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Research article

Determination of water-soluble vitamins and carotenoids in Brazilian tropical fruits by High Performance Liquid Chromatography

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ABSTRACT

Vitamins are organic compounds essential for normal physiological functioning and they need to be provided in adequate amounts by the diet. They are nutrients mainly associated to fruit consumption, playing an important role in the cellular function, growth and development of individuals. The present study aimed to analyze levels of vitamins B, C and carotenoids of fruits from the agrobiodiversity of Northeastern Brazil, among them cajuí (*Anacardium spp*), murici (*Byrsonima crassifolia* (L.) Kunth), pequi (*Caryocar coriaceum* Wittm.), jenipapo (*Genipa americana* L.), mangaba (*Hancornia speciosa* Gomes), bacuri (*Platonia insignis* Mart.), cajá (*Spondias mombin* L.), umbu-cajá (*Spondias bahiensis* P. Carvalho, Van den Berg & M. Machado), umbu (*Spondias tuberosa* Arruda), pitanga (*Eugenia uniflora* L.), araçá (*Psidium sobralianum* Landrum & Proença). The vitamins were quantified using the analytical method High Performance Liquid Chromatography (HPLC). Vitamin B complex levels varied from 0.003 ± 0.01 mg/100 g to 6.107 ± 0.06 mg/100 g. Vitamin C ranged from 0.36 ± 0.06 mg/100 g to 253.92 ± 9.02 mg/100 g. Carotenoid values ranged from 0.12 ± 0.02 μg/100 g to 395.63 ± 113.69 μg/100 g. Thus, the profile of water-soluble vitamins and carotenoids of the fruits analyzed was quantified. Therefore, these fruits can provide varied amounts of vitamins important to human health. However, it is interesting for the individual to consume fruits in a diversified manner, avoiding monotony and thus guaranteeing the daily intake of more nutrients.

1. Introduction

Vitamins are organic compounds essential for normal physiological functioning, and as most are not synthesized endogenously by the body, they need to be provided in adequate amounts by the diet (Kennedy, 2016). They are nutrients contained mainly in fruits, playing an important role in the cellular function, growth and development of individuals (Nakos et al., 2017).

The inadequate concentration of vitamins in the diet can cause physiological problems such as interruption on the DNA and histone methylation-demethylation dynamics, generating phenotypic changes (Camarena and Wang, 2016), deregulation of the secretion of adipokines to maintain homeostasis and leptin for appetite control, in addition to elevation of ROSs (Reactive Oxygen Species) and reduction of ATP formation, impacting Ca^{2+} homeostasis (Berridge, 2017). In case of severe deficiencies, it can cause corneal blindness and opacity (Faustino et al., 2016), cognitive dysfunction, dementia (Kennedy, 2016), scurvy (Camarena and Wang, 2016) and rickets (Creo et al., 2016).

The place of cultivation and the season of the year interfere with the nutrients composition, such as zeaxanthin, provitamin A and vitamin C (Costa et al., 2017). And the vitamin content in the fruits is influenced by the harvest treatment, transport and storage (Pertuzatti et al., 2015). This change in the content of vitamins interferes with the overall quality of the food, thus changing its nutritional value (Bernás and Jaworska, 2016).

In general, the group of fruits and vegetables contains vitamins C, E and carotenoids, providing a natural source of antioxidants (Pertuzatti et al., 2015). Yellow and orange fruits are rich sources of carotenoids provitamin A (Ekesa et al., 2015). Thiamine, folic acid, nicotinic acid, pantothenic acid, riboflavin, cyanocobalamin, pyridoxine and biotin are discreetly present in bananas and citrus fruits (Kennedy, 2016).

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However, the daily consumption of these fruits often does not meet the needs of the population.

According to the Family Budget Survey (POF/2008–2009), the average dietary intake of fruits and vegetables is deficient in Brazil, not meeting the recommendations of FAO/WHO. However, as only fruit presented in databases of validated food composition tables were computed in POF, the consumption of fruits and vegetables from native biodiversity may have been underestimated due to the lack of data on nutritional composition (Vargas-Murga et al., 2016).

On the other hand, it is undeniable that the consumption of fruits native to Brazilian biodiversity represents an important source of vitamins and may influence the national political scenario the diversification of the diet and obtaining food (Tutwiler et al., 2017). In addition to bringing benefits regarding the use of small-scale family farming to improve food and nutritional security, it can collaborate with the eradication of global poverty (Graeub et al., 2016). Know the contribution of local fruits to the vitamin recommendation of the Brazilian population, to encourage their consumption and production.

The present study aimed to analyze levels of vitamins B, C and carotenoids from fruits of the sociobiodiversity of Northeastern Brazil, among them cajuí (*Anacardium spp*), murici (*Byrsonima crassifolia* (L.) Kunth), pequi (*Caryocar coriaceum* Wittm.), jenipapo (*Genipa americana* L.), mangaba (*Hancornia speciosa* Gomes), bacuri (*Platonia insignis* Mart.), cajá (*Spondias mombin* L.), umbu-cajá (*Spondias bahiensis* P. Carvalho, Van den Berg & M. Machado), umbu (*Spondias tuberosa* Arruda), pitanga (*Eugenia uniflora* L.), araçá (*Psidium sobralianum* Landrum & Proença). Unpublished data on nutritional composition may be used to encourage fruit consumption and nutrition professionals may have reliable data in food planning calculations for individuals and population groups.

2. Material and methods

2.1. Samples

The fruits were collected in different geographical locations in the Northeast of Brazil. Table 1 shows detailed information on the place (seven Northeast's states) of collection of each species of fruit (11) and their lots (three lots/fruit).

The fruits were processed immediately after acquisition, and the seeds and peels were removed when necessary. The edible part of the fruit was homogenized entirely in an industrial blender and stored in a freezer at -18 °C in 100 g packages, adequately packaged and identified. Subsequently, they were lyophilized macerated in gral and pistil, and vacuum-packed, being stored at room temperature.

2.2. Chemical reagents

The reagents used for water-soluble vitamins analysis were: sodium phosphate monobasic, trichloroacetic acid (TCA), orthophosphoric acid 85%, methanol HPLC, enzyme α-amylase fungus (Diastase from *Aspergillus oryzae*; ≥3500 U/g), thiamine hydrochloride standard (B1), riboflavin standard (B2), nicotinamide-niacinamide standard (B3),

Table 1. Tropical fruits from Brazilian Northeast agrobiodiversity species list.

