaching 43.5 million tons in 2017. Notably, 53% of these fruits are earmarked for commercial purposes, underscoring the significance of Brazil's fruit sector in both domestic and international markets. The distribution of fruit production across states further elucidates Brazil's geographic diversity, with São Paulo, Bahia, Rio Grande do Sul, Minas Gerais, and Pará emerging as leading fruit-producing regions. By examining the interplay of geographical, climatic, and economic factors, this research offers insights into Brazil's fruit industry landscape and its implications for agricultural development and economic growth. Through a nuanced analysis, this paper aims to contribute to a deeper understanding of Brazil's role in global fruit production and stimulate further research and investment in this vital sector.

Keywords: Brazil, Fruit production, Agricultural sector, Infrastructure, Logistics innovation

INTRODUCTION

Brazil is one of the largest fruits producing countries in the world. It generated about 43.5 million tons of fruit in the year 2017. This is due to its large territorial extension, adequate climate and soil and its sectors both private and public investing heavily in both infrastructure and logistics innovation.

According to the Brazilian Institute of Fruit Growing - IBRAF (2013), of the total fruits produced in Brazil, 53% are fresh fruits used for commercial purpose and the remaining 47% are for the agro-industrial sector.

The main Brazilian fruit-producing states are São Paulo (39%), Bahia (12%), Rio Grande do Sul (6%), Minas Gerais (6%) and Pará (3.7%), according to the data provided by IBRAF (2013).

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In producing food of plant origin, there are the problems of residues and wastes in the production chain. There is estimated loss of 10% during harvesting, 50% losses in transport and industrialization stages, and preparation of the food, and 10% of the plant purchased is not used (Roriz, 2012). The large residues are generated in the industries producing pulps and commercial juices, mainly the husks and seeds.

According to Gondim et al. (2005), food waste plus hunger is one of the biggest problems facing Brazil. Such waste is an important source of nutrients such as minerals, fatty acids, compounds with antioxidant activity and source of vitamins (Scherer et al., 2012); they can be used in the food industry, and in the elaboration of functional foods with great biotechnological potential. These nutrients are usually found in higher concentrations in seeds and husks than in the pulps. Thus, they can be used for the development of new products, contributing to valorization of the products obtained with positive impact economically and socially (Ayala-Zavala et al., 2011).

The objective of this work is to evaluate the bromatological, mineralogical composition and characterization of fatty acids of seeds extracted from fruits in the Northern Amazonia: abiu (Pouteria caimito), acerola (Malpighia emarginata), araçá (Psidium cattleianum), bacuparí (Rheedia gardneriana), biribá (Rollinia mucosa), camu-camu (Myrciaria dubia), frutado-conde (Annona squamosa), graviola (Annona muricata) and taperebá (Spondias mombin L.). It also aims to use these seeds as substrates for the recovery of compounds or for the development of new products with interest as functional food.

MATERIALS AND METHODS

Samples preparation

Samples (Table 1) were collected from fruit markets and producers in Roraima State, Brazil. Thereafter, the fruits collected were taken to the Laboratory of the Agronomic Research Center, at the Agricultural Sciences Center, Cauamé Campus, Federal University of Roraima. Fruits with good appearance were selected, washed at first with distilled water and then with hypochlorite solution of sodium chloride and finally with distilled water again.

The fruits were pulped, weighed and frozen in an ultra-freezer at -80°C for further lyophilization in Liotop L101 lyophilizer for 48 h, until complete drying. Thereafter, the samples were ground in a knife mill and sieved between 30-40 Mesh. They were stored in hermetically sealed sachets and protected from light to perform nutritional, fatty acids and mineralogical analysis.

Nutritional analysis

The physical parameters evaluated to determine the nutritional composition were the percentage of moisture and ash. The other nutritional parameters evaluated were the determination of total proteins, lipids and carbohydrates, to determine the total energy content.

Determination of humidity

To determine moisture, 5 g of fresh samples were placed in porcelain capsules for 6 h at 105°C to constant mass, and then cooled in desiccator to room temperature (IAL, 2008).

Humidity (g/100 g) = [(P' –P'') / (P'-P)] × 100

where:

P = weight of porcelain capsule (g)

P' = weight of the porcelain capsule + fresh sample (g)

P'' = weight of the capsule + sample after the oven (g).

Determnation of ashes

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To determine the ash in the samples, the modified methodology proposed for the food analysis by IAL (2008) was used, where 5 g of the lyophilized samples were weighed. These were placed in preheated porcelain crucibles in an oven at 110°C for one hour, to remove moisture, and then cooled in a desiccator to room temperature. The samples were incinerated at 600°C in an FDG 3P-S EDG muffle for 16 h, after which the samples were left in the desiccator until room temperature was attained.

% ashes = (N × 100) / M

N = Mass in grams of ash and M = mass of the sample in grams.

