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Characterization of Bioactive Compounds in Northern Amazon Fruits

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Abstract

Fruits and vegetables are highly appreciated because they are constituted by active phytochemicals with functional properties for the organism acting with modulating pharmacological effect. Given the pharmacological properties of this type of food, in this work were studied the concentrations of vitamin C, total carotenoids and reducing and non-reducing sugars of nine fruits developed in the northern Amazon region: *Abiu, Acerola*, *Araçá*, *Bacuparí*, *Biribá*, *Camu-camu*, *Fruta-do-conde*, *Graviola* and *Tapereba*. The concentration of vitamin C, the highest concentration in the shell of *Camu-camu* 2521.51 mg 100 g^{-1} and for acerola with 1731.4 mg 100 g^{-1} stand out. The highest concentrations of total carotenoids were also found for the *Camu-camu*, with concentrations of 0.67 mg 100 g^{-1} the shell of *Camu-camu* and 0.57 mg 100 g^{-1} for the pulp. The concentrations of sugars are higher for the pulps, with the highest concentrations for the pulp of the Fruta-do-conde with 16.31 g 100 g^{-1} followed by the pulp of the *Graviola*, both of the Annonaceae family with a concentration of 15.61 g 100 g^{-1}. The different bioactive molecules were correlated for the different parts of the fruit, by means of multivariate analysis techniques (PCA and HCA), where 90.1% of the cases were explained for the pulps, 65.4% for the shell of the fruits and finally the 88.5% of the cases for the seeds. Given the results obtained in this work, these fruits can be used for the preparation of foods with functional interest.

Keywords: ascorbic acid, carotenoids, total sugars, multivariate analysis

1. Introduction

The antioxidant capacity of fruits varies as to its composition in phenolic compounds such as carotenoids and flavonoids as well as the concentrations in vitamins E and ascorbic acid (Saura-Calixto & Goñi, 2006). The phenolic compounds that exist in plant sources are divided into flavonoids and non-flavonoids, while the anthocyanins and carotenoids are within the flavonoids and the color of antioxidants is related to the molecular structure (Rodríguez-Amaya, 2004). Foods rich in these active molecules, have aroused increasing interest among consumers, especially in the European and North American continent, where there is 92% of consumption of this type of products (Sahota, 2015). The bioactive compounds are functional ingredients for foods that provide health benefits, as well as influence physiological processes that reduce the risk of chronic diseases, including antioxidants, carotenoids and vitamins (Jiménez-Colmenero, 2013; Cantillano et al., 2013).

Ascorbic acid, also known as vitamin C, is a type of volatile organic acid present in fruits and vegetables, providing the fruit with certain organoleptic characteristics and stability properties, being one of the main characteristics of ascorbic acid, its property as an antioxidant (Sherer et al., 2012). According to Davey et al.

(2000), due to the antioxidant capacity of this acid, it is one of the main vitamins for human nutrition, due to its main active molecule, L-ascorbic acid.

Another group of biomolecules of interest in the quality of the fruit are the sugars, since they are related to the flavor of the same, since as the fruit matures, the amount of soluble organic acids decreases and the quantity of soluble sugars increases, acquiring the same sweet taste. Of the simple sugars present in fruits, fructose and glycose stand out, with lower concentrations of sucrose and sorbitol (Barreiros, Bossolan, & Trinidade, 2005).

The objective of this work was to quantify the content of vitamin C, total carotenoids and reducing and non-reducing sugars in pulps, peels and seeds of fruits developed in the northern Amazon and correlate the different biomolecules by chemometric techniques of multivariate analysis.

2. Material and Method

2.1 Collection and Preparation of Samples

Samples of the different species studied in this work were collected in several points of the State of Roraima (Brazil), as well as in the markets of the city of Boa Vista and directly with producers who owned the fruits, in order to prepare a representative composite sample for each of the fruits, their botanical and common names being shown in Table 1.

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

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

The samples were taken to the laboratory of Environmental Chemistry of the Federal University of Roraima (Brazil), where they were selected those that had an excellent state of conservation, washed previously with distilled water, then with 1% sodium hypochlorite solution and again with distilled water.

After separating the material in pulp, shell and seed, they were taken to the laboratory of the Agronomic Research Center (NUPAGRI), at the Agricultural Sciences Center, Cauamé Campus, UFRR, where they were lyophilized in LÍOTOP liquefaction model L101 for 48 hours until drying the material. Subsequently, the material was dried, milled with LABOR model SP31 knife mill and placed in hermetically sealed bags and stored away from the light until the analyzes were carried out.

