

*Full Length Research Paper*

# **Nutrients in Amazonian fruit pulps with functional and pharmacological interest**

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**In this research, nine fruits cultivated in Northern Amazon were studied: Abiu, acerola, araçá, bacupari, biribá, camu-camu, fruta-do-conde, graviola and taperebá, with the objective of carrying out a proximate and nutritional study of the pulps of the Northern Amazon fruits. They were graviola ( $76.83 \pm 0.02$  Kcal  $100\text{ g}^{-1}$ ), bacupari ( $53.15 \pm 0.02$  Kcal  $100\text{ g}^{-1}$ ) and fruta-do-conde ( $46.66 \pm 0.02$  Kcal  $100\text{ g}^{-1}$ ). Among the macronutrients, potassium with high concentration stood out, especially in graviola ( $541.16 \pm 0.24$  mg  $100\text{ g}^{-1}$ ) and biribá ( $468.21 \pm 0.13$  mg  $100\text{ g}^{-1}$ ). Among the micronutrients, iron concentrations was high in araçá pulp ( $3.04 \pm 0.02$  mg  $100\text{ g}^{-1}$ ), and abiu was abundant in zinc ( $3.71 \pm 0.02$  mg  $100\text{ g}^{-1}$ ) and manganese ( $6.61 \pm 0.11$  mg  $100\text{ g}^{-1}$ ). The presence of cobalt at the level of traces in some of the pulps studied stood out. The Pearson correlation coefficient was evaluated, as well as the statistical treatment by multivariate analysis Principal Component Analysis (PCA) to establish the correlation between the variables studied.**

**Key words:** Amazonian fruit, functional food, nutrients.

## **INTRODUCTION**

The Amazon Region plus the sweet water biome represents the largest biodiversity on the planet with more than 5000 species (Hubbell et al., 2008). The fruits of this biodiversity, native and exotic, present an expressive potential of bioactive compounds, which can be a source of bio-products for the benefit of humanity

(Mariutti et al., 2014).

The Amazonian fruits arouse great study interest due to their great biodiversity in fruits, which, according to Drewnowaki and Fulgoni (2008) and Darmon et al. (2004), present outstanding results in quality and attractive attributes such as appearance in large sizes,

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

| Scientific name             | Family        | Name in Brazil |
|-----------------------------|---------------|----------------|
| <i>Pouteria caimito</i>     | Sapotaceae    | Abiu           |
| <i>Malpighia emarginata</i> | Malpighiaceae | Acerola        |
| <i>Psidium cattleianum</i>  | Myrtaceae     | Araçá          |
| <i>Rheedia gardneriana</i>  | Clusiaceae    | Bacuparí       |
| <i>Rollinia mucosa</i>      | Annonaceae    | Biribá         |
| <i>Myrciaria dubia</i>      | Myrtaceae     | Camu-camu      |
| <i>Annona squamosa</i>      | Annonaceae    | Fruta-do-conde |
| <i>Annona muricata</i>      | Annonaceae    | Graviola       |
| <i>Spondias mombin</i> L.   | Anacardiaceae | Taperebá       |

different shapes, colors, textures and different flavors. In human diet, fruits are considered as the main sources of necessary minerals, playing a vital role in the peculiar development and good health of the human body (Hardisson et al., 2001), because they are involved in many biochemical reactions, being divided, according to Krause and Mahan (2005), into macronutrients (minerals required for humans in amounts greater than or equal to 100 mg day<sup>-1</sup> such as calcium, magnesium, potassium, phosphorus, sulfur, chlorine and sodium) and micronutrients (minerals required for humans in amounts less than 100 mg day<sup>-1</sup>, such as copper, iron, zinc, manganese, selenium, molybdenum and fluorine).

On the other hand, besides minerals, Arts and Hollman (2005) affirm that the beneficial effects in the fruits are also due to the high content of antioxidants, micronutrients including vitamin C, carotenoids and polyphenolic compounds.

Many tropical fruits are not well known, which can be associated to the lack of knowledge of the production and conservation system, as well as other aspects related to the quality of these fruits (Leterme et al., 2006). Thus, many of the pulps fruits cultivated from Amazon 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 Northern Amazon (Table 1 and Figure 1) and the correlation between existing data using the Pearson test and multivariate analysis methods such as Principal Component Analysis (PCA) and Hierarchical Component Groupings (HCA).

## MATERIALS AND METHODS

### Preparation of samples

The samples of the different fruits studied were collected in randomized points of the State of Roraima (Brazil) to guarantee the representativeness of the sample. Each of the fruits was collected in the corresponding production period and was collected in the ripening stage suitable for consumption. From all the samples collected at the different sampling points, a single composite sample was prepared for each of the fruits where they were taken

to the Environmental Chemistry Laboratory of the Federal University of Roraima; those that presented an optimum conservation status were selected and washed with 1% sodium hypochlorite solution and again with distilled water.

