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Bromatological and mineralogical studies in fruit pulps cultivated in the Northern Amazon

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Abstract: In this work, nine fruits cultivated in the northern Amazon were studied: abiu, acerola, araçá, bacupari, biribá, caçarí, fruta-do-conde, graviola and taperebá, with the objective of carrying out a bromatological and nutritional study of the pulps of fruits studied. Of all of them, are the pulps of graviola (76.83 ± 0.02 kcal 100 g-1) bacupari (76.83 ± 0.02 kcal 100 g-1) and fruta-do-conde (46.66 ± 0.02 kcal 100 g-1). Among the macronutrients, the high concentration of potassium stands out, especially in the graviola (541.16 ± 0.24 mg 100g-1) and the biribá (468.21 ± 0.13 mg 100g-1). Among the micronutrients, iron concentrations are representative for araçá pulp (3.04 ± 0.02 mg 100g-1), abiu is rich in zinc (3.71 ± 0.02 mg 100g-1) and manganese (6.61 ± 0.11 mg 100g-1). The presence of cobalt at the level of traces in some of the pulps studied stands out. The Pearson correlation coefficient was evaluated, as well as the statistical treatment by multivariate analysis PCA to establish the correlation between the variables studied.

Keywords: *Amazonian fruit, funtional food, PCA, Person.*

1. Introduction

The Amazon region along with the freshwater biome, presents the largest biodiversity on the planet with more than 5000 species [1]. The fruits of this biodiversity, native and exotic, present an expressive potential of bioactive compounds, which can be a source of bioproducts for the development of humanity [2].

The Amazonian fruits arouse great study interest due to their great biodiversity, which, according to [3-4] present outstanding results in quality and attractive attributes such as appearance in large sizes, different shapes, colors, textures and different flavors.

In the human diet, fruits are considered the main sources of necessary minerals, playing a vital role in the peculiar development and good health of the human body [5] because they participate in many biochemical reactions, being divided according to [6] in macronutrients (minerals required for humans in amounts greater than or equal to 100 mg day^{-1} as calcium, magnesium, potassium, phosphorus, sulfur, chlorine and sodium) and micronutrients (minerals required for humans in amounts less than 100 mg day^{-1}, such as copper, iron, zinc, manganese, selenium, molybdenum and fluorine.

Thus, many of the fruits cultivated, Amazonian or introduced in the region, do not present information on the nutritional and mineralogical composition. For this reason, the objective of this work is to analyze the composition of minerals and nutrients in the pulp of nine fruits grown in the Northern Amazon (Figure 1) and to study the correlation between existing data using the Pearson test as well as to use multivariate analysis methods such as Principal Component Analysis (PCA).

Figure 1. Fruits grown in the North Amazon under study (Pictures by Ismael Montero Fernández)

2. Materials and Methods

2.1. Preparation of samples.

Samples (Table 1) were collected from fruit markets and producers in Roraima state, Brazil. Then, the collected fruits 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 previously with distilled water and then with hypochlorite solution of sodium chloride and finally with distilled water again according to the procedure described [7].

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	Myrtaceae	*Caçarí*
Annona squamosa	Annonaceae	*Fruta-do-conde*
Annona muricata	Annonaceae	*Graviola*
Spondias mombin L.	Anacardiaceae	*Taperebá*

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

2.2. 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.

2.2.1. Determination of Humidity

To determine moisture, 5 g of fresh samples were placed in porcelain capsules for 6 hours at 105 °C to constant mass, and then cooled in desiccator to room temperature [8].

$$\text{Humidity } (g\ 100g^{-1}) = ((P' - P'')/(P' - P)).100$$

being:

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)

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2.2.2. Determination of ashes

To determine the ash in the samples, the methodology proposed for the food analysis [8] with modifications was used, where 5 grams 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 cool them in a desiccator to room temperature. The samples were incinerated at 600 °C in a FDG 3P-S EDG muffle for 16 hours, after which the samples were left in the desiccator until reaching room temperature.