2.2 Quantification of Vitamin C by Reduction of Cupric Ion

Weighed 2.0 g of lyophilized material and transferred to an Erlenmeyer flask with 10 mL of 5% metaphosphoric acid solution and 10 mL of 0.05 M sulfuric acid. Posteriorly, the samples were agitated for 30 minutes and after agitation, 10 g were transferred to a 50 mL volumetric flask and were completed with one volume of water. From there, an aliquot of 10 mL was taken and 5 mL of chloroform was added to the flask and stirred for 1 minute. Then they were left at rest to separate the layers and 5 mL of the aqueous (limpid) layer was pipetted and taken to a separating flask, where 1 mL of the buffer solution and 5 mL of the complexing solution were added. Stir later for 90 seconds and let the layers separate. Remove 3 mL of the top part (isoamyl alcohol) and transfer to a 25 mL Erlenmeyer flask. Add 0.5 mL of isoamyl alcohol and shake gently. Prepare the blank, pipetting 5 mL of solution A (pipette 2 mL of 5% metaphosphoric acid solution, transferred to a 100 mL volumetric flask with distilled water) directly into the reaction tube and then with the sample, making the readings at 545 nm. The calibration curve was prepared by diluting aliquots of the standard solution of 0.5: 1.0; 1.5; 2.0 and 2.5 mL of the standard solution 20 µg mL^{-1} (This solution is prepared from the dilution of a concentration of ascorbic acid PA of concentration 1 mg mL^{-1} for a 100 mL flask and add 2 mL of the 5% metaphosphoric acid solution completing the volume with distilled water) corresponding to 10, 20, 30, 40 e 50 µg of ascorbic acid and completing up to 5 mL of solution A. Subsequently, 1 mL of the buffer solution and 5 mL of the complexing solution. Shake the solution vigorously and let the layers separate. From the upper layer, 3 mL of the upper part is removed and transferred to a 25 mL Erlenmeyer flask and 0.5 mL of isoamyl alcohol is added, shake and read at 544 nm in UV-visivel molecular absorption spectrophotometer model SHIMADZU UV -1800 (Badolato et al., 1996; Contreras-Guzmán, 1984).

2.3 Quantification of Sugars

Using the methodology described in IAL (2008), certain carbohydrates are not present in different fruit. This section is determined by the reducing agents and not reducers. The first ones are determined by a Fehling reaction, using the Lane-Aynon method, onde or aldehyde or ketonic free group in position C1, or sugar considered a redutor, thus reducing indicators, as the complexes of (Cu^{2+}) to cuprous form (Cu^{+}). Or agent in these reactions is an open chain form of aldose or ketosis. On the other hand, non-reducing sugars are not determined, but based on reductive sugar (copper sugar sulphate) in the alkaline (Fehling's solution), forming a precipitate of cupric oxide. After hydrolysis acid two non-reducing disaccharides. This method will determine the theory of non-reducing glycides (Macedo, 2005).

2.4 Determination of Total Carotenoids

The determination of total carotenoids was also performed by UV-visible molecular spectrophotometry, in a spectrophotometer model SHIMADZU UV-1800 by the technique described by Lichtenthaler and Buschmann (2001) modified, where 1 g of lyophilized material was weighed to which was added 18 mL of acetone, the carotenoids being extracted by shaking for 20 minutes in the absence of light. The samples are filtered and the absorbance readings are carried out at concentrations of 661 nm, 644 nm and 470 nm respectively, to calculate the carotenoid concentration by means of equations 1-3.

$$C \text{ carotenoids } (\mu g\ mL^{-1}) = (1000\ A_{470} - 1.90\ C_a - 63.14\ C_b)/214 \quad (1)$$

$$C_a\ (\mu g\ mL^{-1}) = 11.24\ A_{661} - 2.04\ A_{644} \quad (2)$$

$$C_b\ (\mu g\ mL^{-1}) = 20.13\ A_{664} - 4.19\ A_{661} \quad (3)$$

2.5 Statistic Analysis

Correlations between the amounts of the different minerals in the seeds of the fruit were evaluated using the statistical program INFOSTAT Rienzo et al. (2016) for significance levels of 5%, 1% and 0.1% respectively, as well as the principal component analyzes (PCA) and Hierarchical component analysis (HCA).

3. Result

Tables 2-4 show the results of ascorbic acid, total carotenoids and sugars (reducing and non-reducing) for the pulp, skin and seeds respectively.

Table 2. Quantification of bioactives molecules in fruit pulps

Fruit	Vitamins C (mg 100 g^{-1})	Total carotenoids (mg 100 g^{-1})	Sugars (g 100 g^{-1})		
			Reducers	No reducers	Totals
Abiu	43.1±0.2	0.018±0.001	7.38±0.03	7.30±0.13	14.68±0.15
Acerola	1104.67±0.31	0.37±0.08	4.3±0.02	0.20±0.04	4.5±0.06
Araçá	117.14±0.18	0.11±0.03	0.57±0.04	0.77±0.01	1.34±0.05
Bacupari	41.34±0.2	0.021±0.01	8.12±0.07	5.09±0.02	13.21±0.10
Biribá	11.45±0.13	0.19±0.03	10.40±0.12	4.95±0.08	15.35±0.2
Camu-camu	1471.48±0.11	0.57±0.02	1.95±0.11	2.46±0.12	4.41±0.23
Fruta-do-conde	36.1±0.07	0.21±0.07	12.41±0.03	3.90±0.01	16.31±0.04
Graviola	26.15±0.12	0.26±0.01	11.67±0.15	3.94±0.07	15.61±0.22
Taperebá	27.1±0.12	0.022±0.02	4.40±0.2	0.15±0.13	4.55±0.23