Subsequently, a representative sample of each fruit was selected according to the following criteria: 1 kg of fresh acerola, camu-camu and taperebá were selected; 2 kg of abiu, araçá and bacuparí was selected; 10 units of biribá, fruta-do-conde and graviola were selected according to NTON 17002-02 (2002). The pulps of the different fruits were separated from the different parts of the fruits and placed in Ultrafreezer at -80 °C; they were lyophilized in lyophilizer LIOTOP model L 101 for 48 h until complete drying of the material. Subsequently, they were ground in LABOR model SP31 punch mill and stored in airtight bags in the absence of light until the different analyses were done.

### 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 (IAL, 2008) to determine the total energy content according to the following Equation 1 (Mendes-Filho et al., 2014).

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

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

The extraction of the minerals into the pulps 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 then 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 P. A. of 1000 mg L<sup>-1</sup> Qhemis High Purity PACU 1000-0125, according to the specific conditions of each element (Table 2).

For the ionization suppressor for the Ca, Mg and K elements, 0.1% of the lanthane oxide solution (La<sub>2</sub>O) was used. In the case of sodium (Na), it was determined in the same equipment, but in



**Figure 1.** Fruits grown in the Northern Amazon under study.  
Source: Pictures by I. F. Montero.

**Table 2.** Analytical parameters.

| Element | Technique           | ( $\lambda$ ) nm | Calibration Line                     |
|---------|---------------------|------------------|--------------------------------------|
| Ca      | FAAS                | 422.70           | $y = 0.0092x - 0.0005$ $r^2 = 0.999$ |
| Mg      | FAAS                | 285.21           | $y = 0.2353x - 0.0658$ $r^2 = 0.997$ |
| P       | UV-Vis spectroscopy | 660.00           | $y = 0.2181x - 0.0005$ $r^2 = 0.999$ |
| K       | AES                 | 766.50           | $y = 0.1231x - 0.0013$ $r^2 = 0.993$ |
| S       | UV-Vis spectroscopy | 420.00           | $y = 0.0213x - 0.0012$ $r^2 = 0.998$ |
| Fe      | FAAS                | 248.33           | $y = 0.0399x + 0.0067$ $r^2 = 0.996$ |
| Zn      | FAAS                | 213.80           | $y = 0.060x - 0.0171$ $r^2 = 0.991$  |
| Mn      | FAAS                | 279.48           | $y = 0.0282x + 0.0041$ $r^2 = 0.999$ |
| Cu      | FAAS                | 324.75           | $y = 0.0512x - 0.0099$ $r^2 = 0.997$ |
| Na      | FAAS                | 589.0            | $y = 1.00x + 0.0005$ $r^2 = 0.999$   |
| Al      | FAAS                | 309.3            | $y = 0.0088x + 0.0005$ $r^2 = 0.998$ |
| B       | UV-Vis spectroscopy | 420.00           | $y = 0.0537x + 0.0002$ $r^2 = 0.999$ |
| Co      | FAAS                | 240.73           | $y = 0.0286x - 0.0066$ $r^2 = 0.997$ |

FAAS = Flame atomic absorption spectroscopy. AES = Flame atomic emission spectroscopy.

**Table 3.** Nutritional composition in Amazonian fruit pulps.

| Fruit                 | Nutritional contribution |             |             |               |             |   |
|-----------------------|--------------------------|-------------|-------------|---------------|-------------|---|
|                       | Moisture                 | Ashes       | Lipids<br>% | Carbohydrates | Proteins    | Energetic value<br>Kcal 100 g <sup>-1</sup> |
| <i>Abiu</i>           | 92.43 ± 0.02             | 0.13 ± 0.07 | 0.12 ± 0.01 | 6.48 ± 0.02   | 0.84 ± 0.01 | <b>30.36 ± 0.03</b>                         |
| <i>Acerola</i>        | 94.21 ± 0.01             | 0.16 ± 0.03 | 0.06 ± 0.00 | 4.45 ± 0.02   | 1.12 ± 0.01 | <b>22.82 ± 0.02</b>                         |
| <i>Araçá</i>          | 59.21 ± 0.08             | 0.21 ± 0.07 | 0.17 ± 0.09 | 30.87 ± 0.03  | 3.93 ± 0.07 | <b>18.09 ± 0.02</b>                         |
| <i>Bacuparí</i>       | 86.61 ± 0.11             | 0.19 ± 0.01 | 0.07 ± 0.00 | 12.36 ± 0.01  | 0.77 ± 0.01 | <b>53.15 ± 0.02</b>                         |
| <i>Biribá</i>         | 91.34 ± 0.01             | 0.31 ± 0.02 | 0.22 ± 0.02 | 6.95 ± 0.03   | 1.18 ± 0.04 | <b>34.5 ± 0.01</b>                          |
| <i>Camu-camu</i>      | 95.21 ± 0.14             | 0.25 ± 0.11 | 0.05 ± 0.00 | 3.14 ± 0.02   | 1.35 ± 0.04 | <b>18.41 ± 0.02</b>                         |
| <i>Fruta do conde</i> | 88.27 ± 0.05             | 0.29 ± 0.07 | 0.18 ± 0.07 | 10.08 ± 0.01  | 1.18 ± 0.04 | <b>46.66 ± 0.02</b>                         |
| <i>Graviola</i>       | 80.77 ± 0.07             | 0.31 ± 0.11 | 0.23 ± 0.08 | 17.34 ± 0.01  | 1.35 ± 0.02 | <b>76.83 ± 0.02</b>                         |
| <i>Taperebá</i>       | 88.23 ± 0.10             | 0.15 ± 0.01 | 0.05 ± 0.01 | 10.01 ± 0.03  | 1.56 ± 0.01 | <b>46.73 ± 0.03</b>                         |