$$\% \text{ ashes} = ((N.100)/M)$$

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

2.2.3. Determination of total protein

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 [8].

$$\% \text{ proteins} =\% \text{ N}. 5.75$$

2.2.4. 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 [8].

$$\% \text{ lipids} = ((N.100).m)$$

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

2.2.5. 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.

$$\text{Carbohydrates} = 100 - (\% \text{ moisture} +\% \text{ ash} +\% \text{ lipids} +\% \text{ proteins})$$

2.2.5. 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 $100g^{-1}$ [9].

$$\text{Energy value (kcal } 100g^{-1}\text{)} = (P * 4) + (L * 9) + (C * 4)$$

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.

2.2. Mineralogical analysis

The extraction of the minerals into the pulps was done according to the methodology described by [10] in which the perchloric nitric digestion (3:1) was used in TECNAL model TE 0079 digester block, 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).

Table 2. Analytical Parameters

Element	Technique	(λ) nm	Calibration Line
Ca	AAS	422.70	y= 0.0092 x - 0.0005 r^2= 0.999
Mg	AAS	285.21	y= 0.2353 x - 0.0658 r^2= 0.997
P	UV-Vis Spectroscopy	660.00	y= 0.2181 x - 0.0005 r^2= 0.999
K	Flame Photometry	766.50	y= 0.1231 x - 0.0013 r^2= 0.993
S	UV-Vis Spectroscopy	420.00	y= 0.0213 x - 0.0012 r^2= 0.998
Fe	AAS	248.33	y= 0.0399 x + 0.0067 r^2= 0.996
Zn	AAS	213.80	y= 0.0600 x - 0.0171 r^2= 0.991
Mn	AAS	279.48	y= 0.0282 x + 0.0041 r^2= 0.999
Cu	AAS	324.75	y= 0.0512 x - 0.0099 r^2= 0.997
Na	EAS	589.00	y= 1.0000 x + 0.0005 r^2= 0.999
Al	AAS	309.30	y= 0.0088 x + 0.0005 r^2= 0.998
B	UV-Vis Spectroscopy	460.00	y= 0.0537 x + 0.0002 r^2= 0.999
Co	AAS	240.73	y= 0.0286 x - 0.0066 r^2= 0.997

AAS = Flame Atomic Absorption Spectroscopy. EAS = Flame Atomic Emission Spectroscopy.

As the ionization suppressor for the Ca and Mg elements, 0.1% of the lithium oxide solution (La_2O) 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 DH-62, calibrated using a Digimed standard solution whose concentration range was 2 - 100 mg .L^{-1}.

For the determination of the phosphorus (P), boron (B) and sulfur (S) elements, the ultraviolet molecular absorption spectrophotometry technique was used using a SHIMADZU UV-1800 model, according to the [10], by formation of the colorimetric reaction with ammonium molybdate ($(NH_4)_2MoO_4$). In the case of P, blue complex formed, where the readings were made at λ = 660 nm; in the case of B complex was formed with azomidine-H of yellow color and absorbs light at λ = 460 nm; and for the sulfur was precipitated with $BaCl_2$, calibrating with potassium sulphate, at λ = 420 nm.

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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 strongly alkaline medium in the Kjeldahl distiller model TECNAL TE-036/1, collected (0.01%) and methyl red (0.04%) and titrated with 0.01 mol L^{-1} HCl solution were added in 2% boric acid solution with a mixture of green bromocresol (0.01%) and methyl [10].

$$\% \text{ N total} = (V.0.028)/m$$

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.

2.3. Statistical analysis

Correlations between the amounts of the different minerals in the different parts of the fruit were evaluated using the Pearson statistical test using INFOSTAT [11] for significance levels of 5%, 1% and 0.1% respectively, as well as the principal component analyzes (PCA).

3. Results and Discussion

3.1 Bromatological analysis from Amazonian fruits

Table 3 presents the nutritional analysis values for the pulps of the different Amazonian fruits studied.

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205 Table 3 - Nutritional composition in Amazonian fruit pulps.