Table 3. Quantification of bioactives molecules in fruit shell

Fruit	Vitamins C (mg 100 g^{-1})	Total carotenoids (mg 100 g^{-1})	Sugars (g 100 g^{-1})		
			Reducers	No reducers	Totals
Abiu	45.8±0.18	0.056±0.012	7.54±0.12	2.83±0.07	10.37±0.19
Acerola	1731.4±0.24	0.47±0.02	1.87±0.07	0.59±0.2	2.46±0.27
Araçá	74.17±0.13	0.074±0.008	0.78±0.09	0.29±0.2	1.07±0.29
Bacuparí	45.68±0.21	0.091±0.007	6.41±0.05	1.91±0.2	8.32± 0.25
Biribá	98.71±0.16	0.21±0.03	6.31±0.07	2.40±0.2	8.71±0.27
Camu-camu	2521.51±0.13	0.67±0.02	2.14±0.04	0.99±0.2	3.13±0.24
Fruta-do-conde	88.17±0.12	0.29±0.04	7.12±0.02	3.05±0.2	10.17±0.22
Graviola	119.21±0.17	0.31±0.01	9.36±0.04	2.04±0.01	11.40±0.05
Taperebá	34.17±0.21	0.041±0.07	2.61±0.03	1.17±0.02	3.78± 0.05

Table 4. Quantification of bioactives molecules in fruit seeds

Fruit	Vitamins C (mg 100 g^{-1})	Total carotenoids (mg 100 g^{-1})	Sugars (g 100 g^{-1})		
			Reducers	No reducers	Totals
Abiu	12.31±0.11	0.012±0.002	10.12±0.09	1.09±0.12	11.21±0.20
Acerola	62.12±0.08	0.087±0.013	6.29±0.12	0.86±0.04	7.15±0.16
Araçá	84.22±0.14	0.057±0.011	9.39±0.07	4.78±0.12	14.17±0.19
Bacuparí	16.21±0.07	0.023±0.002	8.21±0.2	2.57±0.2	10.78±0.4
Biribá	7.13±0.02	0.028±0.004	7.89±0.07	1.62±0.12	9.51±0.19
Camu-camu	6231.13±0.05	0.094±0.004	16.42±0.12	4.83±0.08	18.25±0.20
Fruta-do-conde	10.21±0.12	0.021±0.001	8.11±0.12	1.30±0.07	9.41±0.19
Graviola	7.84±0.04	0.029±0.003	7.21±0.11	2.06±0.04	9.27±0.15
Taperebá	n.d.	0.035±0.002	10.74±0.14	1.43±0.04	12.17±0.18

Note. n.d. = no detected.

The analyzes of the main components were carried out jointly for the evaluated systems (*Abiu*, *Acerola*, *Araçá*, *Bacuparí*, *Biribá*, *Camu-camu*, *Fruta-do-conde*, *Graviola* and *Taperebá*), independently for each part of the fruit, in order to (vitamin C, carotenoids, reducing and non-reducing sugars in different parts of the fruit), in order to find a new set of uncorrelated variables (main components) that explain the structure of the variation, and the weight of each variable analyzed in each component (axes) is represented. The blipot of major component (PCA) for the different parts of the evaluated fruit is shown in Figures 1-3.

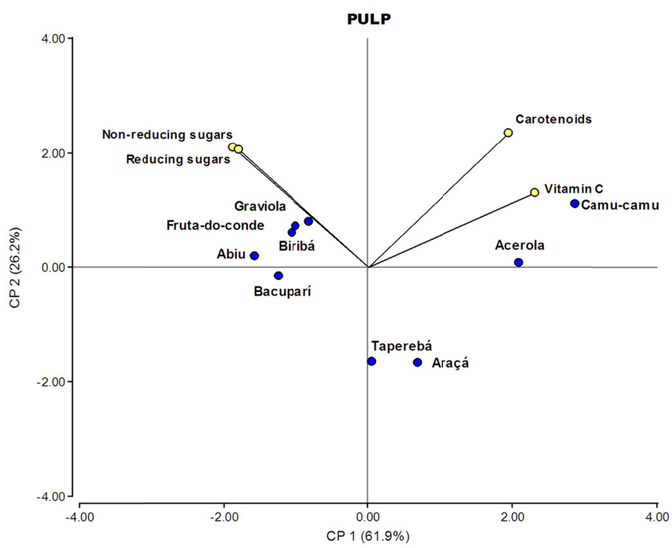

Figure 1. Distribution of the original variables between the different fruits for the pulp on the first and second main component (CP1 and CP2)

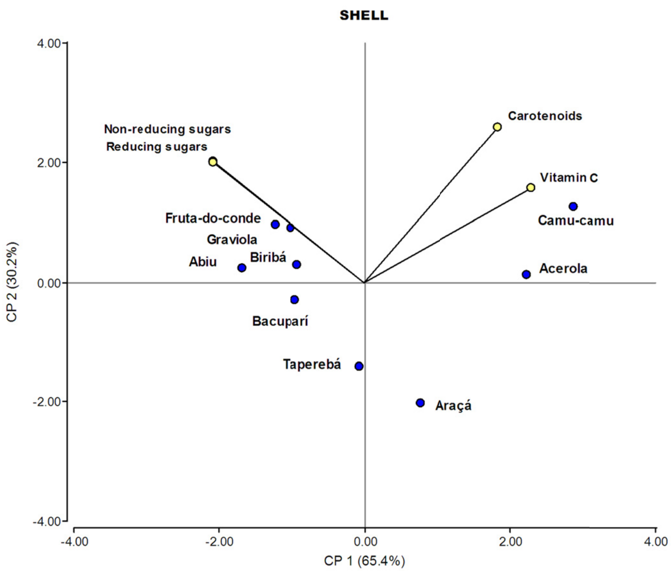

Figure 2. Distribution of the original variables between the different fruits for the shell on the first and second main component (CP1 and CP2)