Scientific name	Common name	Sample name	Fruit collect point	Geographic coordinates	Edible part
Anacardium spp.	Cajuí	CA1	São Luís- Maranhão	Latitude: 2°32′3.27″S Longitude: 44°18′4.61″W	Pulp with peel
		CA2	São Luís-Maranhão	Latitude: 2°32′3.27″S Longitude: 44°18′4.61″W	Pulp with peel
		CA3	Fortaleza- Ceará	Latitude: 3°44′21.54″S Longitude: 38°34′13.91″W	Pulp with peel
Byrsonima crassifolia (L.) Kunth.	Murici	M1	Paraipaba- Ceará	Latitude: 03° 26′ 15.6″ S Longitude: 39° 08′ 43″ W	Pulp with peel
		M2	São Gonçalo do Amarante-Ceará	Latitude: 03° 33′ 09.3″ S Longitude: 38° 53′ 14.4″ W	Pulp with peel
		M3	Fortaleza-Ceará	Latitude: 03° 43′ 49.2″ S Longitude: 38° 32′ 21.8″ W	Pulp with peel
Caryocar coriaceum Wittm.	Pequi	PE1	Parnaíba- Piauí	Latitude: 02° 54′ 04.5″ S Longitude: 41° 46′ 47.8″ W	Pulp
		PE2	Crato- Ceará	Latitude: 07° 13′ 44″ S Longitude: 39° 24′ 28.3″ W	Pulp
		PE3	São Luís-Maranhão	Latitude: 02° 32′ 02.5″ S Longitude: 44° 18′ 03.6″ W	Pulp
Eugenia uniflora L.	Pitanga	PI1	Fortaleza-Ceará	Latitude: 03° 44′ 25.6″ S Longitude: 38° 32′ 01.4″ W	Pulp with peel
		PI2	Ubajara- Ceará	Latitude: 03° 52′ 06.1″ S Longitude: 40° 55′ 26.7″ W	Pulp with peel
		PI3	Aquiraz- Ceará	Latitude: 03° 57′ 44″ S Longitude: 38° 20′ 33.6″ W	Pulp with peel
Genipa americana L.	Jenipapo (unpeeled)	JE1	Caucaia- Ceará	Latitude: 03° 44′ 06″ S Longitude: 38° 39′ 28″ W	Pulp with peel
		JE2	Caucaia-Ceará	Latitude: 03° 41′ 65″ S Longitude: 38° 38′ 43″ W	Pulp with peel
		JE3	Fortaleza-Ceará	Latitude: 03° 43′ 49″ S Longitude: 38° 32′ 20″ W	Pulp with peel
Genipa americana L.	Jenipapo (peeled)	J1	Caucaia- Ceará	Latitude: 03° 44′ 06″ S Longitude: 38° 39′ 28″ W	Pulp
		J2	Caucaia-Ceará	Latitude: 03° 41′ 65″ S Longitude: 38° 38′ 43″ W	Pulp
		J3	Fortaleza-Ceará	Latitude: 03° 43′ 49″ S Longitude: 38° 32′ 20″ W	Pulp

(*continued on next page*)

Table 1 (*continued*)

Scientific name	Common name	Sample name	Fruit collect point	Geographic coordinates	Edible part
Hancornia speciosa Gomes	Mangaba	MA1	Barra Dos Coqueiros- Sergipe	Latitude: 10°54′26.96″S Longitude:37° 1′49.54″W	Pulp with peel
		MA2	Barra Dos Coqueiros-Sergipe	Latitude: 10°54′26.96″S Longitude:37° 1′49.54″W	Pulp with peel
		MA3	Cascavel- Ceará	Latitude: 4° 7′58.22″S Longitude: 38°14′15.03″W	Pulp with peel
Platonia insignis Mart.	Bacuri	B1	Alcântara-Maranhão	Latitude: 2°24′13.62″S Longitude: 44°24′49.83″W	Pulp
		B2	Rosário- Maranhão	Latitude: 2°56′27.86″S Longitude: 44°14′48.33″W	Pulp
		B3	Teresina- Piauí	Latitude: 5° 7′59.17″S Longitude: 42°47′47.04″W	Pulp
Psidium sobralianum Landrum & Proença	Araçá	A1	Petrolina- Pernambuco	Latitude: 09° 04′ 16″ S Longitude: 40° 18′ 49″ W	Pulp with peel
		A2	Petrolina-Pernambuco	Latitude: 09° 04′ 16″ S Longitude: 40° 18′ 49″W	Pulp with peel
		A3	Petrolina-Pernambuco	Latitude: 09° 04′ 16″ S Longitude: 40° 18′ 49″ W	Pulp with peel
Spondias mombin L.	Cajá	C1	Maranguape-Ceará	Latitude: 03° 52′ 15″ S Longitude: 38° 40′ 08″ W	Pulp with peel
		C2	Forquilha- Ceará	Latitude: 03° 47′ 51″ S Longitude: 40° 15′ 34″ W	Pulp with peel
		C3	Açu-Rio Grande do Norte	Latitude: 05° 34′ 23″ S Longitude: 36° 54′ 21″W	Pulp with peel
Spondias tuberosa Arruda	Umbu	U1	Brumado- Bahia	Latitude: 14°12′43.85″S Longitude: 41°40′17.99″W	Pulp with peel
		U2	Irecê-Bahia	Latitude: 11°18′13.99″S Longitude: 41°51′30.20″W	Pulp with peel
		U3	Teresina- Piauí	Latitude: 5° 7′59.17″S Longitude: 42°47′47.04″W	Pulp with peel
Spondias bahienis P. Carvalho, Van den M. Machado	Umbu-Cajá	UC1	Altos dos Rodrigues- Rio Grande do Norte	Latitude: 5°17′20.49″S Longitude: 36°45′38.48″W	Pulp with peel
		UC2	Açu- Rio Grande do Norte	Latitude: 05° 34′ 23″ S Longitude:36° 54′ 21″W	Pulp with peel
		UC3	Fortaleza-Ceará	Latitude: 03° 43′ 49″ S Longitude: 38° 32′ 20″ W	Pulp with peel

pyridoxine hydrochloride standard (B6), D-pantothenic acid hemi-calcium salt standard (B5) and d-biotin standard, all from Sigma-Aldrich, which were stored as recommended by the manufacturer.

Also, for the analysis of water-soluble vitamins, the following solutions were used: 0.1 M chlorhydric acid 0.1 M, 5 M sodium acetate, 50% trichloroacetic acid and 0.05 M sodium phosphate buffer solution for the mobile phase watery.

The reagents and solutions used for the analysis of carotenoids were acetone P.A., petroleum ether/ethyl ether mixture (2:1), 10% (v/v) potassium hydroxide solution in methanol and methyl tert-butyl ether.

2.3. Determination of vitamins by HPLC (High Performance Liquid Chromatography)

2.3.1. Analysis of water-soluble vitamins (vitamins B and C)

The extraction method was carried out by weighing 1 g of the lyophilized sample, being then transferred to the Duran flask and 10 mL of the 0.1 chlorhydric acid added and placed in the water bath at 100 °C for 30 min. After cooling, pH was adjusted to 4.0–4.5 with a 5 M sodium acetate solution. It was added 500 mg of diastase enzyme that was left in a water bath at 47 °C for 4 h. After cooling, it was added 200 μL of 50% trichloroacetic acid solution. The water bath was kept at 100 °C for 5 min again. After cooling it down, the pH was adjusted back to 3.0 with a 5 M sodium acetate solution, having the solution filtered and then transferring it to a 25 mL volumetric flask completing with a test solution (Abe-Matsumoto et al. 2016).

The analysis was carried out according to with an HPLC-Diode Array Detector (DAD). The chromatographic conditions for the quantification of water-soluble vitamins were: C_{18} column, 4 μm, 250 × 4.6 mm (Atlantis). 20 μL were injected without extraction in the HPLC system. The mobile phase consisted of two phases, A: 0.05 M sodium buffer solution pH 3.0; B: HPLC grade methanol. With running gradient: time 0 - mobile phase A: mobile phase B (98:2); time 9 min - mobile phase A: mobile phase B (40:60); time 15 min - mobile phase A: mobile phase B (98:2); time of 15 min until the end of the race - mobile phase A: mobile phase B (98:2) in 25 min. With a flow rate of 0.6 mL/min. The chromatograms were processed in maxim wavelenght: λ 209 nm for D-pantothenic acid (B5 vitamin) and biotin, λ 254 nm for thiamine (B1 vitamin) and for nicotinamide-niacinamide (B3 vitamin), λ 268 nm for riboflavin (B2 vitamin), λ 283 nm for pyridoxin (B6).

Vitamins were quantified by HPLC-DAD using five-point analytical curves. The limit of detection (LOD) was calculated using the parameters of each standard curve: LOD = 3.3 × SD/S, where SD is the standard deviation of the response and S is the slope of the curve. For all analytical curves of vitamins, $r^2 = 0.99$, the limit of detection was 0.1 mg/mL and the limit of quantification was 0.5 mg/mL. The carotenoid concentration was expressed in mg/100 g edible fraction.