Fruits	Nutritional Contribution					
	Moisture	Ashes	Lipids	Carbohydrates	Proteins	Energetic Value
	%					Kcal 100 g^{-1}
Abiu	92.43 ± 0.02	0.13 ± 0.07	0.12 ± 0.01	6.48 ± 0.02	0.84 ± 0.01	30.36 ± 0.03
Acerola	94.21 ± 0.01	0.16 ± 0.03	0.06 ± 0.00	4.45 ± 0.02	1.12 ± 0.01	22.82 ± 0.02
Araçá	59.21 ± 0.08	0.21 ± 0.07	0.17 ± 0.09	30.87 ± 0.03	3.93 ± 0.07	18.09 ± 0.02
Bacuparí	86.61 ± 0.11	0.19 ± 0.01	0.07 ± 0.00	12.36 ± 0.01	0.77 ± 0.01	53.15 ± 0.02
Biribá	91.34 ± 0.01	0.31 ± 0.02	0.22 ± 0.02	6.95 ± 0.03	1.18 ± 0.04	34.5 ± 0.01
Caçari	95.21 ± 0.14	0.25 ± 0.11	0.05 ± 0.00	3.14 ± 0.02	1.35 ± 0.04	18.41 ± 0.02
Fruta do conde	88.27 ± 0.05	0.29 ± 0.07	0.18 ± 0.07	10.08 ± 0.01	1.18 ± 0.04	46.66 ± 0.02
Graviola	80.77 ± 0.07	0.31 ± 0.11	0.23 ± 0.08	17.34 ± 0.01	1.35 ± 0.02	76.83 ± 0.02
Taperebá	88.23 ± 0,10	0.15 ± 0.01	0.05± 0.01	10.01 ± 0.03	1.56 ± 0.01	46.73 ± 0.03

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The first parameter analyzed is moisture, which according to [12] the moisture content is used as a factor indicative of propensity for food spoilage, and may think that the greater stability of the food is in the control of the minimum humidity.

The amount of moisture in the pulps varies from 64.22-95.21%, where the highest moisture values are for *caçari* (95.21 ± 0.14%) and acerola (94.21 ± 0.11%); and the lowest value for *araçá* with 64.22 ± 0.12%. Regarding the values of humidity for *abiu*, *acerola* and *graviola*, are slightly lower, but close to those presented by [13] and in the case of *araçá* lower than those presented by the same author.

The presented values of humidity are within the percentage humidity range given by the [8] that establishes the values in fruits between 65-90%. In the case of caçari, [14] determined the percentage of moisture in the camu-camu pulp of 92.65%, close to that found in the present study.

The ash content reflects the amount of minerals present in the food. On the other hand, the [8] establishes the values of percentage of fruit ashes between 0.3 - 2.1%, being the values of ashes studied in this work according to this range.

For proteins, it is those of animal origin that have higher biological value compared to proteins of plant origin [15] and the identification of plant species with a certain content of proteins, are important to satisfy the nutritional deficiencies of people with different dietary habits and diets [16] plus many native Amazonian species have not yet been studied to evaluate their protein potential.

The protein content in the fruit pulps studied in this study ranged from 0.77% for the *bacuparí* to 3.93% for the *araçá* pulp. *Caçari* has a protein content of 1.35% as does *graviola* with the same value.

The three groups of primary metabolites in fruits, carbohydrates are the major ones, presenting values between 3.14-30.87% for pulps, being the one with the lowest value is the potato pulp and the highest is the *araçá* pulp.

The lipid content observed in the fruits cultivated in the Northern Amazon was observed in the *caçari* pulps, 0.05%, *taperebá*, 0.05%, and *biribá*, 0.22%, with lipid values being relatively low in fruit pulps. Among the fruits of the Annonaceae family, the species that had the highest lipid content was *graviola* with 0.23%, followed by the *biribá* with 0.22% and the fruit of the count with 0.18%. The values obtained for the *biribá* are close to those determined [17]. The oil of other fruits of the Annonaceae family, as is the case of *A. squamosa* and *A. atemoya*, presents natural bioinsecticidal properties [18], as well as other biological properties such as *A. hypoglauca* on inhibition of fungi and bacteria and the acetylcholinesterase enzyme [19].