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<sup>-1</sup>.

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. The determination of P was done by forming the blue complex with ammonium molybdate ((NH<sub>4</sub>)<sub>2</sub>MoO<sub>4</sub>); the readings were done at  $\lambda = 660$  nm. The determination of boron was carried out by the formation of a yellow complex with azomethine-H; the readings were done at 460 nm. The determination of S was performed by forming a precipitate with BaCl<sub>2</sub>; the readings were done in Uv-visivel at  $\lambda = 420$  nm and calibrated with potassium sulphate, according to Embrapa (2009). Nitrogen determined by the distillation method followed by titration (Kjeldahl), according to the methodology of Embrapa (2009).

Correlations between the amounts of the different minerals in the different parts of the fruit were evaluated using the Pearson statistical test with INFOSTAT (Rienzo et al., 2016) for significance levels of 5, 1 and 0.1% respectively, as well as the principal component analyses (PCA) and Hierarchical Component Groupings (HCA).

## RESULTS AND DISCUSSION

### Nutritional analysis from Amazonian fruits

Table 3 showed the nutritional analysis values for the pulps of the different Amazonian fruits studied. The first parameter analyzed was the moisture, which according to Welti and Vergara (1997), was used as a factor indicative of propensity for food spoilage; the greater stability of food was in the control of the minimum moisture content. It was, therefore, significant to dry food to minimize physical and chemical changes of the product (Herrera et al., 2001). The amount of moisture in the pulps ranged from 64.22-95.21%, where the highest moisture values were for camu-camu (95.21 ± 0.14%) and acerola (94.21 ± 0.11%) and the lowest value was for araçá (64.22 ± 0.12%). The values of moisture for abiu, acerola and graviola were slightly lower, but close to those presented by Canuto et al. (2010); in the case of araçá it was lower

than those presented by that same author.

The reported values of moisture were within the concentrations of moisture range given by the IAL (2008) that established the values in fruits between 65-90%. In the case of camu-camu, Maeda et al. (2006) determined the percentage of moisture in the camu-camu pulp (92.65%), which was close to that found in the present study. The ash content reflected the amount of minerals presented in food. According to Moreto (2008), the amount of ash in food may vary depending on the food or the conditions in which it was presented. On the other hand, IAL (2008) established the values of levels of fruit ashes were between 0.3 - 2.1%, being the values of ashes studied in this work according to this range. For proteins, it was those of animal origin that had higher biological value compared to proteins of plant origin (Kinupp and Barros, 2008); and the identification of plant species with a certain content of proteins was considerable to satisfy the nutritional deficiencies of people with different dietary habits and diets (Aletor and Adeogun, 1995). Also, many native Amazonian species have not yet been studied to evaluate their protein content potential.

The protein content in the fruit pulps studied in this study ranged from 0.77% for the bacuparí pulp to 3.93% for the araçá pulp. Camu-camu had a protein content of 1.35%. Compared to the table proposed by Aguiar (1996) on the food composition of the Amazon, camu-camu had a value of 0.45 g 100 g<sup>-1</sup> of proteins and araçá had a value 0.60 g 100 g<sup>-1</sup>. Among the three groups of primary metabolites in fruits, carbohydrates were the major ones, presented values between 3.14-30.87% for pulps; the one with the lowest value was camu-camu while araçá pulp had the highest. Among the factors that characterize the quality of the fruits, the most important was the flavor. It is given by the balance between soluble sugars and organic acids. As the fruit ripens, there was an increase in soluble sugars, and therefore increases in the sweet taste; and at the same time, the amount of organic acids decreases (Medlicott and Thompson, 1985).