2.3.2. Determination of carotenoids

The carotenoids were exhaustively extracted from 5 to 10 g of the lyophilized samples with acetone. Then they were transferred to a mixture of petroleum ether/ethyl ether (2:1) and subjected to saponification with a 10% potassium hydroxide solution in methanol for 12 h at room temperature and in the dark. The extracts were then washed with water until the alkali was removed and concentrated in a rotary evaporator until they were dry ($T < 38$ °C) (De Rosso and Mercadante, 2007a; b).

The dry extract was redissolved in methanol/methyl *tert*-butyl ether (1:1; v:v) for injection into the equipment. The carotenoids were separated using an HPLC-PDA, using a C30 column (YMC, 3 μm, 250 × 4.6 mm) and as mobile phase, it was used a linear gradient of methanol and methyl *tert*-butyl ether from 95:5 to 70:30 in 30 min and to 50:50 in 20 min, fixed flow rate of 0.9 mL/min. The spectra were acquired between 250 and 600 nm and the chromatograms processed at 450 nm (De Rosso and Mercadante, 2007a; b).

The identification of carotenoids was based on the reverse phase elution order (C_{30}), comparison of the maximum absorption wavelength (λmax), fine spectrum structure (%III/II) intensity of the *cis* peak with data from the literature (Britton et al., 2004) and co-chromatography with patterns.

Carotenoids were individually quantified by HPLC-DAD using five-point analytical curves of all-*trans*-lutein (1.0–50.0 μg/mL), all-*trans*-β-cryptoxanthin (1.0–60 μg/mL), all-*trans*-β-carotene (1.0–50 μg/mL), and all-*trans*-lycopene (1.0–50 μg/mL). The limit of detection (LOD) was calculated using the parameters of each standard curve: $LOD = 3.3 \times SD/S$, where SD is the standard deviation of the response and S is the slope of the curve. For all analytical curves of carotenoids, $r^2 = 0.99$, the limit of detection was 0.1 μg/mL and the limit of quantification was 0.5 μg/mL. The carotenoid concentration was expressed in μg/100 g edible fraction.

2.3.3. Determination of provitamin A

Provitamin A was calculated according to the conversion factor (IOM, 2001), in which 12 μg of β-carotene, 24 μg of α-carotene and 24 μg of β-cryptoxanthin stands for 1 RAE (retinol activity equivalent).

2.4. Statistical analysis

Data of all variables of the fruit lots were subjected to analysis of variance (ANOVA) using the Statistical software & data analysis add-on for Excel program (XLSTAT 2020, version 1.0). The significance levels of the differences between means of each lot were determined using the t-test of Tukey ($p < 0.05$). The correlations between all parameters studied were determined by Principal Component Analysis (PCA) using the same software. A matrix of 22 × 36 (22 variables & 36 samples) was used in PCA.

3. Results and discussion

3.1. Water-soluble vitamins

Table 2 shows the content of the water-soluble vitamins Thiamine (B1), Riboflavin (B2), Nicotinamide (B3), Pantothenic acid (B5), Pyridoxine (B6), Biotin (B7) and Ascorbic Acid (C) of the analyzed fruits. These vitamins were found in most fruits in varying amounts. Figure 1 shows the chromatograms obtained for the B complex vitamin standards and Figure 2 shows of the fruits chromatograms.

The B complex vitamins comprise eight water-soluble components that affect various metabolic pathways in the body performing functions in cell synthesis and repair, chemical methylation, lipid regulation, insulin sensitivity, energy production, free radical management, and inflammatory processes, including pain regulation (Jaffe, 2013).

Vitamin B3 was the most present in all fruits, except araçá. Concentrations varied from 0.081-0.130 mg/100 g in mangaba to 0.482–3.119 mg/100 g in jenipapo pulp. These values are similar to those presented in the Table of Food Composition, containing about 95 species of fruits consumed in Brazilian territory, where minimum levels of 1.03 mg/100 g stand out in the edible part of papaya (*Carica papaya* L.) and maximum levels of 4.34 mg/100 g of cupuaçú (*Theobroma grandiflorum* (Willd. ex Sprengel) Schumann) (TACO, 2011).

Due to the presence of small amounts of vitamins B1 and B2, it was not possible to quantify these compounds in all samples. B1 being found only in cajuí (0.007–0.018 mg/100 g) and in jenipapo pulp (0.260–0.706 mg/100 g) and B2 being detected in mangaba fruits (2.290–2.471 mg/100 g), umbu (1.255–6.107 mg/100 g) and umbu-cajá (0.099–0.455 mg/100 g). Popular exotic tropical fruits such as orange (*Citrus sinensis*) and banana (*Musa* spp.) have similar levels of B1, B2 and B3, although they are in different families from those studied (USDA, 2013).

Regarding to vitamin B5, the values ranged from 0.035-0.136 mg/100 g (cajá) to 1.317–1.615 mg/100 g (umbu-cajá). The fruits cajuí, murici, pequi and jenipapo polpa did not present detectable amounts in any of the investigated lots. As of vitamin B6, the concentrations varied between 0.004 and 0.005 mg/100 g (pitanga and jenipapo with peel) to 0.090–0.108 mg/100 g (bacuri), with undetectable amounts in murici, mangaba, umbu and umbu-cajá.

Vitamin B7 values ranged from 0.018-0.330 mg/100 g (umbu-cajá) to 1.485–3.234 mg/100 g (murici), and jenipapo, mangaba, araçá and cajá did not show detectable quantities in any of the lots under study. In an extensive nutritional analysis of noni (*Morinda citrifolia* L.), fruit of the same family as jenipapo, was detected levels <0.0018 mg/g of B1, B2, B5 and B6, contents of 0.02 μg/g of B7 and <0.0012 μg/g of B12 (West et al., 2011). Thus, reinforcing the similarities of different species in the same family.

Caju had higher levels of vitamin C (5.55–36.86 mg/100 g) compared to other fruits (Table 2). This vitamin is important in several vital processes, such as wound healing, reduced susceptibility to infection, prevention of mucosal hemorrhage, iron absorption, in addition to having an antioxidant role and being used as a natural preservative by the food industry (Cunha-Santos et al., 2019).

The Recommended Dietary Allowance (RDA) advocates consumption of 75 mg of vitamin C/day for women and 90 mg for men (IOM, 2000), thus, the cajuí in 200 g of the edible fraction provides between 14.8 to 98.3% of the recommended amount for women and between 12.34 to 81.92% of the recommended amount for men. As ascorbic acid is found mainly in foods of plant origin such as fruits (Xu et al., 2020), the consumption of cajuí isolated or with other fruits and vegetables, can contribute to the adequate intake of this nutrient.

On average, 200 g of jenipapo provides 0.63 mg of thiamine (B1), the recommendation being 1.1 mg for women and 1.2 mg for men, thus equivalent to 57.27% and 52.5% of daily consumption of this nutrient, respectively. The concentration of riboflavin in the umbu-cajá varied from 1.27 mg/100 g to 6.11 mg/100 g. If the individual consumes 120 g of this fruit (on average 10 units), he will consume a variation from 1.52 mg to 7.33 mg, which extrapolates the recommendation of riboflavin (B2) which is 1.1 mg for women and 1.3 mg for men (IOM, 2000).