3.2 Mineral analysis.

In tables 4 and 5, the values of macronutrients and micronutrients are presented for the different pulps studied.

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Table 4 - Macronutrients analyzed in fruits grown in the northern Amazon.

Fruit	Macronutrients					
	Calcium (Ca)	**Magnesium (Mg)**	**Phosphorous (P)**	**Potassium (K)**	**Sulfur (S)**	**Nitrogen (N)**
	mg 100 g^{-1}					**%**
Abiu (P. caimito)	4.51 ± 0.02	1.71 ± 0,07	8.21 ± 0,04	255.21 ± 0.03	11.11 ± 0.04	0.15 ± 0.01
Acerola (M. emarginata)	11.23 ± 0.12	18.41 ± 0.21	11.93 ± 0.04	154.34 ± 0.18	34.13 ± 0.14	0.19 ± 0.01
Araçá (P. cattleianum)	24.13 ± 0.03	12.21 ± 0.08	6.32 ± 0.04	137.11 ± 0.08	9.02 ± 0.01	0.68 ± 0.07
Bacupari (*R. gardneriana*)	32.41 ± 0.02	14.21 ± 0.08	12.31 ± 0.14	329.12 ± 0.04	5.21 ± 0.04	0.13 ± 0.01
Biribá (R. mucosa)	32.11 ± 0.08	112.32 ± 0.12	23.41 ± 0.01	468.21 ± 0.13	21.31 ± 0.12	0.21 ± 0.04
Caçari (*M. dubia*)	9.51 ± 0.02	8.49 ± 0.04	6.21± 0.04	124.13 ± 0.12	7.21 ± 0.04	0.23 ± 0.04
Fruta do conde (A. squamosa)	52.21 ± 0.13	32.12 ± 0.09	17.30 ± 0.12	431.21 ± 0.17	27.78 ± 0.13	0.21 ± 0.04
Graviola (A. muricata)	39.21 ± 0.13	27.11 ± 0.15	19.24 ± 0.16	541.16 ± 0.24	29.31 ± 0.08	0.23 ± 0.02
Taperebá (S. mombin)	38.12 ± 0.12	16.32 ± 0.09	24.12 ± 0.11	149.13 ± 0.23	4.38 ± 0.08	0.27 ± 0.01

Table 5 - Micronutrients analyzed in fruits grown in the northern Amazon.

Fruit	**Micronutrients**							
	Iron (Fe)	**Zinc (Zn)**	**Manganese (Mn)**	**Copper (Cu)**	**Sodium (Na)**	**Aluminum (Al)**	**Boron (B)**	**Cobalt (Co)**
	mg 100 g^{-1}							
Abiu (P. caimito)	0.18 ± 0.04	3.71 ± 0.22	6.61 ± 0.11	0.12 ± 0.02	0.22 ± 0.01	0.17 ± 0.02	0.27 ± 0.07	N.D.
Acerola (M. emarginata)	0.80 ± 0.12	0.08 ± 0.01	0.24 ± 0.05	0.17 ± 0.01	35.13 ± 0.12	0.93 ± 0.04	0.11 ± 0.03	N.D.
Araçá (P. cattleianum)	3.04 ± 0.02	1.14 ± 0.02	1.25 ± 0.07	1.73 ± 0.02	1.93 ± 0.02	0.14 ± 0.06	0.10 ± 0.02	0.012 ± 0,003
Bacuparí (*R. gardneriana*)	0.71 ± 0.02	3.46 ± 0.02	0.24 ± 0.01	0.15 ± 0.00	0.09 ± 0.01	0.12 ± 0,01	0.14 ± 0.01	0.021 ± 0.000
Biribá (R. mucosa)	1.82 ± 0.11	1.23 ± 0.04	0.33 ± 0.04	1.14 ± 0,13	18.44 ± 0.21	0.06 ± 0.01	0.51 ± 0.05	0.006 ± 0,001
Caçari (*M. dubia*)	0.29 ± 0.03	0.13 ± 0.04	2.39 ± 0.02	0.17 ± 0.08	1.91 ± 0.04	0.09 ± 0.01	0.11 ± 0.06	0.067 ± 0.001
Fruta do conde (A. squamosa)	0,91 ± 0.09	0.22 ± 0.03	0.12 ± 0.02	0.31 ± 0.08	4.24 ± 0.31	0.04 ± 0.01	0.12 ± 0.03	0.018 ± 0.001
Graviola (A. muricata)	0.87 ± 0.12	0.39 ± 0.02	0.09 ± 0.00	0.19 ± 0.04	8,76 ± 0,31	0.07 ± 0.01	0.17 ± 0.02	0.012 ± 0.001
Taperebá (S. mombin)	1.13 ± 0.05	0.19 ± 0.03	0.04 ± 0.00	0.07 ± 0.00	3.24 ± 0.83	0.02 ± 0.00	0.19 ± 0.01	N.D.