Determination of total proteins

Protein determination is performed from the total nitrogen analysis by Kjeldahl distillation, in which the existing organic matter is transformed into ammonia. The nitrogen content of the different proteins is approximately 16%, which introduces the empirical factor of 5.75 (conversion factor for vegetable protein). This will transform the number of grams of nitrogen, found with the number of grams of protein (IAL, 2008).

% proteins =% N × 5.75

Determination of lipids

To determine the total amount of lipids, 20 g of each sample was weighed, and placed in the Soxhlet extractor apparatus with hexane as the solvent for six hours. The solvent was recovered in a rotary evaporator (IAL, 2008).

% lipids = (N × 100) × m

Where: N = mass in grams of lipids and M = mass of the sample in grams.

Determination of carbohydrates

The carbohydrate content is achieved by the difference of the value 100 subtracted from the sum of the already obtained values of moisture, ashes, lipids and proteins.

Carbohydrates = 100 - (% moisture + % ash + % lipids + % proteins)

Table 1. Names and families of fruits cultivated in the Northern Amazon studied in this work.

Scientific name	Family	Name in Brazil
Pouteria caimito	Sapotaceae	Abiu
Malpighia emarginata	Malpighiaceae	Acerola
Psidium cattleianum	Myrtaceae	Araçá
Rheedia gardneriana	Clusiaceae	Bacuparí
Rollinia mucosa	Annonaceae	Biribá
Myrciaria dúbia (Krunth) Mc Vaugh	Myrtaceae	Camu-camu
Annona squamosa	Annonaceae	Fruta-do-conde
Annona muricata	Annonaceae	Graviola
Spondias mombin L.	Anacardiaceae	Taperebá

Table 2. Analytical parameters of calibration.

Element	Technique	(λ) nm	Correlation coefficient (r^2)	LOD (mg L^{-1})	LOQ (mg L^{-1})
Ca	FAAS	422.70	0.999	0.481	2.004
Mg	FAAS	285.21	0.997	0.571	1.992
P	UV-Vis spectroscopy	660.00	0.999	0.113	1.773
K	AES	766.50	0.993	0.571	1.754

S	UV-Vis spectroscopy	420.00	0.998	0.074	0.897
Fe	FAAS	248.33	0.996	0.002	0,011
Zn	FAAS	213.80	0.991	0.002	0.071
Mn	FAAS	279.48	0.999	0.001	0.603
Cu	FAAS	324.75	0.997	0.003	0.010
Na	AES	589.0	0.999	0.098	1.103
Al	FAAS	309.3	0.998	0.0008	0.078
B	UV-Vis spectroscopy	460.00	0.999	0.089	0.123
Co	FAAS	240.73	0.997	0.0005	0.0008

FAAS = Flame Atomic Absorption Spectroscopy. AES = Flame Atomic emission Spectroscopy. LOD = detection limit. LOQ = Quantification limit.

Energetic value

In order to quantify the energy value, it was necessary to use the protein (P), lipid (L) and carbohydrate (C) contents of each sample. The result should be expressed in kcal 100 g^{-1} (Mendes-Filho et al., 2014).

Energy value (kcal / 100 g) = (P * 4) + (L * 9) + (C * 4)

P = value of protein (%), L = lipid value (%), C = carbohydrate value (%), 4 = conversion factor in kcal determined in calorimetric pump for proteins and carbohydrates and 9 = conversion factor in kcal determined in a calorimetric pump for lipids.

Mineralogical analysis

Extraction of the minerals into the seeds was done according to the methodology described by EMBRAPA (2009) in which the perchloric nitric digestion (3:1) was used in TECNAL model TE 0079 digester block, and washed with distilled water up to 25 mL for subsequent analysis.

Calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and aluminum (Al) were determined by Flame Atomic Absorption Spectrophotometry (FAAS) Shimadzu AA-7000, coupled with ASC-7000 auto sample. Calibration was performed with standard solutions prepared from commercial standards of 1000 mg L-1 Qhemis High Purity PACU 1000-0125, according to the specific conditions of each element (Table 2).

For the ionization suppressor of Ca and Mg elements, solutions 0.1% of the lanthanum oxide (La_2O_3) was used. In the case of sodium (Na), it was determined in the same equipment, but in atomic emission mode. As for potassium (K), it was determined by means of flame photometry on the Digimed Flame Photometer DH62, calibrated using a Digimed standard solution whose concentration range was 2 - 100 mg. L^{-1}.

For the determination of phosphorus (P), boron (B) and sulfur (S) elements, the ultraviolet molecular absorption spectrophotometry technique was used with a SHIMADZU UV-1800 model, according to EMBRAPA (2009), in which colorimetric reaction was formed with ammonium molybdate ($(NH_4)_2MoO_4$). In the case of P, blue complex was formed, where the readings were made at λ = 660 nm. B complex was formed with azomidine-H of yellow color and absorbed light at λ = 420 nm; sulfur was precipitated with $BaCl_2$, calibrating with potassium sulphate, at λ = 420 nm.