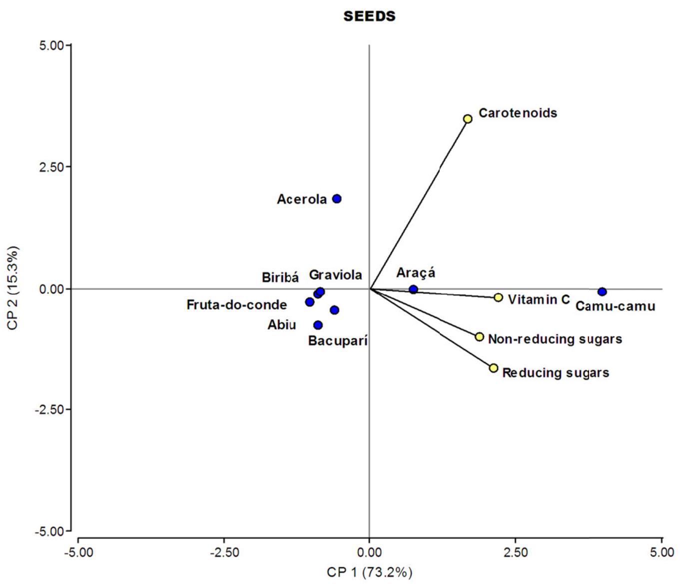

Figure 3. Distribution of the original variables between the different fruits for the seeds on the first and second main component (CP1 and CP2)

Figures 4-6 show the dendrograms for hierarchical groupings (HCA) of the bioactive molecules in the different parts of the studied fruits.

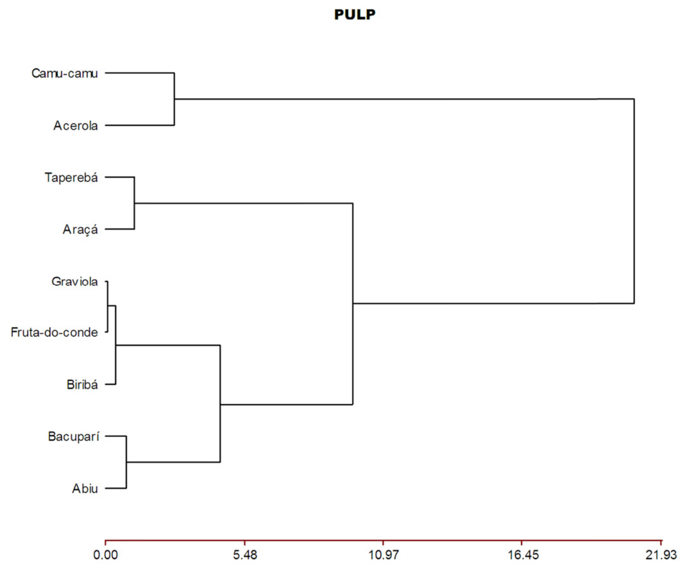

Figure 4. Dendrogram by HCA, Euclidean distance and incremental connection technique for the bioactive molecules in the fruits pulps studied

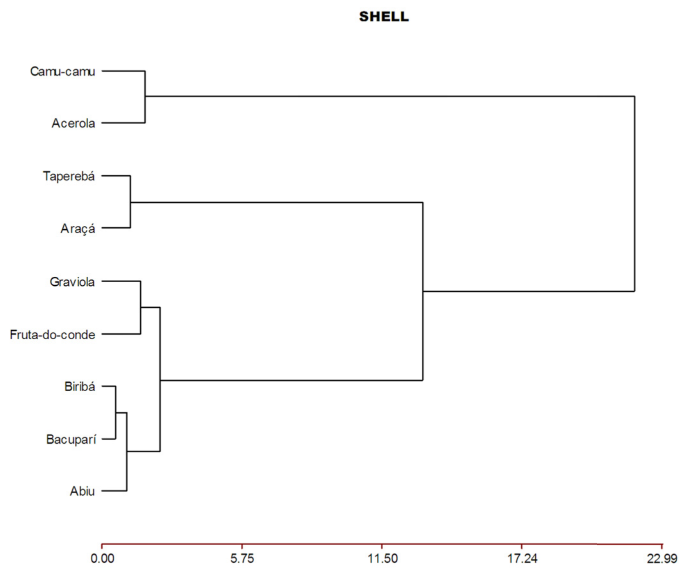

Figure 5. Dendrogram by HCA, Euclidean distance and incremental connection technique for the bioactive molecules in the fruits shell studied

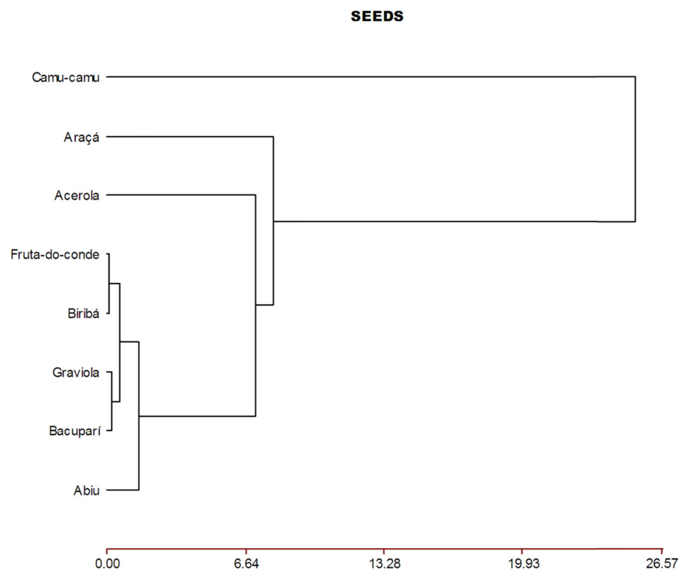

Figure 6. Dendrogram by HCA, Euclidean distance and incremental connection technique for the bioactive molecules in the fruits seeds studied