A study carried out on seven fruits of the mytarceaes family (araçá, cherry, feijoa, guabiroba, jabuticaba, pitanga and uvaia) in southern Brazil, significantly reinforces the similarities in water-soluble vitamin contents in this food group. Ranging from 0.00001 g/100 g–0.00029 g/100 g of B1, 0.00002 g/100 g–0.00028 g/100 g of B2, 0.00149 g/100 g–0.00921 g/100 g of B5, 0.00092 g/100 g–0.00412 g/100 g of B6, 0.00001 g/100 g–0.00159 g/100 g of B7 and 0.016 g/100 g–3.683 g/100 g of vitamin C. Therefore, it is clear the importance of diversified consumption, in order to maintain the daily intake of the different nutrients that constitute fresh fruits (Schmidt et al., 2019).

3.2. Composition of carotenoids

The chromatographic and UV-vis characteristics of carotenoids from fruits were shown in Table 3 and Figure 3 shows the typical chromatogram of standards and sample. Twelve carotenoids (Table 4) were identified in the fruits studied Carotenoids are a group of fat-soluble pigments and are divided into class carotenes and xanthophylls (Saini et al., 2015). Carotenoids are well known for their importance to human health, playing roles in the prevention of cancer and lifestyle-related

Table 2. Composition of water-soluble vitamins (mg/100g wet sample) of tropical fruits from agrobiodiversity in Northeast Brazil.

Fruits*	LOT	Thiamine B1	Riboflavin B2	Nicotinamine B3	Pyridoxine B6	Pantothenic Acid B5	Biotin B7	Vitamin C
Cajuí	1	0.018 (0.01)^{a}	0.00	0.691 (0.12)^{a}	0.007 (0.01)^{a}	0.00	0.713 (0.46)^{a}	45.66 (3.31)^{c}
Cajuí	2	0.007 (0.01)^{c}	0.00	0.695 (0.52)^{a}	0.006 (0.01)^{a}	0.00	0.300 (0.25)^{b}	98.59 (8.69)^{b}
Cajuí	3	0.011 (0.01)^{b}	0.00	0.321 (0.07)^{b}	0.005 (0.01)^{a}	0.00	0.218 (0.05)^{c}	253.92 (9.02)^{a}
Murici	1	0.00	0.00	0.657 (0.11)^{a}	0.00	0.00	3.234 (1.52)^{a}	14.52 (2.48)^{b}
Murici	2	0.00	0.00	0.319 (0.10)^{c}	0.00	0.00	0.000^{c}	4.13 (0.69)^{c}
Murici	3	0.00	0.00	0.506 (0.19)^{b}	0.00	0.00	1.485 (0.59)^{b}	52.19 (2.56)^{a}
Pequi	1	0.00	0.00	1.635 (0.30)^{a}	0.011 (0.01)^{a}	0.00	0.055 (0.01)^{a}	0.89 (0.27)^{b}
Pequi	2	0.00	0.00	0.759 (0.10)^{b}	0.007 (0.01)^{b}	0.00	0.00	0.54 (0.21)^{b}
Pequi	3	0.00	0.00	1.855 (0.26)^{a}	0.008 (0.01)^{b}	0.00	0.00	4.69 (0.38)^{a}
Pitanga	1	0.00	0.00	0.908 (0.22)^{b}	0.004 (0.01)^{a}	0.080 (0.03)^{a}	0.00	2.52 (0.39)^{b}
Pitanga	2	0.00	0.00	1.023 (0.24)^{a}	0.005 (0.01)^{a}	0.00	0.06 (0.02)^{a}	6.10 (0.36)^{a}
Pitanga	3	0.00	0.00	0.767 (0.31)^{c}	0.005 (0.01)^{a}	0.00	0.00	3.10 (1.62)^{b}
Jenipapo_casca	1	0.00	0.00	0.236 (0.01)^{a}	0.004 (0.01)^{b}	0.00	0.00	2.83 (0.37)^{a}
Jenipapo_casca	2	0.00	0.00	0.136 (0.02)^{c}	0.004 (0.1)^{b}	0.00	0.00	2.13 (0.42)^{a}
Jenipapo_casca	3	0.00	0.00	0.194 (0.02)^{b}	0.005 (001)^{a}	0.995 (0.37)^{a}	0.00	0.36 (0.06)^{b}
Jenipapo_polpa	1	0.706 (0.39)^{a}	0.00	0.482 (0.09)^{c}	0.100 (003)^{a}	0.00	0.00	2.31 (0.45)^{c}
Jenipapo_polpa	2	0.424 (0.13)^{b}	0.00	1.034 (0.30)^{b}	0.006 (001)^{b}	0.00	0.00	4.28 (1.09)^{a}
Jenipapo_polpa	3	0260 (0.08)^{c}	0.00	3.119 (0.81)^{a}	0.010 (001)^{b}	0.00	0.00	3.02 (0.09)^{b}
Mangaba	1	0.00	0.290 (0.07)^{b}	0.081 (0.02)^{b}	0.00	0.254 (0.10)^{b}	0.00	0.62 (0.87)^{b}
Mangaba	2	0.00	0.00	0.000^{c}	0.00	0.169 (0.10)^{c}	0.00	Nd
Mangaba	3	0.00	2.471 (0.38)^{a}	0.130 (0.03)^{a}	0.00	0.468 (0.06)^{a}	0.00	1.32 (0.46)^{a}
Bacuri	1	0.00	0.00	0.257 (0.20)^{a}	0.090 (0.04)^{a}	0.997 (0.17)^{b}	1.645 (0.40)^{a}	7.70 (1.28)^{a}
Bacuri	2	0.00	0.00	0.202 (0.08)^{a}	0.096 (0.01)^{a}	1.562 (0.08)^{a}	1.743 (0.40)^{a}	1.48 (0.08)^{b}
Bacuri	3	0.00	0.00	0.197 (0.08)^{a}	0.108 (0.03)^{a}	1.463 (0.07)^{a}	0.628 (0.21)^{b}	1.08 (0.40)^{b}
Araça	1	0.00	0.00	0.00	0.007 (0.01)^{c}	0.653 (0.20)^{a}	0,00	3.11 (0.75)^{a}
Araça	2	0.00	0.00	0.00	0.022 (0.01)^{a}	0.203 (0.07)^{b}	0.00	2.03 (0.14)^{b}
Araça	3	0.00	0.00	0.00	0.012 (0.01)^{b}	0.630 (0.23)^{a}	0.00	4.13 (1.60)^{a}
Cajá	1	0.00	0.00	0.441 (0.22)^{a}	0.039 (0.02)^{a}	0.136 (0.10)^{a}	0.00	7.03 (0.65)^{b}
Cajá	2	0.00	0.00	0.225 (0.05)^{b}	0.002 (0.01)^{b}	0000^{c}	0.00	6.44 (0.96)^{b}
Cajá	3	0.00	0.00	0.156 (0.02)^{c}	0.003 (0.01)^{b}	0.035 (0.01)^{b}	0.00	14.20 (1.24)^{a}
Umbu-cajá	1	0.00	1.265 (0.06)^{c}	0.315 (0.07)^{b}	0.00	0.927 (0.77)^{b}	0.244 (0.06)^{b}	8.94 (1.71)^{b}
Umbu-cajá	2	0.00	6.107 (0.06)^{a}	0.379 (0.32)^{a}	0.00	1.106 (0.47)^{a}	0.275 (0.02)^{a}	4.02 (0.46)^{c}
Umbu-cajá	3	0.00	2.204 (0.11)^{b}	0.361 (0.12)^{ab}	0.00	0.179 (0.35)^{c}	0.286 (0.01)^{a}	16.69 (0.39)^{a}
Umbu	1	0.00	0.099 (0.81)^{b}	0.344 (0.17)^{c}	0.00	1.615 (0.22)^{a}	0.330 (0.10)^{a}	3.81 (0.60)^{c}
Umbu	2	0.00	0.120 (2.03)^{b}	0.620 (0.09)^{a}	0.00	1.317 (0.46)^{b}	0.018 (0.12)^{b}	13.17 (0.47)^{b}
Umbu	3	0.00	0.455 (0.47)^{a}	0.478 (0.20)^{b}	0.00	1.391 (0.08)^{b}	0.000 (0.09)^{c}	32.88 (14.71)^{a}