N.D. not detected

Among the macroelements, the high values of potassium in the fruits studied were the lowest, with the lowest value presented for the caçari pulp, with 124.13 ± 0.12 mg 100 g^{-1} and 541.16 ± 0.24 mg 100 g^{-1}. The levels of potassium daily are 4700 mg day^{-1} [20], with consumption of potassium-rich foods beneficial for controlling blood pressure, type II diabetes and bone health.

Phosphorus is an essential element that, besides appearing in fruits, its main contribution to the organism is the source of animal origin, mainly in red, white and viscera meats [21], in fruits, the phosphorus levels oscillate between 20-100 mg 100 g^{-1} [22]. The fruits in the study presented low values of phosphorus, being the *caçari* pulp, which presents a lower value 6.21 ± 0.04 mg 100 g^{-1} and for *taperebá* 24.12 ± 0.11 mg 100 g^{-1}. the recommended dose of phosphorus per day is 800 mg [22].

The fruits studied, it is the abiu that presents a lower concentration of calcium 4.51 ± 0.02 mg 100 g^{-1}, 52.21 ± 0.13 mg 100 g^{-1} The nutritional contribution of Ca in adults.is 1000-1200 mg day^{-1} [23].

Magnesium is other important macroelement in fruits, and it appears within a very variable range in the fruits studied. In the *abiu* pulp, it is in low concentrations 1.71 ± 0.07 mg 100 g^{-1}, presenting the highest concentration of magnesium for pulp of the *biribá* with 112.32 ± 0.12 mg 100 g^{-1}. The main function of magnesium in the body is to stabilize the structure of ATP in enzymatic reactions, as cofactor in enzymatic reactions, in neuromuscular transmission [24].

As for sulfur, it is required in small concentrations, being an element that forms part of the structure of essential amino acids such as cysteine and methionine and enzymatic activator [25]. Of the fruits studied, it is the *acerola* that has the highest concentrations of sulfur, 34.13 ± 0.14 mg day^{-1}, being the pulp of *taperebá*, which presents lower concentrations.

Nitrogen is not one of the most studied micronutrients in fruits, being more studied associated with the proteins of the fruit. Its fruit pulp quantity is low, presenting the lowest value for the *bacuparí* with 0.13 ± 0.01%, being the fruit that presents a higher value the pulp of *araçá* with 0.68 ± 0.07%.

In the case of *graviola*, the values obtained for the case of Ca, K and Mg are close to those obtained [26] in the sodium and potassium are lower than those obtained by the same author and in the case of sulfur the value obtained is bigger.

In the fruit of the earl, the value obtained from Ca, K and S, are similar to those obtained by the same author for the Mg and Na are many lower than those presented [26].

Among the micronutrients, iron is very important in the human diet, because its deficiency can cause anemia, fatigue and impairment in neurological growth and development [27]. The highest values of iron presented in this work are for *araçá* with concentrations of 3.04 ± 0.02 mg.100 g^{-1}, the fruit having the lowest amounts of iron 0.18 ± 0.04 mg 100g^{-1}. Another of the rich fruits in iron is the pulp of *biribá* with 1.82 ± 0.11 mg 100 g^{-1}.