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

| Fruit                 | Macronutrients         |                   |                    |                  |               |                 |
|-----------------------|------------------------|-------------------|--------------------|------------------|---------------|-----------------|
|                       | Calcium<br>(Ca)        | Magnesium<br>(Mg) | Phosphorous<br>(P) | Potassium<br>(K) | Sulfur<br>(S) | Nitrogen<br>(N) |
|                       | mg 100 g <sup>-1</sup> |                   |                    |                  |               | %               |
| <i>Abiu</i>           | 4.51 ± 0.02            | 1.71 ± 0.07       | 8.21 ± 0.04        | 255.21 ± 0.03    | 11.11 ± 0.04  | 0.15 ± 0.01     |
| <i>Acerola</i>        | 11.23 ± 0.12           | 18.41 ± 0.21      | 11.93 ± 0.04       | 154.34 ± 0.18    | 34.13 ± 0.14  | 0.19 ± 0.01     |
| <i>Araçá</i>          | 24.13 ± 0.03           | 12.21 ± 0.08      | 6.32 ± 0.04        | 137.11 ± 0.08    | 9.02 ± 0.01   | 0.68 ± 0.07     |
| <i>Bacuparí</i>       | 32.41 ± 0.02           | 14.21 ± 0.08      | 12.31 ± 0.14       | 329.12 ± 0.04    | 5.21 ± 0.04   | 0.13 ± 0.01     |
| <i>Biribá</i>         | 32.11 ± 0.08           | 112.32 ± 0.12     | 23.41 ± 0.01       | 468.21 ± 0.13    | 21.31 ± 0.12  | 0.21 ± 0.04     |
| <i>Camu-camu</i>      | 9.51 ± 0.02            | 8.49 ± 0.04       | 6.21 ± 0.04        | 124.13 ± 0.12    | 7.21 ± 0.04   | 0.23 ± 0.04     |
| <i>Fruta do conde</i> | 52.21 ± 0.13           | 32.12 ± 0.09      | 17.30 ± 0.12       | 431.21 ± 0.17    | 27.78 ± 0.13  | 0.21 ± 0.04     |
| <i>Graviola</i>       | 39.21 ± 0.13           | 27.11 ± 0.15      | 19.24 ± 0.16       | 541.16 ± 0.24    | 29.31 ± 0.08  | 0.23 ± 0.02     |
| <i>Taperebá</i>       | 38.12 ± 0.12           | 16.32 ± 0.09      | 24.12 ± 0.11       | 149.13 ± 0.23    | 4.38 ± 0.08   | 0.27 ± 0.01     |

The lipid content observed in the fruits cultivated in Northern Amazon was observed in the pulps of *camu-camu* (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* (0.23%), followed by *biribá* (0.22%) and *fruta-do-conde* (0.18%). The values obtained for the *biribá* are close to those determined by Berto et al. (2015). In addition to the biological benefits that the aforementioned oils present, the main use of oils and fats is, according to Ribeiro et al. (2007), in the human diet as essential nutrients, thus being vital in providing essential fatty acids and energy.

### Mineral analysis

In Tables 4 and 5, the values of macronutrients and micronutrients were illustrated for the different pulps studied. Among the macro-elements, the high values of potassium in the fruits studied were presented for *graviola* pulp, with 541.16 ± 0.24 mg 100 g<sup>-1</sup> and 468.21 ± 0.13 mg 100 g<sup>-1</sup> for *biribá* pulp. The levels of potassium daily, according to the Food and Nutrition Board of the Institute of Medicine (2013), are 4700 mg day<sup>-1</sup>; consumption of potassium-rich foods is 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 organisms is that it is the source of animal origin, mainly in red, white and viscera meats (Cozzolino, 2007). According to Tomassi (2002), in fruits, the phosphorus levels oscillated between 20-100 mg 100 g<sup>-1</sup>. The fruits in the study presented low values of phosphorus, being *camu-camu* pulp, which presented a lower value of 6.21 ± 0.04 mg 100 g<sup>-1</sup> and *taperebá* pulps with 24.12 ± 0.11 mg 100 g<sup>-1</sup>. According to Tomassi (2002), the recommended dose of phosphorus per day is 800 mg. An element that can

influence the absorption of phosphorus is calcium, and it is estimated that the absorption of both elements is optimal when the relation between both is equal to 1 (Douglas, 2002). The relation between the two elements is closer to 1 for *acerola* pulp with 1.06 and for *biribá* pulp with 0.72. Of the fruits studied, it is *abiu* that presented a lower concentration of calcium 4.51 ± 0.02 mg 100 g<sup>-1</sup> and the higher concentration of calcium for *fruta-do-conde* pulp with 52.21 ± 0.13 mg 100 g<sup>-1</sup>. The nutritional contribution of Ca in adults according to Pereira et al. (2009) is 1000-1200 mg day<sup>-1</sup>.