Results are expressed in mean ± standard deviation. ($n = 3$) Student's t-test ($p < 0.05$).
*cajuí (*Anacardium spp*), murici (*Byrsonima crassifolia* (L.) Kunth), pequi (*Caryocar coriaceum* Wittm.), jenipapo (*Genipa americana* L.), mangaba (*Hancornia speciosa* Gomes), bacuri (*Platonia insignis* Mart.), cajá (*Spondias mombin* L.), umbu-cajá (*Spondias bahiensis* P. Carvalho, Van den Berg & M. Machado), umbu (*Spondias tuberosa* Arruda), pitanga (*Eugenia uniflora* L.), araçá (*Psidium sobralianum* Landrum & Proença).

diseases and also contributing effectively to the aesthetics industry (Maoka, 2019).

The molecular properties of xanthophylls are different and vary according to their hydrophobicity. They act as oxidizing agents in the control of membrane permeability to O_2 and modulation of photoactive pigment activity (Ruban and Johnson, 2010). Besides interacting positively with protein pigments that regulate plant photosynthesis (Welc et al., 2016). Xanthophylls are not produced by humans and need to be obtained through food.

Among the carotenes (highly conjugated C40 hydrocarbon chains), β-carotene and α-carotene were identified, and among the xanthophylls (oxygenated carotenes), β-cryptoxanthin, α-cryptoxanthin, lutein and zeaxanthin.

Table 4 show the carotenoids levels detected in fruits. Lutein and zeaxanthin are abundant in a variety of foods. In many respects, there is strong potential in neurocognitive function along with a healthy lifestyle to promote brain health (Lindbergh et al., 2017). It is relevant to comment that the carotenoid content in breast milk is associated with pre-mature or non-mature birth condition, but this condition does not impair the content of lutein and xanthophylls that are directly related to the development of the retina and the baby's brain (Xavier et al., 2018).

Plasma carotenes can be increased through supplementation and have the potential to reduce oxidative stress induced by hyperglycemia, or other complications related to diabetes and chronic vascular diseases (Stonehouse et al., 2016).

Pitanga was the only fruit in which all-*trans*-lycopene, all-*trans*-rubixanthin and 9-*cis*-rubixanthin were detected, in addition to having substantial amounts of all-*trans*-β-cryptoxanthin, all-*trans*-α -carotene and all-*trans*-β-carotene (Table 4).

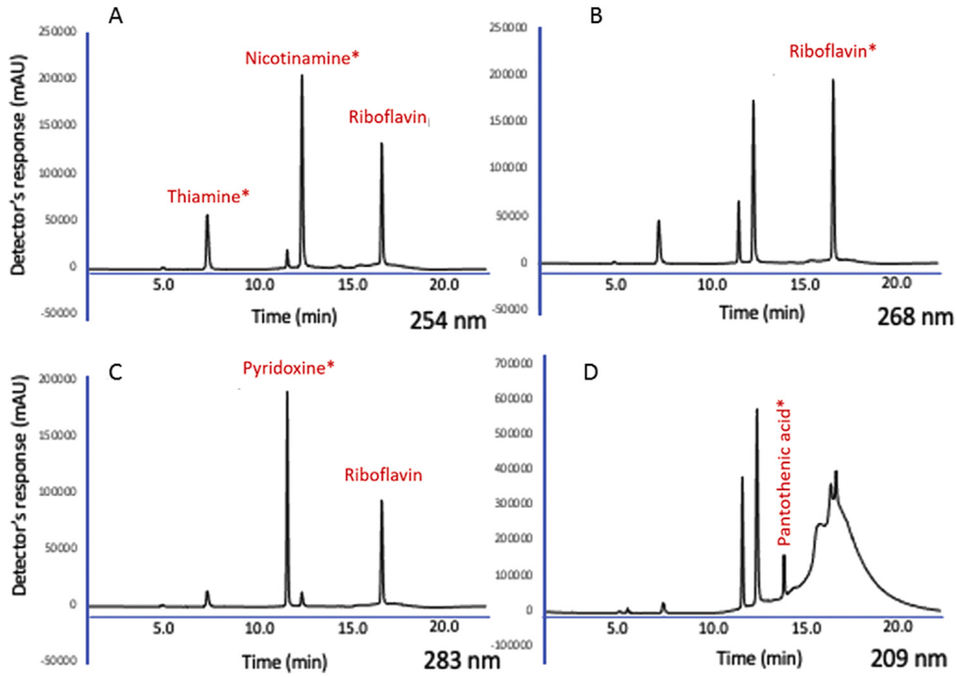

Figure 1. Typical chromatograms of water-soluble vitamins standards. From A (thiamine, nicotinamine, riboflavin), B (riboflavin), C (pyridoxine, riboflavin) and D (pantothenic acid).

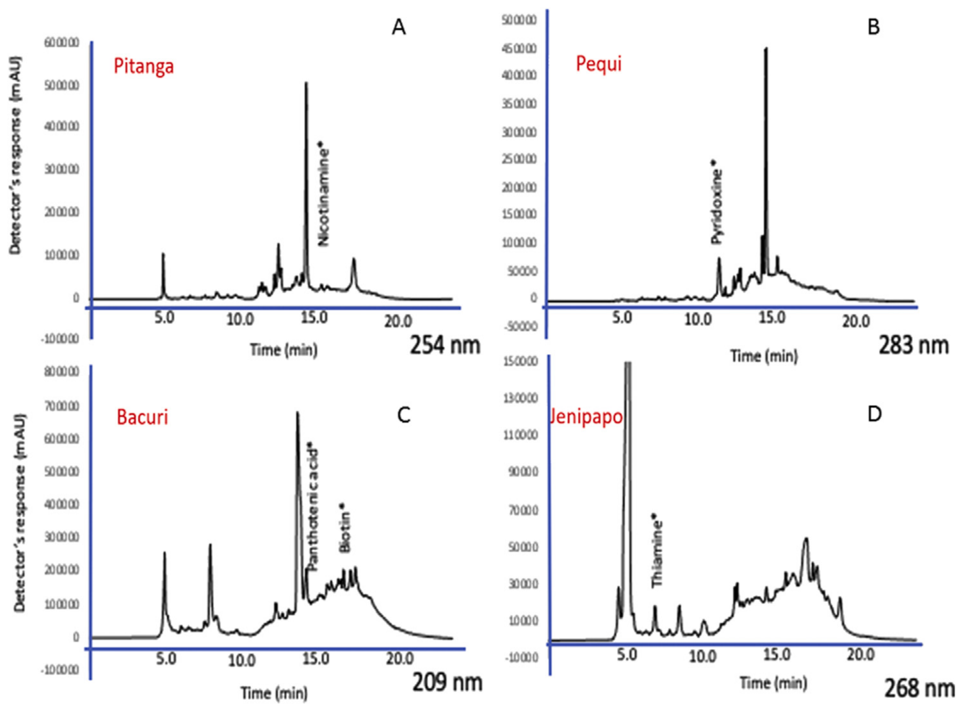

Figure 2. Chromatograms of water-soluble vitamins from pitanga (A), pequi (B), bacuri (C) and jenipapo (D) fruits.