As for zinc, it is important in the organism at the physiological level as an antioxidant [28], as well as developing a fundamental role in the polymer organization of macromolecules such as DNA and RNA, as well as their synthesis [29]. According to Food and Nutrition Board [30]. The zinc recommendations for the population are 8 mg day^{-1} for women and 11 mg day^{-1} for men. In the fruits studied, the highest pulp concentration was pulp pulp 3.71 ± 0.22 mg 100 g^{-1}, with the acerola pulp being 0.08 ± 0.01 mg 100 g^{-1}.

Several Amazonian fruits, among them the *araçá* and *acerola*, presenting values of zinc concentration in the *araçá* of 0.17 mg 100 g^{-1} e for acerola of 0.19 mg 100 g^{-1} [26], for the edible fraction of fruit, being for *acerola* lesser than that obtained in this work (table 5) and in the case of *araçá* is smaller than the value presented in Table 5.

Other important microelement in enzymatic metabolic reactions is manganese is part of two metalloenzymes, carboxylase pyruvate and Mn-superoxide dismutase [31].

Among the studied fruits, the *abiu* presents high concentrations for the pulp with 6.61 ± 0.11 mg 100 g^{-1}. Other fruits with considerable concentrations of manganese are the *caçari* pulp with 2.39 ± 0.02 mg 100 g^{-1}, with the lowest values of manganese in the *graviola* pulp 0.09 ± 0.00 mg 100 g^{-1} and the *taperebá* pulp 0.04 ± 0.00 mg 100 g^{-1}.

Minerals estudies in tropical fruits and found values of manganese for the *graviola* of 0.07 ± 0.02 mg 100 g^{-1} low value in relation to the value found in the present work for the pulp 0.39 ± 0.02 mg 100 g^{-1} and for the fruit of the count 0.16 ± 0.00 mg 100 g^{-1}, a value close to the finding in this work for the pulp 0.12 ± 0.02 mg 100 g^{-1} [32]. On the other hand, evaluated fruits cultivated in Colombia and found manganese values for the *araçá* 0.08 mg 100 g^{-1} [26], the value found in this work for the pulp of 1.25 ± 0.07 mg 100 g^{-1} slightly higher than the value described by the previous author and for *acerola* 0.09 mg 100 g^{-1}, being lower than that found in the present study with a value of 0.24 ± 0.05 mg 100 g^{-1}.

Copper is a trace element that may exhibit various oxidation states and within the cell predominates the cuprous ion [33]. Copper levels, compared to the other elements, are low, with the exception of Araçá that presents copper concentrations of 1.73 ± 0.02 mg 100 g^{-1} for the pulp, and the taperebá is the one with the lowest concentration of copper, with only 0.07 ± 0.00 mg 100 g^{-1}.

The need for copper is 1-2 mg dia^{-1}, and 10 mg dia^{-1} is tolerated according to DRIs [34] for the maintenance of the human organism, the above fruits being above tolerable levels for the organism [32] determined copper concentrations in the soursop of 0.15 ± 0.03 mg 100 g^{-1}, being close to that found in the present study with 0.19 ± 0.04 mg 100 g^{-1} and for 0.22 ± 0.03 mg 100 g^{-1}, the concentration of copper for the pulp in 0.31 ± 0.08 mg 100 g^{-1}, slightly higher to the value found in the literature.

An important trace element is boron, being related to the cerebral metabolism [35] among other functions. In the case of fruits, boron has an important function of stimulating the germination and generation of pollen and pollen tube growth, being a fundamental factor for the adequate formation of fruits [36]. The highest concentration of boron was found in the pulp of the *biribá* 0.51 ± 0.05 mg 100 g^{-1} and the lowest concentration was the *aracá* 0.10 ± 0.02 mg 100 g^{-1}.