Magnesium is other important macro-element in fruits, and it appears within a very variable range in the fruits studied. In *abiu* pulp, it was in low concentrations 1.71 ± 0.07 mg 100 g<sup>-1</sup>, reporting the highest concentration of magnesium for *biribá* pulp with 112.32 ± 0.12 mg 100 g<sup>-1</sup>. The main function of Magnesium in the body is to stabilize the structure of ATP in enzymatic reactions, as cofactor in enzymatic reactions, neuromuscular transmission (Iseri and French, 1984) and in reactions of the dark phase of photosynthesis it is activated by manganese (Malavolta, 2006). The recommendation for magnesium is 310-320 mg day<sup>-1</sup> for women and 410-420 mg day<sup>-1</sup> for men (Yuyama et al., 1992).

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 (Silva et al., 2004). Of the fruits studied, it was the *acerola* pulp that had the highest concentrations of sulfur (34.13 ± 0.14 mg 100 g<sup>-1</sup>); *taperebá* pulp presents lower concentrations with 4.38 ± 0.08 mg 100 g<sup>-1</sup>.

Nitrogen in fruits is important in its size, as well as being part of amino acids, proteins, coenzymes, nucleic acids and vitamins; it takes part in the processes of photosynthesis, cellular respiration and multiplication (Malavolta, 2006). Nitrogen is not one of the most studied micronutrients in fruits; it is studied in association with the proteins of fruit. Its fruit pulp quantity was low, presenting

**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 <sup>-1</sup> |                |             |                |             |              |               |             |               |
| <i>Abiu</i>            | 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.          |
| <i>Acerola</i>         | 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.          |
| <i>Araçá</i>           | 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 |
| <i>Bacuparí</i>        | 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 |
| <i>Biribá</i>          | 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 |
| <i>Camu-camu</i>       | 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 |
| <i>Fruta do conde</i>  | 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 |
| <i>Graviola</i>        | 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 |
| <i>Taperebá</i>        | 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.

the lowest value for *bacuparí* pulp (0.13 ± 0.01%); it was the fruit that presents a higher value, *araçá* pulp (0.68 ± 0.07%).

Leterme et al. (2006) analyzed the *graviola* pulps and *fruta-do-conde* pulps. In the case of *graviola*, the values obtained for Ca, K and Mg was close to those obtained by Leterme et al. (2006); sodium and potassium are lower than those obtained by the same author and in the case of sulfur the value obtained was bigger.

In *fruta-do-conde*, the values obtained from Ca, K and S were similar to those obtained by the same author. For Mg and Na there were lower than those presented by Leterme et al. (2006). Feitosa and Maker (2007) determined the concentration of Ca, P and Fe in *taperebá*; the values were superior in the case of Ca and P. There were studies on other Amazonian fruits where nitrogen values were evaluated, such as in the case of *Pitaya vermelha* with 11.30% nitrogen (Cordeiro et al., 2015); they were larger than those presented in this study. Among the micronutrients, iron is very important in human diet; its deficiency can cause anemia, fatigue and impairment in neurological growth and development (Carvalho et al., 2010). According to 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 were for *araçá* pulp with concentrations of 3.04 ± 0.02 mg.100 g<sup>-1</sup>; the lowest concentration of iron was for *abiu* pulp with 0.18 ± 0.04 mg 100 g<sup>-1</sup>. Another fruit rich in iron was *biribá* pulp with 1.82 ± 0.11 mg 100 g<sup>-1</sup>.

Zinc is important in organisms at the physiological level as an antioxidant (Powell, 2000); it also has a fundamental role in the polymer organization of macromolecules such as DNA and RNA and their synthesis (Vallee and Falchuk, 1993). According to Food and Nutrition Board (2001), zinc recommendations are 8 mg day<sup>-1</sup> for women and 11 mg day<sup>-1</sup> for men. In the fruits

studied, the pulp with the highest concentration was *abiu* pulp (3.71 ± 0.22 mg 100 g<sup>-1</sup>) and the lowest concentration of zinc was found in *acerola* pulp (0.08 ± 0.01 mg 100 g<sup>-1</sup>).

According to Leterme et al. (2006), of the several Amazonian fruits, zinc concentration in *araçá* was 0.17 mg.100 g<sup>-1</sup> while in *acerola* it was 0.19 mg 100 g<sup>-1</sup>. The edible fraction of fruit was found in *acerola* which was lesser than that obtained in this work (Table 5). *Araçá* pulp has smaller value as presented in Table 5. Other important microelement in enzymatic metabolic reactions was manganese, which, according to Panziera et al. (2011), is part of two metalloenzymes, carboxylase pyruvate and Mn-superoxide dismutase. It also participates in mitochondrial energy production, activating other enzymes such as superoxide dismutase, and phosphoenolpyruvate carboxycinase of great importance in gluconeogenesis (Mahan and Escott-Stump, 2002).