Nitrogen determination was carried out by the distillation method followed by titration (Kjeldahl), where the ammonium ion produced in the digestion with sulfuric acid (H_2SO_4) is distilled in strong alkaline medium in the Kjeldahl distiller model TECNAL TE-036/1; 0.01% of it is collected with red methyl (0.04%) and titrated with

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0.01 mol. L^{-1} HCl solution. It was then added to 2% boric acid solution with a mixture of green bromocresol (0.01%) and methyl (EMBRAPA, 2009).

% N total = (V × 0.028) / m

Where V = difference in the titration volume of the sample blank; m = mass of the sample in grams; and the value 0.028 = milliequivalents grams of nitrogen multiplied by the concentration.

Composition of fatty acids by GC-FID

An aliquot (10 mg) of samples was transferred to a 2-mL cryotube, which contained 100 µL of a mixture made of ethanol (95%) and KOH 1 mol L^{-1} (5%). After vortexing for 10 s, esters in the oil were hydrolyzed in a microwave oven (Panasonic Piccolo) at 80 W (power 2) for 5 min. After cooling and neutralizing with 400 µL of hydrochloric acid (20%), 20 mg NaCl and 600 µL of ethyl acetate were added. Afterwards, free fatty acids were obtained by using an adapted protocol of the one reported by Christie (1989) with adaptation. After vortexing for 10 s and resting for 5 min, aliquots (300 µL) of the ethyl acetate layer were taken, placed in microcentrifuge tubes and dried by evaporation. Free fatty acids were methylated using 100 µL of BF_3/methanol (14%) and the reaction mixture was heated for 10 min in a water-bath at 60°C. After diluting with 400 µL methanol, fatty acid methyl esters were analyzed by Gas Chromatography.

Free fatty acids profile was resolved by Gas Chromatography using HP7820A (Agilent) system equipped with flame ionization detector. An Innowax column (HP) 15 m × 0.25 mm × 0.20 µm was used and the following temperature gradient: 100°C min and 0.7°C min^{-1} up to 240°C; injector (1/30 split) to 250 and 260°C detector. Hydrogen was used as carrier gas (3 $mL.min^{-1}$) while injection volume was 1 µL. The data acquisition program used was EZChrom Elite Compact (Agilent). The peaks were identified using FAME Mix C14-C22, CRM18917 Supelco fatty acid methyl esters standard.

RESULTS AND DISCUSSION

Nutritional analysis of seeds of Amazon fruits

Table 3 presents the nutritional analysis values for the seeds of the different Amazonian fruits studied. The first parameter analyzed is moisture, which according to Welti and Vergara (1997), is the content used as a factor indicative of propensity for food spoilage, and food with greater stability is in control of minimum humidity. The determination of humidity is important, since the amount of water exerts a pronounced influence on the physical and chemical properties of seeds; its determination in all stages of the process of seeds technology is important, from its handling to its processing and storage (Carvalho, 2005).

In this work, the seeds have low moisture values; all of them are less than 50%; the lowest values are the camucamu seeds with 8.21% and the one with the highest value is the bacupari seed with 41.77%. The concentrations of the different elements may vary according to fruit maturity, geographical origin, seasonal variation and processing conditions.

The seeds have high energy content, and the values are between 252.68 kcal 100 g^{-1} for bacuparí seeds and 369.08 kcal 100 g^{-1} for the seeds of camu-camu. For acerola, the energy value determined in this work is close to that found by Aguiar et al. (2010), 332.0 kcal 100 g^{-1}.

The lipids in the seeds vary from 0.02% for taperebá to 21.03% obtained for the fruta-do-conde seeds. Compared to other works, such as abiu, the value obtained is lower than that determined by de Melo Filho et al. (2018) who obtained a yield extract of 14.01%. It is the same with the seeds of camu camu, having yield of 0.84% compared to the value of 2.98% obtained by Filho et al. (2018). Proteins are macromolecules of great importance in living

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cells and constitute amino acids. They present diverse biological functions and at the same time are the molecular instruments by which genetic information is expressed (Nelson et al., 2002). The protein values in this work are relatively low with 0.04% for taperebá, while the highest value is found in fruta-doconde (7.32%). In other Amazonian fruits, the values of proteins determined by Souza et al. (2009) were 6.1% in the araça seeds slightly higher than those found in this work; for acerola residue it is determined as 5%, very close to the value of 5.41% found in this work; for the graviola seeds it is determined 6.3%, slightly lower than the value determined in this work (7.29%) and for camucamu seeds it is determined as 6.3%, slightly higher than that found in this work (7.29%).

Of the nutritional parameters, carbohydrates contribute a greater energetic percentage to the fruit seeds analyzed. Through the reaction of photosynthesis, there is the conversion of solar energy into chemical energy; it is assimilated from carbon in organic compounds, mainly carbohydrates, which are used in turn in the synthesis of other organic compounds such as amino acids and lipids (Geigenberger et al., 2005). The determined values of carbohydrates in this work are between 0.81% for the seeds of araçá and 84.41% for the seeds of camu-camu. For acerola seeds, the value determined in this work is 78.13% higher than that determined by Aguilar et al. (2010).