4. Discussion

4.1 Determination of Bioactive Molecules in Amazonian Fruits

In Table 2, the results of vitamin C, carotenoids and sugars are presented in the different fruits studied. The composition of vitamin C, it is the *camu-camu* pulp that presents the highest concentration of all the pulps studied, with a value close to that determined by Justi et al. (2000) who obtained an ascorbic acid concentration of 1410.0 mg 100 g^{-1}. The next pulp that presents a high value of vitamin C is acerola with a concentration of 1104.67 mg 100 g^{-1}, whose value is within the limits established by Nunes et al. (2002) and Santos et al. (2002). Franco (1999) classifies the concentration of ascorbic acid according to different levels: high sources for those fruits in which the ascorbic acid is in concentrations between 100-300 mg 100 g^{-1}, medium sources for concentrations of 25-50 mg 100 g^{-1} and finally very low sources for those fruits whose concentrations are less than 25 mg 100 g^{-1} in pulps. In this classification, the *camu-camu* and the *acerola* are above the classification of Franco (1999), the araçá is in high concentration. On the other hand, the *abiu*, *bacuparí*, *fruta-do-conde* and *graviola* in low concentrations and finally, the *biribá* in very low concentrations according to that classification. Another fruit with a high concentration of vitamin C among those studied is the araçá pulp whose concentration was 117.14 mg 100 g^{-1}, being within the values determined by Sánchez et al. (2017) where the concentration of ascorbic acid for the pulp of this fruit varies between 103.6-141.8 mg 100 g^{-1}. The *taperebá*, presents low values of vitamin C, nevertheless these values are lower to those found by Botánico (2016) who finds concentrations of ascorbic acid in the *taperebá* pulp of 31 mg 100 g^{-1}.

The next group of bioactive substances studied in the pulps were the total carotenoids (Table 2) whose values vary in a wide range, with the lowest values for the *abiu* and *taperebá* pulp. The *abiu* had a value of total carotenoids in the pulp extremely low, 0.018 mg 100 g^{-1}, value close to that found by Virgolin et al. (2017) that obtained a total carotenoid value of 25.55 µg 100 g^{-1} for the *abiu* pulp and the highest values found again for the *camu-camu* and *acerola* pulp. Neves et al. (2015) studied the total carotenoids in Amazonian fruits, including *camu-camu*, where they determined concentrations of 0.6 mg 100 g^{-1} for the pulp. Rufino et al. (2010) determined carotenoid concentrations of 0.4 mg 100 g^{-1} for the *camu-camu* pulp, this value being below the concentrations determined in this work. The value of carotenoids for the acerola obtained is close to the value determined by Aquino et al. (2011) whose carotenoid concentration was 0.35 mg 100 g^{-1}. *Tapereba* pulp the carotenoid concentration is also relatively low, values close to those found by Mattietto et al. (2010) who obtain values of 0.028 mg 100 g^{-1}. For the *araçá* pulp, the concentration of carotenoids is 0.11 mg 100 g^{-1}, close to the value determined by Sanches et al. (2017) that obtains 0.129 mg 100 g^{-1} of carotenoids in the *araçá* pulp.

Finally, the total sugars vary from 4.5 g 100 g^{-1} for acerola to 16.31 mg 100 g^{-1} for the *fruta-do-conde.* For the *abiu* pulp, the value of total sugars determined in this work is close to that determined by Virgolin et al. (2017) with a value of 14.70 mg 100 g^{-1}. Another of the fruits studied by these authors is *araçá*, whose total sugar value is 1.18 mg 100 g^{-1}, slightly lower than the value found in this study. *Taperebá* pulp, the concentration of total sugars is low compared to other fruits, but with values close to those determined by Mattietto et al. (2010), who found sugar concentrations of 4.54 g and 100 g^{-1}.

In Table 3, the results of the concentrations of the bioactive molecules for the shells of the fruits studied are presented. In comparison, the values of vitamin C between the pulp and the shell of the fruits, it is found that these are superior to those of the pulps, being generally a discarded part of the fruit. For the shell, the lowest vitamin C values were found in the *taperebá* shell with only 34.17 mg 100 g^{-1} and the highest values again for the shell of *acerola* and *camu-camu*. Correa et al. (2011), study the pulp and shell of *camu-camu* in different stages of maturity, where they also determine concentrations of vitamin C in the shell above the pulp, concentrating vitamin C in the shell as it matures. The fruit, being the determined values of vitamin C of 2792.82-2496.23 mg 100 g^{-1} of *camu-camu* shell, these values being within those found in this work. Carotenoids already have higher concentrations than pulp, with the lowest value for *taperebá* shell 0.041 mg 100 g^{-1} and the highest values for *camu-camu* shell 0.67 mg 100 g^{-1} and *acerola* 0.47 mg 100 g^{-1}. The concentration of these compounds is greater in the shell of fruits since these compounds have as a mission to protect plant cells from oxidation and free radicals, in addition to promoting the formation of antibodies that act specifically against substances or elements strangers that can affect the organism (Palencia, 2010).