Among the fruits studied, *abiu* pulp presented high concentrations, 6.61 ± 0.11 mg 100 g<sup>-1</sup>. Other fruits with considerable concentrations of manganese were *camu-camu* pulp, 2.39 ± 0.02 mg 100 g<sup>-1</sup>; the lowest values of manganese were in *taperebá* pulp with 0.04 ± 0.00 mg 100 g<sup>-1</sup>. Almeida et al. (2009) studied minerals in tropical fruits and found manganese of 0.07 ± 0.02 mg 100 g<sup>-1</sup> in *graviola* next to the value found in the present work (0.09 ± 0.00 mg 100 g<sup>-1</sup>) as well as in *fruta-do-conde* (0.16 ± 0.00 mg 100 g<sup>-1</sup>), a value close to the finding in this work for *fruta-do-conde* pulp (0.12 ± 0.02 mg 100 g<sup>-1</sup>). On the other hand, Leterme et al. (2006) evaluated fruits cultivated in Colombia and found manganese values of 0.08 mg 100 g<sup>-1</sup> for *araçá*; the value found in this work for *araçá* pulp (1.25 ± 0.07 mg 100 g<sup>-1</sup>) was slightly higher than the value described by previous author and for *acerola* (0.09 mg 100 g<sup>-1</sup>), which was lower than that found in the present study with a value of 0.24 ± 0.05 mg 100 g<sup>-1</sup>.

Copper is a trace element that may exhibit various oxidation states and within the cell predominates cuprous ion (Bairele et al., 2010). The same is present in the skeletal muscles, presenting on average 40% of all the content of the body; it plays an important role in the production of mitochondrial energy, as well as protective action against oxidizing agents and free radicals. It promotes the synthesis of melanin and catecholamines (Maddie et al., 2003). Copper levels, compared to the other elements, were low, with the exception of *araçá* that presents copper concentrations of  $1.73 \pm 0.02 \text{ mg } 100 \text{ g}^{-1}$  for pulp, and *taperebá* which had the lowest concentration of copper ( $0.07 \pm 0.00 \text{ mg } 100 \text{ g}^{-1}$ ).

The need for copper is  $1\text{-}2 \text{ mg day}^{-1}$ , and  $10 \text{ mg day}^{-1}$  is tolerated according to (DRIs) (Dietary Reference Intakes, 2004) for the maintenance of humans. The above fruits were above the tolerable levels for organisms. Almeida et al. (2009) determined copper concentrations of  $0.15 \pm 0.03 \text{ mg } 100 \text{ g}^{-1}$  in *graviola*; it was close to that found in the present study ( $0.19 \pm 0.04 \text{ mg } 100 \text{ g}^{-1}$  and  $0.22 \pm 0.03 \text{ mg } 100 \text{ g}^{-1}$ ). The concentration of copper in *fruta-do-conde* pulps was  $0.31 \pm 0.08 \text{ mg } 100 \text{ g}^{-1}$ , slightly higher than the value found in the literature. An important trace element was boron; it is related to the cerebral metabolism (Penland, 1994), 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; it is a fundamental factor for the adequate formation of fruits (Sang Hyun et al., 2009). The highest concentration of boron was found in the *biribá* pulp with  $0.51 \pm 0.05 \text{ mg } 100 \text{ g}^{-1}$  and the lowest concentration was in *aracá* pulp with  $0.10 \pm 0.02 \text{ mg } 100 \text{ g}^{-1}$ .

Aluminum is a toxic metal, whose concentration in food is low, in the order of  $5 \text{ mg kg}^{-1}$  (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 fruits analyzed had relatively low concentrations, varying between  $0.02\text{-}0.17 \text{ mg } 100 \text{ g}^{-1}$  in pulps; it was within the recommended levels. Among all the evaluated minor elements, cobalt was the lowest concentration in relation to the micro-constituents; it is only present in some of the studied fruits and the highest values were found in *camu-camu* pulp with  $0.067 \pm 0.001 \text{ mg } 100 \text{ g}^{-1}$ . According to Vaitsman et al. (2011), the estimated cobalt doses were between  $0.5\text{-}1.4 \text{ mg dia}^{-1}$ ; therefore, the levels found in the fruits studied would be below the recommended levels.

Berto et al. (2015) determined seven minerals in different Amazonian fruit. The values obtained for *biribá* fruit were very close to those presented by Berto et al. (2015), with the exception of sodium concentration obtained for the pulp of the *biribá* that presents a much lower value. For *camu-camu*, Yuyama et al. (2013) studied six minerals in different samples and compared them with the mineral concentrations in the pulps. The values were within the range, except sodium, whose

value was lower than the values presented by the author. For cobalt, the concentrations obtained by the author were higher than the values presented in this research.