Finally, the last parameter analyzed as a bromatological component is the ash. After subjecting the seeds to a calcination process, in the ashes remains the inorganic fraction in which the minerals values vary between 0.21% for bacuparí and up to 2.31% for araça.

In studies undertaken by Geigenberger et al. (2005), the amount of ash for the acerola residue is 1.9%, slightly higher than that of this work and for araça seeds it is 1.6%, slightly lower than the one found in this work. The same authors determined that the amount of ash in graviola residues is 1.6% ash, slightly higher than the one determined in this work, which is 0.95%.

Table 3. Nutritional composition in Amazonian fruit seeds.

Fruit	Moisture	Ashes	Nutritional contribution			
			Lipids	Carbohydrates	Proteins	Energetic value
			%			(Kcal 100 g^{-1})
Abiu	38.53 ± 0,04	0.27 ± 0.04	4.89 ± 0.11	53.20 ± 0.01	3.11 ± 0.01	269.25 ± 0.02
Acerola	15.34 ±0.07	0.41 ± 0.12	0.75 ± 0.12	78.13 ± 0.03	5.41 ± 0.03	340.55 ± 0.02
Araçá	9.31 ± 0.01	2.31 ± 0.04	0.74 ± 0.12	0.81 ± 0.04	1.24 ± 0.02	20.86 ± 0.02
Bacuparí	41.77 ± 0.09	0.21 ± 0.06	4.12 ± 0.12	51.52 ± 0.01	2.38 ± 0.01	252.68 ± 0.02
Biribá	31.11 ± 0.04	1.52 ± 0.07	19.06 ± 0.12	41.07 ± 0.04	7.24 ± 0.02	364.78 ± 0.05
Camu-camu	8.21 ± 0.03	0.57 ± 0.07	0.84 ± 0.02	84.41 ± 0.03	5.97 ± 0.08	369.08 ± 0.02
Fruta do conde	38.11 ± 0.09	0.92 ± 0.04	21.05 ± 0.03	32.60 ± 0.01	7.32 ± 0.01	349.13 ± 0.04
Graviola	38.29 ± 0.14	0.95 ± 0.13	20.62 ± 0.17	32.85 ± 0.01	7.29 ± 0.02	346.14± 0.02
Taperebá	32.12 ± 0.23	1.34 ± 0.05	0.02 ± 0.00	66.48 ± 0.01	0.04 ± 0.00	266.26 ± 0.08

Analyzes performed in triplicate and using as a standard deviation the value of the t-student for 95%.

Mineral analysis

In Tables 2 and 3, the values of macronutrients and micronutrients are presented for the different seeds studied. The levels of calcium in the seeds of the fruits studied vary between 12.42 mg 100 g^{-1} for abiu seeds, and were very high in fruits of the family of Anonaceae; in fruta-do-conde with a value of 74.41 mg 100 g^{-1} and 63.13 mg

100 g^{-1} for biribá seeds. The calcium nutritional intake for adults, according to Pereira et al. (2009), is between 1000-1200 mg dia^{-1}. That means the calcium levels found in these seeds are significant to incorporate them in the development of new products since calcium is an element of utmost importance in various physiological processes in the body; it plays a role in chemical synapse, muscle contraction processes, blood coagulation and nerve impulse transmission (Guéguen and Pointillart, 2000; Henry, 2006).

Related to the absorption of calcium is phosphorus, according to Douglas (2002) and Hossain and Yoshimatsu (2014). The absorption of both elements is optimal when the relationship between both elements is equal to unity. In the fruits studied in this work, the values of this relationship are as follows: abiu: 0.39; acerola: 1.00; araça: 0.35; bacupari: 0.41; biribá: 0.99; camucamu: 0.39; fruta-do-conde: 3.23; graviola: 2.25 and taperebá: 1.95. It can be observed that of all of them that have exactly the value of the unit is acerola and next to the unit is biribá. These two seeds facilitate the greater absorption of these elements. According to Tomassi (2002), phosphorus levels range between 20-100 mg 100 g^{-1}, with the highest phosphorus values found in biribá (64.02 mg 100 g^{-1}); the lowest value for graviola seeds is 21.03 mg 100 g^{-1}. These values are within the normal values and at the same time, the recommended phosphorus levels per day are 800 mg dia^{-1} (Tomassi, 2002).

Another element related to physiological activities in the human body is magnesium, whose main function is to stabilize the structure of ATP, a cofactor in enzymatic reactions acting on neuromuscular transmission (Iseri and French, 1984) and an activator in the reactions of the dark phase of photosynthesis (Malavolta, 2006). In this work, the concentrations of magnesium in the seeds of biribá (123.11 mg 100 g^{-1}) are surprisingly high; the seeds of abiu had the lowest value, 7.21 mg 100 g^{-1}. 310320 mg dia^{-1} of this element is recommended for women and 410-420 mg dia^{-1} for men (Yuyama et al., 2003). For acerola, the concentration was 22.04 mg 100 g^{-1}; a value similar to that determined by Aguiar et al. (2010) who finds a magnesium value of 22.24 mg 100 g^{-1} in the acerola seed.