The concentration of sugars in the shell of the different fruits is lower than that found in the pulps, with the lowest concentrations in the *araçá* shell with 1.07 g 100 g^{-1} and 10.37 g 100 g^{-1} the highest concentration, for the shell of the *abiu*. The sugars together with the acidity influence the sensory quality of the fruit, being found in ripe fruits, simple sugars such as sucrose, glucose and fructose acting as primary source of energy (Miller et al., 1986).

In Table 4, the results for the seeds are presented, where the concentration of vitamin C in the seeds of the fruits studied was not detected in the *taperebá* seed and in others the values were extremely low as in the case of the *biribá* with 7.13 mg 100 g^{-1} and the *graviola* with 7.84 mg 100 g^{-1} being again, the highest values of vitamin C for the *camu-camu* and *acerola* seeds. The vitamin C content in the *camu-camu* seed was studied by Neves et al. (2015), in a flour obtained with the shell residue together with the seed where the concentration of ascorbic acid was 9004 mg 100 g $^{-1}$, values higher than those of the husk and isolated pulp, as it happens in this work, where the concentration is higher than for the other parts studied. The content of vitamin C decreases in fruits as they mature as well as with storage, since the acid ascorbic acid oxidase (ascorbinase) acts directly or by the action of oxidizing enzymes such as peroxidase (Poliniati, 2010). For *acerola* seeds, the value determined in this work is close to that determined by Aguiar et al. (2010), which obtain a concentration value of ascorbic acid of 66 mg 100 g^{-1}.

The concentration of carotenoids found in the seeds of the fruits studied, these are found in low concentrations compared to other parts of the fruit studied, with the lowest values for the seed of the *Abiu* with 0.012 mg 100 g^{-1} and the highest value for the seeds of *biribá* and *camu-camu* with 0.094 mg 100 g^{-1}. Given their characteristic of being soluble in vegetable oils, they give pigmentation to the different vegetable oils concentrated mainly in the seeds. The main carotenes found in vegetable oils are β-carotene, α-carotene and phytoene (Ferrari, 2001). According to Basu et al. (2001), carotenoids play an important role in the cellular protection against lipid peroxidation, preventing degenerative diseases such as cancer, heart disease or reduction in the creation of cataracts and strengthening of the immune system.

Finally, the concentration of total sugars in the seeds varies between 7.15 g 100 g^{-1} for the *Araçá* seed, 18.25 g 100 g^{-1} for the *camu-camu* seed. These fruit seeds are richer in reducing sugars than in non-reducing sugars (Table 4). Within these reducing sugars are glucose, fructose, maltose and aldose that can be reduced in the presence of transition elements such as copper or iron (Demiate et al., 2002).

4.2 Analysis of Main Components (PCA) in Different Parts of the Fruits

In the blipot (Figure 1), the results of the principal component analysis (PCA) for the concentration of the bioactive molecules in the different pulps studied are presented, explaining 90.1% of the original variability of the data retained in these components.

The arrangement of the sequence in Figure 1, shows that the systems can be grouped into two sets, the first major component (CP1), contributed with 61.9% of the total variance explained, however most of the variables that were strongly affected contributed positively to CP1 carotenoids and vitamin C, and inverse with reducing and non-reducing sugars. These results indicate that CP1 allowed to distinguish the fruits that are associated with the pulp of camu-camu and acerola which are strongly associated. The second main component (CP2) explained 26.2% of the total data, appearing in the values of reducing and non-reducing sugars. The analysis of this component also showed that this attribute projects negatively on vitamin C and carotenoids. *graviola*, *fruta-do-conde*, *biribá*, *abiu* and *bacupari* pulps were associated.

In the blipot (Figure 2), the results of the analysis of the main components (PCA) for the bioactive molecules of the shell of the fruits studied are explained, explaining the 95.6% of the original variability of the data retained in these components.

The arrangement of the sequence in Figure 2 shows that the systems can be grouped into two sets, the first major component (CP1), contributed 65.4% of the total variance explained, however most of the variables that were strongly affected contributed positively to CP1 the vitamin C and carotenoids and inverse with the reducing and non-reducing sugars as happens with the pulps studied. These results indicate that CP1 allowed distinguishing that *camu-camu* and *acerola* are strongly associated. The second main component (CP2) explained 30.2% of the total data, appearing in this case the reducing and non-reducing sugars. The analysis of this component also showed that this attribute projects negatively on vitamin C and carotenoids, and the bioactive molecules in the barks of *biribá*, *fruta-do-conde*, *graviola*, *abiu* and *bacuparí* showed to be associated.

In the blipot (Figure 3), the results of the main component analyzes (PCA) for the bioactive molecules of the seeds of the fruits studied are represented, accounting for 88.5% of the original variability of the data retained in these components. The arrangement of the sequence in Figure 3 shows that the systems can be grouped into two sets, the first major component (CP1), contributed with 73.2% of the total variance explained, however most of the variables that were strongly affected contributed positively to CP1 vitamin C and sugars and to a lesser extent carotenoids. These results indicate that CP1 allowed distinguishing that *araçá* and *camu-camu* and *acerola* are strongly associated. The second main component (CP2) explained 15.3% of the total data, appearing in this case associated with the remaining fruit seeds.