Regarding the β-carotene content, pequi showed a higher amount when compared to the fruits studied (Table 4), as well as tomatoes (0.32 ± 0.6 mg/100 g) and carrots (6.15 ± 9 mg/100 g) that are recognized sources of this nutrient (Niizu and Rodriguez-Amaya, 2005).

Many vegetables rich in carotenoids, such as carrots, are low in lipids that are important for the bioavailability of these same carotenoids (Kopec and Failla, 2018). Thus, pequi having relevant amounts of lipids may, in addition to improving the bioavailability of carotenoids, provide anti-inflammatory and hypolipidemic effects (Figueiredo et al., 2016).

The average total carotenoids provitamin A (β-cryptoxanthin, β-carotene and α-carotene) ranged from 0.63 to 23.89 μg/100 g equivalent of retinol activity (RAE) in bacuri and pequi fruits, respectively. Among the 11 species studied, pequi (11.78–23.89 μg/100 g RAE), cajá (7.80–12.73 μg/100 g RAE), umbu-cajá (5.52–12.29 μg/100 g RAE) and

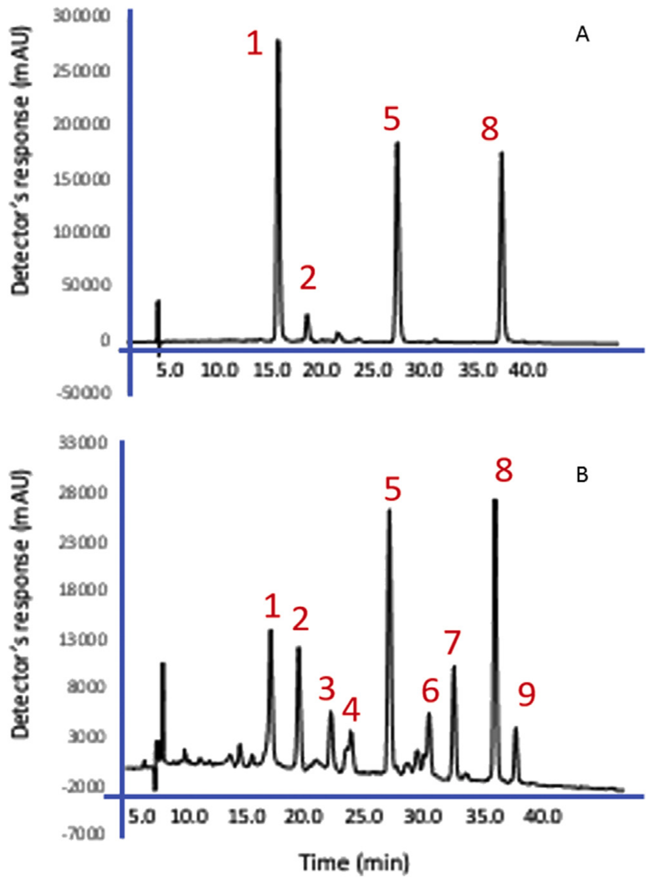

Figure 3. Typical carotenoid chromatograms from standards (A) and fruit sample (B). Processed at 450 nm. 1 (all-trans-lutein), 2 (all-trans-zeaxanthin), 3 (13-cis-β-cryptoxanthin), 4 (all-trans-α-cryptoxanthin), 5 (all-trans-β-cryptoxanthin), 6 (15-cis-β-carotene), 7 (all-trans-α-carotene), 8 (all-trans-β-carotene), 9 (9-cis-β-carotene).

pitanga (2.39–11.86 μg/100 g RAE) presented significant amounts of these carotenoids, which may contribute to the improvement of hypovitaminosis A, which, according to the United Nations Standing Committee on Nutrition, is a serious worldwide public health problem (SCN, 2010).

The carotenoids most researched for their involvement in human health are β-carotene, α-carotene, β-cryptoxanthin, lycopene, lutein and zeaxanthin. With the exception of zeaxanthin, they are the most commonly found in food, with β-carotene being the most widely distributed (Rodriguez-Amaya et al., 2008). It is important to highlight the relevance of recognizing these sources of carotenoids in fruits to increase their consumption by the population and stimulate their cultivation, since fruit trees play an important economic role for the Brazilian population and local industries, although they are still under-explored (Ribeiro et al., 2014; Souza et al., 2018).

The violaxanthin and all-trans-violaxanthin carotenoids are present only in the mangaba fruit lot 2 (1.84 ± 0.2 μg/100 g) and in the araçá fruit lot 2 (1.60 ± 0.34 μg/100 g), this absence occurs due to these carotenoids being present with more emphasis in algae (Maroneze et al., 2019; Faé Neto et al., 2018).

3.3. Principal Component Analysis

Principal Component Analysis (PCA) was performed on vitamin and carotenoids content data for all fruits (Figure 4). The first and second PCA components represented 83.02% and 8.05% of the total variation, respectively, which meets the general requirement of cumulative percent variation (CPV) > 70%–85% for PCA analysis (Liu, 2007; Gu et al., 2020).

Pitanga, cajá, umbu-cajá lot L1, pequi, murici L1 and L3 fruits are clearly differentiated from other fruits by higher levels of carotenoids. Carotenoids are characterized by their antioxidant role, protecting body cells against free radicals in excess (Krishnaswamy et al., 2020). Thus, these fruits can be consumed in the perspective of preventing various diseases related to oxidative stress and can be considered functional foods.

Different from lot 1, which was cultivated in Fortaleza, lots 2 and 3 of pitanga stood out for the highest number of total carotenoids, all-*trans*-rubixanthin, 9-*cis*-rubixanthin, all-*trans*-lycopene and all-*trans*-β-cryptoxanthin. Species of *Eugenia*, to which pitanga belongs, cereja-do-mato, uvaia and araçá-boi are fruits with excellent nutritional characteristics, because they have, in addition to other phytochemicals, carotenes, lycopenes and cryptoxanthin, providing health benefits due to their antioxidant, anti-inflammatory and anti-diabetic properties among others (Araújo et al., 2019).

Cajá, umbu-cajá lot L1, pequi, muri L1 and L3 were differentiated by greater amounts of 13-cis-β-cryptoxanthin, all-*trans*-α-cryptoxanthin, 13-*cis*-β-carotene, all-*trans*-α-carotene, all-*trans*-lutein, all-*trans*-β-carotene, all-*trans*-zeaxanthin, 9-*cis*-β-carotene and all-*trans*-lutein. Lutein and zeaxanthin play an important role in reducing eye disorders due to their antioxidant, anti-inflammatory properties and ability to filter blue light

Table 3. Chromatographic and UV-vis characteristics of carotenoids from fruits of Northeast Brazil, obtained for HPLC-DAD.

Peak[a]	Carotenoid[b]	t_R (min)	λ_{max} (nm)[c]	% III/II	$\%A_B/II$
1	*all-trans*-lutein	15.3	420, 444, 472	57	0
2	all-*trans*-zeaxanthin	18.5	427, 450, 475	25	0
3	13-*cis*-β-cryptoxanthin	22.4	338, 418, 444, 470	23	50
4	*all-trans*-α-cryptoxanthin	24.4	420, 444, 472	50	0
5	*all-trans*-β-cryptoxanthin	22.8	421, 450, 477	22	0
6	15-*cis*-β-carotene	25.6	337, 420, 448, 471	15	61
7	*all-trans*-α-carotene	29.7	420, 445, 472	60	0
8	*all-trans*-β-carotene	33.9	425, 451, 478	25	0
9	9-*cis*-β-carotene	36.0	338, 421, 447, 471	66	18
10	all-*trans*-rubixanthin	46.9	439, 463, 492	36	0
11	9-*cis*-rubixanthin	47.9	350, 437, 460, 488	30	30
12	all-*trans*-lycopene	83.9	447, 474, 505	75	0

[a] Numbered according to the chromatograms shown in Figure 2.
[b] Tentative identification tr: Retention time on C_{30} column using linear gradient of methanol/MTBE; λ_{max}: maximum absorption wavelength (nm); % III/II: spectral fine structure; % AB/II: intensity of *cis* peak.