Potassium is another of the most abundant elements participates in the metabolism of carbohydrates and proteins (Czajka-Narins, 1998). In the fruits studied, high potassium values were found; the lowest values were found in taperebá with 11.34 mg 100 g^{-1} and the highest was found in graviola with 554.23 mg 100 g^{-1}. Other studies except for graviola seeds produced high levels of potassium (523 mg 100 g^{-1}) (Leterme et al., 2006).

Sulfur is classified as a macronutrient, but it is required in low concentrations. Its main function is part of the amino acids cysteine and methionine, and an enzymatic activator (Silva et al., 2004). Of the fruits studied, the highest sulfur levels are found in acerola seed with 41.22 mg 100 g^{-1} and the lowest value is found in taperebá seeds with 1.12 mg 100 g^{-1}.

Finally, among the macro-constituents, there is nitrogen, an element of great biological importance because it is part of proteins, functions as a coenzyme, nucleic acids and vitamins, and is a part of the processes of photosynthesis and cellular respiration (Malavolta, 2006). Generally, it is not studied in an isolated way in fruits, but it is studied in association with the protein formed. In this work, the highest protein values were detected in the seeds of biribá with 6.44% and in seeds, they were determined in trace concentrations (Table 4).

Among the micronutrients, iron is very important in human diet, because its deficiency can cause anemia, fatigue and impairment in neurological growth and development (Carvalho, 2006). According to the World Health Organization (WHO), the required iron dose per adult person and day is 20-45 mg. The highest values of iron presented in this work are for araçá with concentration of 3.78 mg.100 g^{-1} while the lowest concentration of iron was in abiu seeds with only 0.14 mg.100 g^{-1} (Table 5).

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Given that in Brazil, anemia mainly in children is a worrisome problem that affects their development; these fruits would be an important source of iron for the development of food supplements to correct those deficiencies in children. Zinc is important in organisms at the physiological level as an antioxidant (Powell, 2000), and plays a fundamental role in the polymer organization of macromolecules such as DNA and RNA, as well as their synthesis (Vallee and Falchuk, 1993). According to Food and Nutrition Board (2001), zinc recommendations for people are 8 mg day^{-1} for women and 11 mg day^{-1} for men. In this work, the highest zinc concentration is found in abiu seeds with 4.14 mg.100 g^{-1} and the lowest value is found in acerola seeds with 0.14 mg.100 g^{-1}. In a work developed by Aguiar et al. (2010) on acerola seeds, zinc values of 0.09 mg.100 g^{-1} were determined.

Another important microelement in enzymatic metabolic reactions is manganese which, according to Panziera et al. (2011), is part of two metalloenzymes: carboxylase pyruvate and Mn-superoxide dismutase. In this work, the concentrations of manganese found in the seeds vary between 0.17 mg.100 g^{-1} for camu-camu seeds, and up to 4.12 mg.100 g^{-1} for abiu seeds. In abiu, the values of Mn are very close to the value of Zn. Copper is a trace element that may exhibit various oxidation states and within the cell it predominates the cuprous ion (Bairele et al., 2010). For the seeds studied in this paper, the copper values are very low; the lowest value is seen in the seeds of bacuparí, with 0.07 mg.100 g^{-1} and up to 2.07 mg.100 g^{-1} for abiu seeds. The need for copper is 1-2 mg dia^{-1}, whereas 10 mg dia^{-1} is tolerated according to DRIs (Dietary Reference Intakes, 2004) for the maintenance of humans. The above fruits are above the tolerable levels for man (Almeida et al., 2009).

Sodium is an important element in man since it works as a regulator of osmotic pressure, prevents dehydration and acts in the maintenance of cellular permeability. According to Food and Nutrition Board, Institute of Medicine (2005), sodium recommendations in the human diet is between 1.2 to 1.5 g day^{-1}. The sodium levels in the fruits studied vary in a wide range, from 0.41 mg 100 g^{-1} for abiu to 22.03 mg 100 g^{-1} for acerola. An important trace element is boron, being related to the cerebral metabolism (Penland, 1994), among other functions. In fruits, boron has an important function of stimulating the germination and generation of pollen and pollen tube growth; it is a fundamental factor for the adequate formation of fruits (SangHyun et al., 2009). The highest concentration of boron in the seeds studied is in acerola seeds with concentration of 0.74 mg 100 g^{-1}; it is excessively low in the fruta-do-conde (0.06 mg 100 g^{-1}) and is not detected in taperebá seeds.

Aluminum is a toxic metal, whose concentration in food is low, 5 mg kg^{-1} (Dantas et al., 2007). The consumption of foods contaminated by this metal may be related to Alzheimer's disease (Martyn et al., 1997). Thus, the seeds of the fruits analyzed had relatively low concentrations, varying between 0.04 - 0.36 mg 100 g^{-1} within the recommended levels.