The aluminum is a toxic metal, whose concentration in food is low, of the order of 5 mg Kg^{-1} [37]. The consumption of foods contaminated by this metal may be related to Alzheimer's disease [38]. Thus, the fruits analyzed had relatively low concentrations, varying between 0.02 - 0.17 mg 100 g^{-1} in pulps, being within the recommended levels.

Among all the evaluated minor elements, cobalt is the lowest concentration in relation to the microconstituents, only present in some of the studied fruits and the highest values show the crab with 0.067 ± 0.001 mg 100 g^{-1}. The estimated cobalt doses are between 0.5-1.4 mg dia^{-1}, therefore, the levels found in the fruits studied would be below the recommended levels [39].

A present a study of determination of seven minerals in different Amazonian fruits in the different parts of the same, among them the *biribá*, being the values obtained for this fruit, very close to those presented with the exception of the sodium concentration obtained for the pulp of the *biribá* that presents a much lower value [17].

A study of mineral determination in acerola *in natura* and juice, presenting very close values for Mg, P, K and Zn, and for the Fe, Na and Cu elements we obtained larger values compared to the author [40].

The results obtained in this study were similar to those and the values for Ca, Mg and Ca were higher for P, K, Na, Fe, Mn and Cu [41].

3.3. Statistic analysis.

3.3.1. Pearson correlation coefficient

Table 6 presents the Pearson correlation matrix between the different elements for the pulps of the different fruits.

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Table 6 - Pearson correlation matrix between the different elements for the pulps of Amazonian fruits.

	Ca	**Mg**	**P**	**K**	**S**	**N**	**Fe**	**Zn**	**Mn**	**Cu**	**Na**	**Al**	**B**	**Co**
Ca	1													
Mg	0,76*	1												
P	0,40ns	0,13ns	1											
K	0,69*	0,43ns	0,36ns	1										
S	0,22ns	0,23ns	-0,29ns	0,42ns	1									
N	0,02ns	-0,08ns	0,60ns	0,12ns	-0,14ns	1								
Fe	0,28ns	0,22ns	0,76*	0,31ns	-0,04ns	0,92**	1							
Zn	-0,25ns	-0,23ns	0,37ns	0,11ns	-0,47ns	0,02ns	0,10ns	1						
Mn	-0,66*	-0,41ns	-0,43ns	-0,28ns	-0,32ns	-0,10ns	-0,26ns	0,56ns	1					
Cu	0,10ns	0,08ns	0,68*	0,27ns	-0,09ns	0,94**	0,97**	0,22ns	-0,06ns	1				
Na	-0,03ns	0,28ns	0,01ns	-0,02ns	0,66*	0,21ns	0,34ns	-0,34ns	-0,34ns	0,27ns	1			
Al	-0,48ns	-0,21ns	-0,25ns	-0,40ns	0,52ns	-0,11ns	-0,10ns	-0,17ns	-0,05ns	-0,10ns	0,80**	1		
B	0,42ns	0,80**	0,17ns	0,40ns	-0,03ns	0,09ns	0,35ns	0,26ns	0,13ns	0,32ns	0,15ns	-0,27ns	1	
Co	0,21ns	0,45ns	-0,14ns	0,08ns	-0,15ns	-0,09ns	-0,04ns	-0,18ns	-0,08ns	0,02ns	-0,11ns	-0,33ns	0,34ns	1