Table 4. Carotenoid (μg/100g) and Provitamin A (μg RAE/100g) contents in a wet sample of the fruits of the biodiversity of Northeast Brazil.

FRUITS*	L	all-*trans*-lutein	all-*trans*-zeaxathin	13-*cis*-β-cryptoxanthin	all-*trans*-α-cryptoxanthin	all-*trans*-β-cryptoxanthin	13-*cis*-β-carotene	all-*trans* -α-carotene	all-*trans*-β-carotene	9-cis-β-carotene	all-*trans*-rubixanthin	9-cis-rubixanthin	all-*trans*-lycopene	Provitamin A
Cajuí	1	8.0 ± 1.4[c]	6.7 ± 0.6[b]	8.7 ± 0.8[a]	7.2 ± 0.6[b]	20.2 ± 1.9[a]	8.9 ± 0.7[b]	10.9 ± 1.1[b]	20.8 ± 2.4[b]	7.6 ± 0.7[b]	0.0	0.0	0.0	4.8 ± 0.5
Cajuí	2	14.7 ± 0.1[a]	9.1 ± 0.3[a]	9.1 ± 0.8[a]	9.4 ± 0.9[a]	23.4 ± 2.7[a]	13.4 ± 1.8[a]	19.3 ± 2.6[a]	38.8 ± 2.7[a]	10.1 ± 1.0[a]	0.0	0.0	0.0	7.4 ± 0.7
Cajuí	3	10.9 ± 0.7[b]	2.6 ± 0.0[c]	7.0 ± 0.1[b]	8.3 ± 0.0[a]	9.6 ± 0.6[b]	8.2 ± 0.2[b]	10.5 ± 0.5[b]	17.9 ± 1.3[b]	7.8 ± 0.3[b]	0.0	0.0	0.0	4.0 ± 0.2
Murici	1	176.3 ± 14.5[a]	51.9 ± 3.8[a]	0.0	55.1 ± 0.1[a]	12.9 ± 0.6[a]	0.0	12.6 ± 0.2[a]	32.9 ± 0.13[a]	16.2 ± 0.2[a]	0.0	0.0	0.0	5.2 ± 0.0
Murici	2	41.8 ± 0.5[c]	10.5 ± 0.3[c]	0.0	9.1 ± 0.1[c]	6.7 ± 0.7[b]	0.0	0.0[c]	10.28 ± 0.30[c]	7.7 ± 1.2[c]	0.0	0.0	0.0	1.8 ± 0.1
Murici	3	95.2 ± 3.4[b]	33.5 ± 1.0[b]	0.0	43.2 ± 0.1[b]	11.7 ± 0.8[a]	0.0	10.8 ± 0.8[b]	24.5 ± 1.26[b]	11.6 ± 3.1[b]	0.0	0.0	0.0	3.9 ± 0.3
Pequi	1	31.4 ± 0.6[b]	59.9 ± 2.2[b]	29.8 ± 3.0[a]	0.00[c]	51.1 ± 6.4[b]	47.5 ± 3.3[a]	21.8 ± 0.6[b]	144.8 ± 9.2[a]	43.1 ± 1.9[a]	0.0	0.0	0.0	23.9 ± 1.6
Pequi	2	31.4 ± 2.0[b]	54.1 ± 2.5[c]	0.0[b]	12.3 ± 0.1[b]	41.4 ± 3.1[c]	24.3 ± 1.0[b]	20.1 ± 1.1[c]	149.1 ± 9.7[a]	34.2 ± 0.7[b]	0.0	0.0	0.0	19.9 ± 0.9
Pequi	3	55.3 ± 3.0[a]	75.5 ± 3.6[a]	0.0[b]	21.6 ± 0.1[a]	60.0 ± 1.4[a]	28.1 ± 1.1[b]	27.3 ± 0.6[a]	48.6 ± 1.9[b]	21.0 ± 0.1[c]	0.0	0.0	0.0	11.8 ± 0.3
Pitanga	1	0.0	0.0	0.0	0.0	29.6 ± 2.3[c]	0.0	9.5 ± 0.5[c]	9.1 ± 0.4[b]	0.0[b]	49.1 ± 3.5[c]	16.4 ± 0.7[c]	44.5 ± 4.0[b]	2.4 ± 0.2
Pitanga	2	0.0	0.0	0.0	0.0	247.5 ± 34.2[a]	0.0	21.4 ± 2.0[b]	0.0[c]	0.0[b]	395.6 ± 113.7[a]	29.0 ± 3.1[b]	81.6 ± 28.4[a]	11.2 ± 1.5
Pitanga	3	0.0	0.0	0.0	0.0	171.7 ± 9.1[b]	0.0	24.7 ± 1.0[a]	34.4 ± 1.3[a]	9.8 ± 0.5[a]	212.4 ± 8.4[b]	130.5 ± 5.6[a]	84.9 ± 13.3[a]	11.9 ± 0.5
JenipapoP	1	0.0[b]	0.0[b]	0.0	0,0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0	0.0	0.0	0.0
JenipapoP	2	0.0[b]	0.0[b]	0.0	0,0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0	0.0	0.0	0.0
JenipapoP	3	12.2 ± 0.3[a]	0.9 ± 0.0[a]	0.0	7.7 ± 0.6[a]	5.8 ± 0.5[a]	9.6 ± 0.2[a]	13.8 ± 0.6[a]	33.5 ± 3.5[a]	12.9 ± 0.5[a]	0.0	0.0	0.0	5.5 ± 0.4
Mangaba	1	0.0 ± 1.3	17.4 ± 0.3[a]	4.4 ± 0.1[a]	7.2 ± 0.4[a]	17.3 ± 1.3[a]	0.0	6.7 ± 0.3[b]	24.7 ± 1.0[a]	8.2 ± 0.0[a]	0.0	0.0	0.0	3.7 ± 0.2
Mangaba	2	0.0 ± 0.9	9.8 ± 0.1[b]	2.5 ± 0.1[b]	4.3 ± 0.3[c]	8.7 ± 0.4[b]	0.0	0.0[c]	12.7 ± 0.6[c]	4.7 ± 0.1[b]	0.0	0.0	0.0	1.8 ± 0.1
Mangaba	3	0.0 ± 1.6	10.9 ± 0.2[b]	1.4 ± 0.1[c]	5.7 ± 0.3[b]	10.3 ± 0.9[b]	0.0	8.1 ± 0.2[a]	17.1 ± 1.9[b]	8.3 ± 0.3[a]	0,0	0,0	0,0	2.9 ± 0.2
Bacuri	1	0.1 ± 0.0[b]	0.1 ± 0.0[b]	0.0	0.0	3.2 ± 0.1[a]	0.0	0.0	6.0 ± 0.2[a]	0.0	0.0	0.0	0.0	0.6 ± 0.0
Bacuri	2	0.0[a]	0.0[a]	0.0	0.0	0.0[b]	0.0	0.0	0.0[b]	0.0	0.0	0.0	0.0	0.0
Bacuri	3	0.0[a]	0.0[a]	0.0	0.0	0.0[b]	0.0	0.0	0.0[b]	0.0	0.0	0.0	0.0	0.0
Araçá	1	0.0[b]	0.0[b]	0.0	0.0[b]	0.0[b]	0.0	0,0[b]	0.0[b]	0.0[b]	0.0	0.0	0.0	0.0
Araçá	2	2.7 ± 0.6[a]	0.5 ± 0.1[a]	0.0	6.5 ± 0.9[a]	3.5 ± 0.2[a]	0.0	5.4 ± 0.1[a]	8.8 ± 1.0[a]	5.7 ± 0.2[a]	0.0	0.0	0.0	1.6 ± 0.1
Araçá	3	0.0[b]	0.0[b]	0.0	0.0[b]	0.0[b]	0.0	0.0[b]	0,0[b]	0.0[b]	0.0	0.0	0.0	0.0
Cajá	1	67.1 ± 2.6[a]	0.0[b]	0.0[b]	72.2 ± 5.4[b]	119.5 ± 9.0[b]	0,0[b]	31.5 ± 2.5[a]	27.5 ± 2.0[b]	8.4 ± 0.2[a]	0.0	0.0	0.0	9.3 ± 0.7
Cajá	2	39.1 ± 1.4[b]	0.0[b]	0.0[b]	86.1 ± 7.6[a]	153.7 ± 12.4[a]	0,0[b]	54.0 ± 7.0[a]	40.0 ± 1.3[a]	8.9 ± 1.0[a]	0.0	0.0	0.0	12.7 ± 1.2
Cajá	3	20.2 ± 2.0[c]	9.4 ± 0.8[a]	39.4 ± 17.8[a]	48.4 ± 3.8[c]	76.6 ± 8.7[c]	15.1 ± 6.9[a]	25.7 ± 2.5[a]	7.6 ± 0.4[c]	0.0[b]	0.0	0.0	0.0	7.8 ± 0.5
Umbu	1	0.0	2.1 ± 0.1[a]	0.0	15.7 ± 0.4[a]	6.9 ± 0.2[b]	0.0	5.6 ± 0.1 [ab]	17.1 ± 0.6[b]	6.4 ± 0.1[b]	0.0	0.0	0.0	2.5 ± 0.1
Umbu	2	0.0	1.3 ± 0.2[b]	0.0	17.2 ± 2.4[a]	12.6 ± 1.7[a]	0.0	5.9 ± 0.3[a]	22.0 ± 1.3[a]	7.7 ± 0.3[a]	0.0	0.0	0.0	3.3 ± 0.2
Umbu	3	0.0	1.4 ± 0.2[b]	0.0	10.9 ± 0.5[b]	7.5 ± 0.2[b]	0.0	5.4 ± 0.1[b]	12.4 ± 0.4[c]	6.2 ± 0.1[b]	0.0	0.0	0.0	2.1 ± 0.1
Umbu-cajá	1	23.8 ± 0.3[a]	9.6 ± 0.7[a]	31.7 ± 0.8[a]	29.7 ± 1.6[a]	146.4 ± 8.7[a]	0.0	18.5 ± 0.5[a]	34.7 ± 2.4[a]	14.4 ± 0.5[a]	0.0	0.0	0.0	12.3 ± 0.6
Umbu-cajá	2	7.6 ± 0.3[c]	2.5 ± 0.0[c]	11.2 ± 0.1[b]	11.3 ± 0.1[c]	30.0 ± 0.7[c]	0.0	12.5 ± 0.2[c]	16.2 ± 0.4[c]	10.0 ± 0.1[b]	0.0	0.0	0.0	4.4 ± 0.1
Umbu-cajá	3	11.3 ± 0.6[b]	4.2 ± 0.3[b]	13.3 ± 3.6[b]	23.3 ± 1.8[b]	41.9 ± 3.2[b]	0.0	17.0 ± 0.9[b]	19.6 ± 0.8[b]	10.6 ± 0.3[b]	0.0	0.0	0.0	5.5 ± 0.3