Among all the evaluated minor elements, cobalt is the lowest concentration in relation to the micro-constituents. According to Vaitsman et al. (2011), the estimated cobalt doses are between 0.5-1.4 mg dia^{-1}; therefore, the levels found in the fruits studied are below the recommended levels.

Fatty acids in oils and fats of Amazonian fruit seeds

The information provided by the chromatograms of crude oils and fats of the Amazonian fruit seeds is presented in Table 6. In this way, it is possible to verify the saturated fatty acids (SFA) and unsaturated fatty acids (UFA) present in the samples. Of the fatty acids analyzed, the concentration of SFA is lower than the concentration of UFA with the exception of the taperebá seeds that contain a higher percentage of SFA (74.60%) than UFA. Therefore, of the seeds studied in this work it is the only one with solid state at room temperature. Among the saturated fatty acids identified in the oils and fats presented in Table 6, the majority is palmitic acid, being 8.1%

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for araçá seeds and up to 40.4% in taperebá seed. Next to palmitic acid is esteraic acid, which is 3.2% for araçá seeds and up to 30.7% for taperebá seeds. The SFA's identified in this work are considered long chain fatty acids, and for them to be metabolized, they undergo a process of esterification; they form the triglycerides, where they are taken to the heart and transported by the bloodstream, the chylomicrons, and stored as fat in man (Santos et al., 2013). Within the SFA, Lottenberg (2009) points out that the ingestion of palmitic and myristic acid causes increase of cholesterol levels in the blood, but the other major SFA, stearic acid does not promote hypercholesterolemin as it is being converted in the liver to oleic acid.

The minority SFAs detected are the myristic whose concentrations vary between 0.1% for araçá, camu-camu and fruta-do-conde and up to 0.6% for taperebá seeds. Taperebá. Arquídico acid presents concentrations of 0.3% for araçá and up to 2.9% for taperebá. This fatty acid in animal tissues is found in low concentrations, less than 1% but its concentration increases in milk, between 7-12% and in palm oil it is between 15-23%. It is an acid that increases in the plasma concentrations of low- density

Table 4. Macronutrients analyzed in seeds fruit in the northern Amazon.

Fruit	Macronutrient Calcium (Ca)	Magnesium (Mg)	Phosphorous (P)	Potassium (K)	Sulfur (S)	Nitrogen (N)
			(mg 100 g^{-1})			%
Abiu (Pouteria caimito)	12.42± 0.14	7.21± 0.11	31.45± 0.14	324.56± 0.14	23.14 ± 0.14	0.54 ± 0.01
Acerola (Malpighia emarginata)	31.48 ± 0.11	22.04 ± 0.12	31.34 ± 0.04	164.11 ± 0.04	41.22 ± 0.18	0.94 ± 0.01
Araçá (Psidium cattleianum)	17.21 ± 0.04	17.11 ± 0.03	49.32 ± 0.04	361.24 ± 0.02	12.03 ± 0.02	0.04 ± 0.01
Bacuparí (Rheedia gardneriana Planch & Triana)	17.24 ± 0.04	21.11± 0.01	42.11± 0.12	378.02 ± 0.11	1.17± 0.01	0.41 ± 0.01
Biribá (Rollinia mucosa)	63.13 ± 0.09	123.11± 0.21	64.02 ± 0.02	513.33 ± 0.09	32.11 ± 0.08	6.44 ± 0.01
Camu-camu (Myrciaria dúbia (Kunth) Mc Vaugh	18.8 ± 0.07	9.21± 0.09	47.86± 0.12	338.45 ± 0.11	15.11 ± 0.02	1.26 ± 0.02
Fruta-do-conde (Annona squamosa)	72.41 ±0.04	37.21± 0.02	22.41 ± 0.16	421.23 ± 0.13	34.11 ± 0.08	1.27 ± 0.01
Graviola (Annona muricata)	47.32 ± 0.12	32.41 ± 0.17	21.03 ± 0.19	554.23 ± 0.14	38.11± 0.08	1.27 ± 0.02
Taperebá (Spondias mombin L.)	57.24 ± 0.01	33.11 ± 0.02	29.22± 0.03	11.34 ± 0.05	1.12 ± 0.03	6.9.10-3 ± 0.00

Analyzes performed in triplicate and using as a standard deviation the value of the t-student for 95%.

Table 5. Micronutrients analyzed in seeds fruits in the northern Amazon.