4.3 Hierarchical Analysis of Components (HCA) in Diferent Parts of the Fruits

In Figure 4, the hierarchical component analysis (PCA) for fruit pulps is presented. The bioactive molecules in the pulps of the fruits studied, the trends observed through the analysis of PCA main components, were observed through the HCA, mainly observing four large groupings: one of them formed by the association of *graviola* with the *fruta-do-conde* and *biribá* with smaller Euclidean distance, belonging them the same family. Another strong association is the *bacuparí* pulp with *abiu*. *Taperebá* with *araçá* and *acerola* with *camu-camu*. All fruit pulps not counting the *abiu* and *acerola* are associated with the euclidean distance of 10.97, grouping with the other two fruit pulps with euclidean distance of 21.93

In Figure 5 the HCA analysis for the skin of the different fruits is shell. As it ocorre in the pulp of the fruits studied, in the shell there are four groups. On the one hand, the *camu-camu* with the *acerola* that are strongly associated and only joins with the rest of fruits at an elevated Euclidean distance of 22.99. On the other hand, we have an association between the shell of the *biribá* with the *bacuparí* that are associated in turn to a Euclidean distance with the *abiu*, *graviola* with the *fruta-do-conde* are associated and the other grouping is between the *taperebá* and *araçá*.

The dendrogram presented for the seeds (Figure 6) presents atypical behavior if we compare it with the other parts of the fruit. Fruits that appear strongly associated (less Euclidean distance) are the *graviola* with *bacuparí* and practically at the same distance the *fruta-do-conde* with the *biribá* that in turn the bioactive molecules in this group of fruits are going to be associated *abiu* at a slightly higher Euclidean distance.

5. Conclusions

The results obtained show that the fruits studied have a good source of bioactive compounds, especially *acerola* and *camu-camu*, where the concentration of ascorbic acid is especially high in the pulp and in the shell. These fruits are at the same time the source of carotenoids and sugars, with the highest concentrations for *abiu*, *fruta-do-conde* and *graviola*. These fruits, due to the concentrations of these compounds, present socioeconomic potential for the region where they are found, and can be consumed *in natura* or industrialized in the form of foods with high functional potential.

References

Aquino, A. C. M. S., Móes, R. S., & Castro, A. A. (2011). Stability of ascorbic acid, carotenoids and anthocyanins in acerola fruits frozen by cryogenic methods. *Brazilian Journal of Food and Technology, 14*, 154-163.

Badolato, M. I. C. B., Sabino, M., Lamardo, L. C. A., & Antunes, J. L. F. (1996). Comparative study of analytical methods for the determination of an ascorbic acid in the success of natural and industrialized fruits. *Ciênc. Tecnol. Aliment., 16*, 206-210.

Barreiros, R. C., Bossolan, G., & Trindade, C. E. P. (2005). Fructose in humans: Metabolic effects, clinical utilization and associated inherent erros. *Rev. Nutr., 18*, 377-389. https://doi.org/10.1590/S1415-52732005000300010

Basu, H. N., del Vecchio, A. J., Flider, F., & Orthoeter, F. T. (2001). Nutritional and potential disease prevention properties of carotenoids. *Journal of the American Oil Chemists' Society, 78*, 665-675. https://doi.org/10.1007/s11746-001-0324-x

Botánico, J. (2016). *Jobo (ciruelo Amarillo, k'an-abal, zabac-abal, k'ank'an-abal, xkinin-hobo)*. Jardín Botánico.

Cantillano, R., Ávila, J., Peralba, M., Pizzolato, T., & Toralles, R. (2012). Antioxidant activity, phenolic compound and ascorbic acids content in strawberries from two crop production systems. *Horticularia Brasileira, 30*, 620-626. https://doi.org/10.1590/S0102-05362012000400010

Contreras-Gúzmán, E., Strong, I. F. C., & Guernelli, O. (1984). Determination of ascorbic acid (vitamin C), by reduction of copper ions. *Química Nova, 7*, 60-64.

Correa, S. I., Zamudio, L. B., Solís, V. S., & Cruz, C. O. (2011). Vitamin C contente in fruits of camu camu *Myrciaria dubia* (H.B.K.) Mc Vaugh in four states of maturation coming from the collection of germoplasma of the INIA Loreto, Perú. *Scientia Agropecuaria, 2*, 123-130. https://doi.org/10.17268/sci.agropecu.2011.03.01

Davey, M. W., Montagu, M. V., Sanmartin, D. I. M., Kanellis, A., Smirnoff, N., & Benzie, I. J. J. (2000). Plant L-ascorbic acid: Chemistry, function, metabolism, bioavailability and effects of processing. *Journal of the Science of Food Agriculture, 80*, 825-860. https://doi.org/10.1002/(SICI)1097-0010(20000515)80:7%3C825::AID-JSFA598%3E3.0.CO;2-6

De Aguiar, T. M., Rodrigues, F. S., dos Santos, E. R., & Sabaa-Srur, A. U. O. (2010). Chemical characterization and evaluation of the nutritional value of *Malpighia punicifolia* seeds. *J. Brazilian Soc. Nutr, 35*, 91-102.