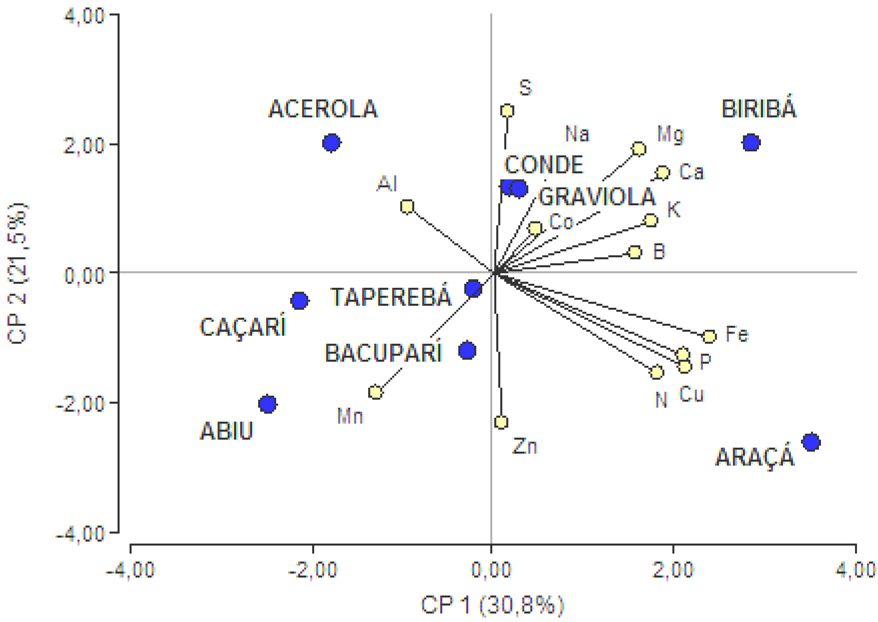
Subtitle: ns (not significant) $p > 0.05$, * $p < 0.05$, ** $p < 0.01$

In Table 6, Pearson correlation coefficient showed highly significant correlation values at 1% significance for the following elements: copper with iron (0.97), iron with nitrogen (0.92), copper with nitrogen (0.94) and aluminum with sodium (0.80). On the other hand, there are significant interactions at the significance level of 5%, calcium with magnesium (0.76), calcium with potassium (0.69), and at the same time, calcium with manganese (0.66). Phosphorus also has a significant interaction with iron and copper. In the case of the interaction of iron with phosphorus presents with Pearson correlation coefficient (0.76) and for the interaction of phosphorus with copper (0.68). Sodium with sulfur also has a significant interaction of (0.66). The other elements do not present significant interactions between them.

3.3.2. Principal component analysis (PCA)

The analyzes of main components were carried out jointly for the evaluated systems (*abiu*, *bacupari*, *acerola*, *graviola*, *caçari*, *araçá*, *biribá* and *taperebá*), independently for each part of the fruit, in order to (minerals present in different parts of the fruit), in order to find a new set of variables (main components), uncorrelated, that explain the structure of the variation, being represented the weight of each variable analyzed in each component (axes).

Figure 2. Distribution of the original variables between the different fruits for the pulp on the first and second main component (CP1 and CP2).



In the blipot (Figure 2), the results of the analysis of the main components (PCA) for the pulps of the different fruits are presented, explaining the 52.3% of the original variability of the data retained in these components.

The arrangement of the sequence in Figure 2 of the supplementary material shows that the systems can be grouped into two sets, the first major component (CP1), contributed with 30.8% of the total variance explained, however most of the minerals that were strongly affected, between (S), sodium (Na), magnesium (Mg), calcium (Ca), cobalt (Co), potassium (K) and boron (B) contributing positively to CP1 and inverse with aluminum elements) and manganese (Mn).

These results indicate that CP1 allowed to distinguish the fruits that are associated to the minerals, being the fruit *araçá*, *biribá*, fruit of the count and *graviola* that have been associated, being the last three of the same family.

The second main component (CP2) explained 21.5% of the total data, relating the elements aluminum (Al) and manganese (Mn). The analysis of this component also showed that these attributes negatively projected on the elements S, sodium (Na), magnesium (Mg), calcium (Ca), cobalt (Co), potassium (K) and boron (B), being the fruits *acerola*, *taperebá*, *abiu*, *caçari* and *bacuparí* who were associated.

4. Conclusions

The present work establishes the nutritional importance of Amazonian fruits, which present a great richness in minerals especially in micronutrients, establishing a correlation between the different constituents, as well as establishing methods of multivariate analysis to establish the relationship between the different studied variables.

Due to the nutritional importance of fruits, they could be used to develop bioproducts with interest being at the same time a part with high energetic potential.

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