Micronutrient (mg 100 g^{-1})						
Fruit	**Manganese**	**Copper**	**Sodium**	**Aluminum**	**Boron**	**Cobalt**

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	Iron (Fe)	Zinc (Zn)	(Mn)	(Cu)	(Na)	(Al)	(B)	(Co)
Abiu (Pouteria caimito)	0.14 ± 0.08	4.14 ± 0.08	4.12 ± 0.05	2,07 ± 0,05	0.41 ± 0.03	0.04 ± 0.00	0.17 ± 0.05	N.D.
Acerola (Malpighia emarginata)	0.63 ± 0.04	0.14 ± 0.06	0.65 ± 0.09	1.58 ± 0.02	22.03 ± 0.11	0.05 ± 0.01	0.74 0.03	±N.D.
Araçá (Psidium cattleianum)	3.78 ± 0.01	0.74 ± 0.01	0.94 ± 0.02	1.04 ± 0.01	16.98 ± 0.01	0.12± 0.04	0.11 0.03	±N.D.
Bacuparí (Rheedia gardneriana Planch & Triana)	0.84 ± 0.02	2.62 ± 0.07	0.42 ± 0.03	0.07 ± 0.02	5.98 ± 0.14	0.13 ± 0.02	0.57 ± 0.09	0.024 ± 0.004
Biribá (Rollinia mucosa)	2.92 ± 0.11	0.87 ± 0.08	0.74 ± 0.04	1.71 ± 0.06	12.24 ± 0.06	0.12 ± 0,06	0.18 ± 0.04	0.009 ± 0.001
Camu-camu (Myrciaria dúbia (Kunth) Mc Vaugh,	0.79 0,07	± 0.22 0.03	± 0.17 ± 0.03	1.12 0.04	± 17.04 0.18	± 0.39 0.07	± 0.12 0.08	± 0.077 0.001 ±
Fruta do conde (Annona squamosa)	1.76 0.06	± 0,85 0.08	± 0.88 ± 0.07	0.16 0.02	± 7.54 ± 0.12	0.03 0.00	± 0.06 0.02	± N.D.
Graviola (Annona muricata)	1.30 0.06	± 2.37 0.08	± 0.91 ± 0.07	0.09 0.01	± 5.84 ± 0.24	0.05 0.01	± 0.08 0.01	± 0.026 0,004 ±
Taperebá (Spondias mombin L.)	1.33 0.02	± 1.37 0.04	± 0.73 ± 0,03	1.52 0.02	± 6.11 ± 0.06	0.31 0.08	± N.D.	N.D.

N.D. not detected. Analyzes performed in triplicate and using as a standard deviation the value of the t-student for 95%.

LDL proteins (Kromhout et al., 2000).

The percentage of saturated oils and fats found in this work are compared, with the oils of the same species and with other vegetable oils. Only the camu-camu, bacupari, aracá, and tapereba species were not compared, since no such information was found for the seeds.

The concentration of myristic acid present in the abiu and fruta-do-conde seeds are lower than those determined in the literature but higher than the amount present in soy oil (de Melo Filho et al., 2018; Rana, 2014 Mariod et al., 2010; Sultan et al., 2015). For the palmitic and myristic acids of the acerola, abiu, graviola and frutado-conde seeds, the determined values are close to the compounds with the same species; the values for the acid, palmitic are within the range of the acid found in olive oil; but steric acids are higher than those found in olive oil.

The unsaturated fatty acids determined in this work were palmitoleic acid, oleic acid (□-9), linoleic acid (□-6) and linolenic acid (□-3) (Table 6). The concentration of unsaturated fatty acids in the studied seeds varies between 23.0% for tapereba and 86.80% for araçá. With the exception of tapereba seed, the concentrations of unsaturated fatty acids are much higher than the concentrations of saturated fatty acids. The benefits of unsaturated fatty acids are known as protectors and as a risk reducer of different diseases. Linolenic acid reduces the risk of cancer and heart disease, in addition to having anti-inflammatory, antithrombotic, anti-arrhythmic and vasodilating properties. On the other hand, linoleic acid when deficient in a diet can cause skin diseases such as squamous dermatitis, or bad healing of a wound. So a balanced relationship of both acids is important to prevent chronic diseases. The levels of these two acids in the body are around 1-4:1 (Fagundes, 2002; Gögus and Chris, 2010; Gomez-Candela et al., 2011), but other organizations such as the World Health Organization or the Food and Agriculture Organization established values of relation between acids □-6- □-3 of 5:1-10:1 (WHO, 1995).

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Of the fatty acids analyzed in this work, the lowest concentration found is palmitoleic acid whose concentrations vary from 0.1% for the oil of camu-camu seeds to 1.7% for bacuparí seeds. This acid can be found in its two isomeric forms: the cis form is associated with insulin sensitivity and the trans form is found in dairy products and hydrogenated oils associated with lower incidence of diabetes (Cao et al., 2008; Ouchi et al., 2011). This acid is produced in liponeogenesis in humans synthesized mainly in the liver and later incorporated into adipose tissue to become part of the phospholipids, triacylglycerols, waxes and cholesterol esters (Frigolet and Gutierrez-Aguilar, 2017). This acid is found in concentrations higher than those determined in this work; it is found in fish oils such as salmon (6%), cod liver (7%) and macadamia oil (17%) and in vegetables in sea buckthorn oil, plant that develops in Asia and Europe, reaching concentrations of up to 32-42% (Maguire et al., 2004; Fatima et al., 2012).