Freitas et al. (2014) studied minerals found in *acerola in natura* juice; they had very close values for Mg, P, K and Zn, and for Fe, Na and Cu elements we obtained larger values compared to that of the author. The results obtained in this study were similar to those obtained by Caldeira et al. (2004), and the values for Ca, Mg and Ca were higher for P, K, Na, Fe, Mn and Cu. Feitosa and Fabricante (2007) determined the concentration of Ca, P and Fe in *taperebá*; the values were superior in the case of Ca and P.

## Statistical analysis

### Pearson correlation coefficient

Table 6 presents the Pearson correlation matrix between the different elements for the pulps of the different fruits. 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 were 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 had a significant interaction with iron and copper. The interaction of iron with phosphorus presented Pearson correlation coefficient of 0.76, and for the interaction of phosphorus with copper it was 0.68. Sodium with sulfur also had a significant interaction (0.66). The other elements do not presented significant interactions between them.

### Principal component analysis (PCA)

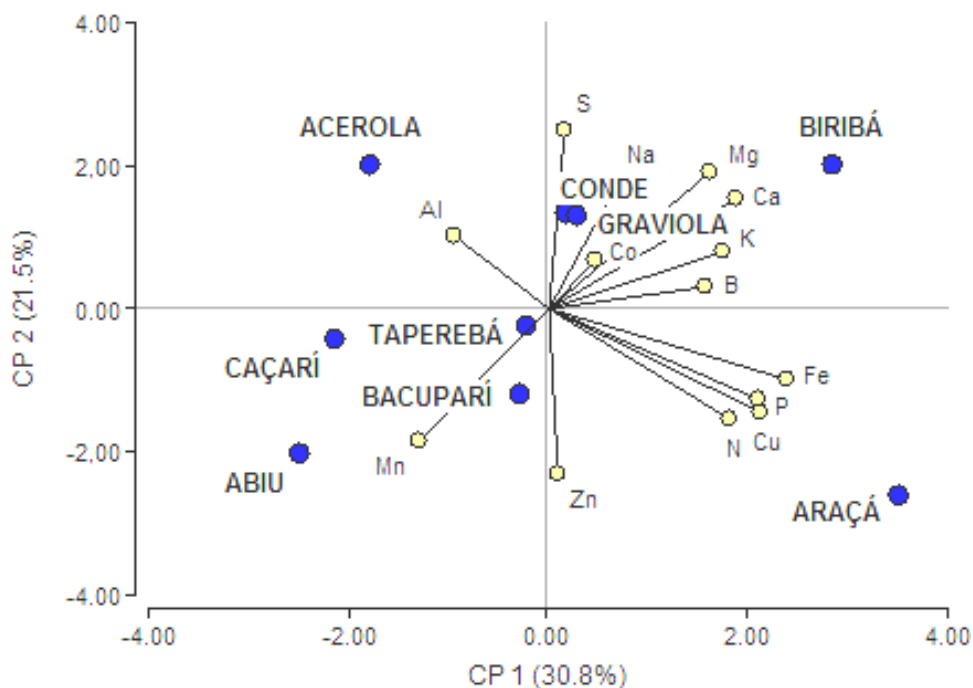
The analyses of the main components were carried out jointly for the evaluated systems (*abiu*, *bacupari*, *acerola*, *graviola*, *camu-camu*, *araçá*, *biribá* and *taperebá*), in pulps fruits, in order to find a new set of variables (main principals components). This shows the structure of the variation represents the weight of each variable analyzed in each component (axes).

In Figure 2, the correlation between the two main components, PC1 and PC2 is shown. PC1 shows more information, with a higher variance value (30.8%) and PC2 carries the maximum part of residual information with a value of 21.5%, explaining 52.3% of the total variance between the different minerals in the different fruit pulps studied. *Araçá* pulp variables with *abiu* and *camu camu (caçari)* were inversely related and are the three variables that were related to the main component primer. Planes PC1 and PC2 reveal that time and quality