Results are expressed in mean ± standard deviation. (n = 3) Student's t-test ($p < 0.05$). *cajuí (*Anacardium spp*), murici (*Byrsonima crassifolia* (L.) Kunth), pequi (*Caryocar coriaceum* Wittm.), jenipapo (*Genipa americana* L.), mangaba (*Hancornia speciosa* Gomes), bacuri (*Platonia insignis* Mart.), cajá (*Spondias mombin* L.), umbu-cajá (*Spondias bahiensis* P. Carvalho, Van den Berg & M. Machado), umbu (*Spondias tuberosa* Arruda), pitanga (*Eugenia uniflora* L.), araçá (*Psidium sobralianum* Landrum & Proença).

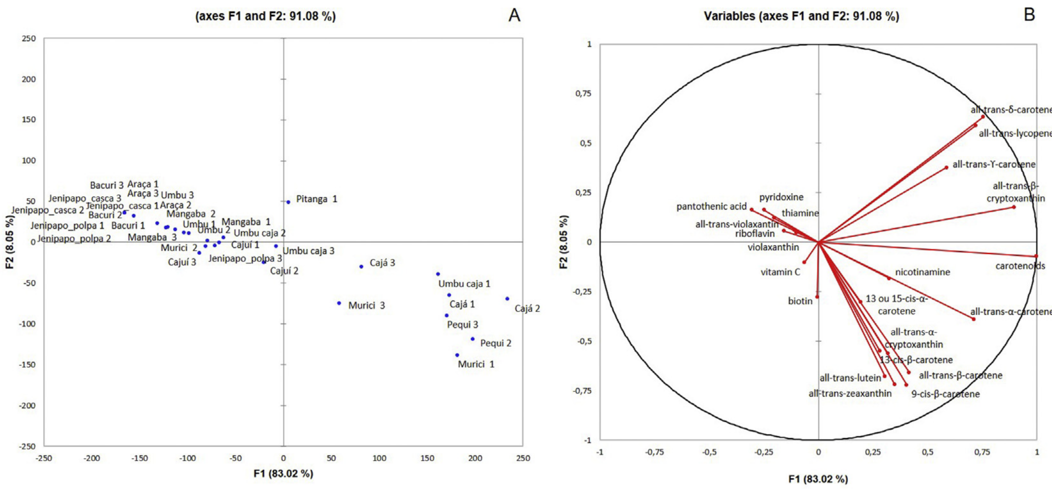

Figure 4. Principal Component Analysis (PCA) from loading (A) and scores (B) for vitamins and carotenoids of the fruit pulps.

(Bungau et al., 2019). Thus, regular consumption of these fruits can prevent, for example, age-related macular degeneration.

Jenipapo, mangaba, bacuri, araçá, umbu-cajá L2 and L3, umbu, cajuí, muri L2 fruits are highlighted by the higher value of pantothenic acid, pyridoxine, all-*trans*-violaxantin, riboflavin, violaxanthin, vitamin C and biotin.

4. Conclusions

The data found in this study agrees with the values found for tropical fruits reported in the literature. The vitamin B3 was the most present in all fruits. The cajuí had higher levels of vitamin C compared to other fruits. Carotenoid analyses were first performed on *Psidium sobralianum* Landrum & Proença.

These fruits can provide varying amounts of vitamins important for human health and can be part of the diet of individuals and populations, especially those vulnerable to nutritional deficiencies. Furthermore, it is important that the individual consumes the fruits in a diversified way, avoiding monotony and, thus, guaranteeing the daily intake of more nutrients.

Declarations

Author contribution statement

Renata Carmo de Assis, Rafaela de Lima Gomes Soares, Paulo Henrique Machado de Sousa, Carla Soraya Costa Maia: Analyzed and interpreted the data; Wrote the paper.

Adriana Camurça Pontes Siqueira, Ana Erbênia Pereira Mendes, Eveline de Alencar Costa, Alessandra Pinheiro de Góes Carneiro: Conceived and designed the experiments.

Veridiana Vera de Rosso: Performed the experiments; Contributed reagents, materials, analysis tools or data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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