Oleic acid is the major unsaturated fatty acid but it is not found in camu-camu and araçá seeds, where the majority is linoleic. The concentrations of this acid vary between 11.6% for camu-camu seed; and are the highest concentrations in the seeds of bacupari with 47.4%. Despite being the most abundant, their levels in these seeds are below the concentrations of acid found in olive oil whose values are between 70-80% (Owen et al., 2000). The daily consumption of this acid is important since it contributes to reducing the risk of suffering from cardiovascular diseases such as the reduction of blood pressure, decrease in cholesterol levels and arteriosclerosis (Ferrara et al., 2000; Owen et al., 2000; Panagiotakos et al., 2009). It is shown to have a protective effect against breast cancer and strengthens the immune system. Therefore, due to these properties, it is important to consume it or unsaturated acid -6, and two other important unsaturated fatty acids in our diet. Seeds studied for fruits with a lower percentage were for taperebá seeds with only 2.2%, presenting the highest values such as camu-camu seeds with 63.7% and araçá seeds with 69%, both from the same Myrtaceae family. These fatty acids together with the □-3 are considered essential, since organisms do not synthesize them and they have to be incorporated into the diet. These fatty acids together with the □-3 are considered essential, since organisms do not synthesize them and they have to be incorporated into the diet. Linoleic acid, like oleic acid, has positive effects on cardiovascular risk factors, reducing the levels of triacylglycerol and plasma cholesterol, improving insulin sensitivity (Lee et al., 1994). Finally, linolenic acid has low concentrations, whose values vary between 0.1% for taperebá seeds and 2.6% for araçá. The linolenic acid, in addition to serving to prevent cardiovascular diseases, is involved with the best development of visual quality (Wu et al., 2015).

Oil paintings and estudados can be compared with the same of their species, in local and commercial oils, as well as unsaturated fatty acids (palimoleic and omega 3, 6 and 9). As you know camu-camu, bacupari, araçá and taperebá were not compared, for they were not found in these seeds.

The concentration of palmitoleic acid in acerola and graviola present great proximity compared to the same species (da Cunha et al., 2017; Aguiar et al., 2010; Pinto et al., 2018), and for fruta-do-conde and abiu, palmitoleic acid compared in the literature was detected only in concentrations of traces. For acerola and graviola, the levels of palmitolico acid found are within the range of this acid found in olive oil (Rana, 2014; Mariod et al., 2010).

The concentration of omega-9 present in the seeds of acerola, biribá, abiu, graviola and fruta-do-conde compared to the same species present a great proximity; omega 9 acid concentration is higher than that in the soybean oil, and for fruta-do-conde and abiu, it is close to the concentration determined in olive oil (Berto et al., 2015).

The values of omega 6 fatty acid in the seeds of frutado-conde, acerola, abiu and graviola are close to the seeds of the same species, inferior to the concentration of acid in soybean seeds, but are in the same range as that found in

olive oil. Finally, the omega 3 fatty acids present in acerola, abiu and graviola are close to those present in the same species being much lower than the value of the acid in soybean oil and close to those found in the oil of olive.

Table 6. Composition of fatty acids in oilseeds and fruit sewage com ods in the Northern Amazon.

Fatty acids (%)	TR (min)	*Abiu*	*Acerola*	*Araçá*	*Bacuparí*	*Biribá*		*Frutado conde*	*Graviola*	*Taperebá*
C16:0 (palmitic)	4.10 5.65	33.8	21.4	8.1	35.3	24.9	12.3	15.8	19.0	40.4
C 16:1 (palmitoleic)	5.87	0.4	1.8	0.9	1.7	0.7	0.1	0.5	1.5	1.5
C18:0 (stearic)	7.26	5.4	11.1	3.2	7.5	6.0	7.9	11.7	4.3	30.7
C18:1 (oleic (ω-9)	7.46	45.0	33.7	14.3	47.4	43.1	11.6	46.9	41.9	19.2
C18:2 (linoleic (ω-6)	7.84	10.9	27.1	69.0	4.4	21.8	63.7	22.2	28.2	2.2
C18:3 (linolenic (ω-3)	8.19	0.7	2.2	2.6	0.8	0.6	0.7	0.8	1.5	0.1
C20:0 (arquidic)	8.82	0.8	1.1	0.3	0.4	0.4	0.9	0.8	0.4	2.9
Others		2.8	1.2	1.5	2.2	2.3	2.7	1.2	2.8	2.4
Σ Saturated fatty acids (SFA)		40.2	34.00	11.70	43.50	31.50	21.2	28.40	24.10	74.60
Σ Unsaturated fatty acids (UFA)		57.0	64.80	86.80	54.30	66.20	76.10	70.40	73.10	23.00
Σ Monounsaturated fatty acids (MFA)		45.4	35.50	15.20	49.10	43.80	11.70	47.40	43.40	20.70
Σ Polyunsaturated fatty acids		11.60	29.30	71.60	5.20	22.40	64.40	23.00	29.70	2.30
Camucamu										
C14:0 (myristic)		0.2	0.4	0.1	0.3	0.2	0.1	0.1	0.4	0.6
(PUFA's)										
Ratio ω6/ω3		1557	1232	2654	50	3633	9100	2775	1880	2200

5.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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