Demiate, I. M., Wosiacki, G., Czelusniak, C., & Nogueira, A. (2002). Analysis of total and reducing sugar in foods. A comparative study between colorimetric and tritation techniques. *Agrarian Sciences and Engineering, 8*, 65-78.

Ferrari, R. A. (2001). Mineral components of vegetable oils. *Óleos & Grãos, 9*, 20-28.

Franco, G. (1999). *Table of the chemical composition of foods* (9th ed.). São Paulo: Atheneu.

IAL (Instituto Adolfo Lutz). (2008). *Physicochemical methods for food analysis* (4th ed.). São Paulo.

Jimenez-Colmenero, F. (2013). Emulsiones multiples: Compuestos bioactivos y alimentos funcionales. *Nutrición Hospitalaria, 28*, 1413-1421.

Justi, K., Visentainer, L., de Souza, N., & Matsushita, M. (2000). Laboratory methods of physical-chemical and microbiological analysis. *Archivos Latinoamericanos de Nutrición, 50*, 405-408.

Lichtenthaler, H. K., & Buschmann, C. (2001). Chloriphylls and carotenoids: Measurement and characterization by UV-VIS Spectroscopy. *Current protocols in Food Analytical Chemistry, 4*, 3-4.8. https://doi.org/10.1002/0471142913.faf0403s01

Macedo, J. A. B. (2005). *Métodos laboratoriais de análise físico-quimicas e microbiológicas*. Consejo Regional de Química. Minas Gerais.

Mattietto, R. A., Lopes, A. S., & Menezes, H. C. (2010). Physical and physicochemical characterization of caja fruit (*Spondias mombim* L.) and its pulp, obtanided using two types of extractor. *Brasilian Journal of Food Technology, 13*, 156-164.

Miller, J. J., Colagiuri, S., & Brand, J. C. (1986). The diabetic diet: Information and implications for the food industry. *Food Technology Australia, 38*, 155-160.

Neves, L., Xavier, V., Alves, J., Flach, A., & Ruffo, S. (2015). Bioactive compounds and antioxidant activity in pre-harvest camu-camu [*Myrciaria dubia* (H.B.K.) Mc Vaugh] fruits. *Scientia Horticulturae, 186*, 223-229. https://doi.org/10.1016/j.scienta.2015.02.031

Nunes, E. S., D'Araújo, C. F. A., & Braz, V. B. (2002). *Selection of woody genotypes (Malpighia spp.)*. Congresso Brasileiro de Fruticultura, 17.

Palencia, Y. (2010). *Sustancias bioactivas en los alimentos*. Zaragoza: UNIZAR.

Poliniati, M. R., Faller, A. L. K., & Fialho, E. (2010). The effect of freezing at -18 ºC and -70 ºC with and without ascorbic acid on the stability of antioxidant in extracts on apple and orange fruits. *International Journal of food Science and Technology, 45*, 1814-1820. https://doi.org/10.1111/j.1365-2621.2010.02333.x

Rienzo, J. A. D., Casanoves F., Balzarini, M. G., Gonzales, L., Tablada, M., & Robledo, C. W. (2016). *InfoStat Release 2016*. InfoStat Group FCA, Universidad Nacional de Córdoba, Argentina.

Rodrigues-Amaya, D. B. (1999). *A guide to carotenoids analyses in foods*. Washington: ILSI PRESS.

Rufino, M. S. M., Alves, R. E., Brito, E. S., Pérez-Jiménez, J., Saura-Calixto, F., & Mancini-Filho, J. (2010). Bioactive compounds and antioxidante capacities of 18 non-traditional fruits from Brasil. *Food Chemistry, 121*, 996-1002. https://doi.org/10.1016/j.foodchem.2010.01.037

Sahota, A. (2015). The global market for organic food and drink. In H. Willer, & J. Lernoud (Eds.), *The World of Organic Agriculture: Statisticsand Emerging Trends 2015* (p. 300). Research Institute of Organic Agriculture (FIBL), Frick Switzerland and International Federation of Organic Agriculture Movement.

Sanches, A. G., Costa, J. M., Silva, M. B., Moreira, E. G. S., Santana, P. J. A., & Cordeiro, C. A. M. (2017). Qualitative aspects of yellow araca treated with UV-C radiation. *Nativa Sinop, 5*, 303-310. https://doi.org/10.5935/2318-7670.v05n05a01

Santos, P. M., Ramos, J. V., & Leite, J. B. V. (2002). *Evaluation of maize (Malpighia glabra L.) genotypes in the Southeast region of Bahia*. Congresso Brasileiro de Fruticultura, 17.

Saura-Calixto, F., & Goñi, I. (2006). Antioxidant capacity of the Spanish Mediterranean diet. *Food Chemistry, 94*, 442-447. https://doi.org/10.1016/j.foodchem.2004.11.033

Scherer, R., Rybka, A. C. P., Ballus, C. A., Meinhart, A. D., Filho, J. T., & Godoy, H. T. (2012). Validation of a HPLC method for simultaneous determination of main organic acids in fruits and juices. *Food Chemistry, 135*, 150-154. https://doi.org/10.1016/j.foodchem.2012.03.111

Virgolin, L. B., Sixas, F. R. F., & Janzantti, N. S. (2017). Composition, content of bioactive compounds and antioxidante activity of fruit pulps from the Brazilian Amazon biome. *Pesq. Agropec. Bras, 52*, 933-941. https://doi.org/10.1590/s0100-204x2017001000013

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