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

| Correlation | Ca                  | Mg                  | P                   | K                   | S                   | N                   | Fe                  | Zn                  | Mn                  | Cu                  | Na                  | Al                  | B                  | Co |
|-------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|--------------------|----|
| Ca          | 1                   |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                    |    |
| Mg          | 0.76*               | 1                   |                     |                     |                     |                     |                     |                     |                     |                     |                     |                     |                    |    |
| P           | 0.40 <sup>ns</sup>  | 0.13 <sup>ns</sup>  | 1                   |                     |                     |                     |                     |                     |                     |                     |                     |                     |                    |    |
| K           | 0.69*               | 0.43 <sup>ns</sup>  | 0.36 <sup>ns</sup>  | 1                   |                     |                     |                     |                     |                     |                     |                     |                     |                    |    |
| S           | 0.22 <sup>ns</sup>  | 0.23 <sup>ns</sup>  | -0.29 <sup>ns</sup> | 0.42 <sup>ns</sup>  | 1                   |                     |                     |                     |                     |                     |                     |                     |                    |    |
| N           | 0.02 <sup>ns</sup>  | -0.08 <sup>ns</sup> | 0.60 <sup>ns</sup>  | 0.12 <sup>ns</sup>  | -0.14 <sup>ns</sup> | 1                   |                     |                     |                     |                     |                     |                     |                    |    |
| Fe          | 0.28 <sup>ns</sup>  | 0.22 <sup>ns</sup>  | 0.76*               | 0.31 <sup>ns</sup>  | -0.04 <sup>ns</sup> | 0.92**              | 1                   |                     |                     |                     |                     |                     |                    |    |
| Zn          | -0.25 <sup>ns</sup> | -0.23 <sup>ns</sup> | 0.37 <sup>ns</sup>  | 0.11 <sup>ns</sup>  | -0.47 <sup>ns</sup> | 0.02 <sup>ns</sup>  | 0.10 <sup>ns</sup>  | 1                   |                     |                     |                     |                     |                    |    |
| Mn          | -0.66*              | -0.41 <sup>ns</sup> | -0.43 <sup>ns</sup> | -0.28 <sup>ns</sup> | -0.32 <sup>ns</sup> | -0.10 <sup>ns</sup> | -0.26 <sup>ns</sup> | 0.56 <sup>ns</sup>  | 1                   |                     |                     |                     |                    |    |
| Cu          | 0.10 <sup>ns</sup>  | 0.08 <sup>ns</sup>  | 0.68*               | 0.27 <sup>ns</sup>  | -0.09 <sup>ns</sup> | 0.94**              | 0.97**              | 0.22 <sup>ns</sup>  | -0.06 <sup>ns</sup> | 1                   |                     |                     |                    |    |
| Na          | -0.03 <sup>ns</sup> | 0.28 <sup>ns</sup>  | 0.01 <sup>ns</sup>  | -0.02 <sup>ns</sup> | 0.66*               | 0.21 <sup>ns</sup>  | 0.34 <sup>ns</sup>  | -0.34 <sup>ns</sup> | -0.34 <sup>ns</sup> | 0.27 <sup>ns</sup>  | 1                   |                     |                    |    |
| Al          | -0.48 <sup>ns</sup> | -0.21 <sup>ns</sup> | -0.25 <sup>ns</sup> | -0.40 <sup>ns</sup> | 0.52 <sup>ns</sup>  | -0.11 <sup>ns</sup> | -0.10 <sup>ns</sup> | -0.17 <sup>ns</sup> | -0.05 <sup>ns</sup> | -0.10 <sup>ns</sup> | 0.80**              | 1                   |                    |    |
| B           | 0.42 <sup>ns</sup>  | 0.80**              | 0.17 <sup>ns</sup>  | 0.40 <sup>ns</sup>  | -0.03 <sup>ns</sup> | 0.09 <sup>ns</sup>  | 0.35 <sup>ns</sup>  | 0.26 <sup>ns</sup>  | 0.13 <sup>ns</sup>  | 0.32 <sup>ns</sup>  | 0.15 <sup>ns</sup>  | -0.27 <sup>ns</sup> | 1                  |    |
| Co          | 0.21 <sup>ns</sup>  | 0.45 <sup>ns</sup>  | -0.14 <sup>ns</sup> | 0.08 <sup>ns</sup>  | -0.15 <sup>ns</sup> | -0.09 <sup>ns</sup> | -0.04 <sup>ns</sup> | -0.18 <sup>ns</sup> | -0.08 <sup>ns</sup> | 0.02 <sup>ns</sup>  | -0.11 <sup>ns</sup> | -0.33 <sup>ns</sup> | 0.34 <sup>ns</sup> | 1  |

ns (not significant)  $p > 0.05$ , \*  $p < 0.05$ , \*\*  $p < 0.01$ .



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

of life are positive for the first principal component and therefore, variations in the means. Regarding the power of discrimination, we have *araçá* pulp, together with *abiu* pulp presented a greater power of discrimination.

In the second main component (PC2), *biribá* was related to *fruta-do-conde* and *graviola*, both of the same

family for the concentrations of elements (S, Na, Mg, Ca, Co, K and B). *Araçá* pulp presented the best contribution to CP2 for the elements Fe, P, N, Cu and Zn as opposed to the others. In the second quadrant, *acerola* was located, which disagrees with the aluminum concentration of the other fruits; in the third quadrant Mn



was found, which correlates with *taperebá*, *camu-camu* (*caçari*), *bacupari* and *abiu* pulp.

## Conclusion

This research established the nutritional significance of Amazonian pulps fruits, which were very rich in minerals especially in micronutrients. This established a correlation between the different constituents, as well as methods of multivariate analysis for the relationship between the different studied variables. Due to the nutritional importance of fruits, they could be used to develop bio-products of interest with high energetic potential.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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