



# Brazilian varieties of acerola (*Malpighia emarginata* DC.) produced under tropical semi-arid conditions: Bioactive phenolic compounds, sugars, organic acids, and antioxidant capacity

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## Abstract

Acerola fruit has gained prominence for its high nutraceutical value, associated with high levels of ascorbic acid and phenolic compounds. The objectives of this study were to analyze the chemistry composition and antioxidant capacity in seven Brazilian varieties of acerola. All acerola genotypes were harvested at the red ripe maturity stage, and the fruit were subjected to metabolite analyses by High-Performance Liquid Chromatography. The varieties presented high levels of ascorbic acid and malic acid. The main sugars observed in acerola were glucose and fructose. Cyanidin-3-rhamnoside was the main phenolic compound in the fruit (149–682 mg/kg FW), which had higher concentration in the varieties BRS 235-Apodi, BRS 236-Cereja, and BRS 237-Roxinha. Other phenolic compounds also observed in the fruit were quercetin-3-glucoside, isorhamnetin, catechin, procyanidin A2, naringenin, hesperidin, chlorogenic acid, and *trans*-resveratrol. In conclusion, the observed wide range of acerola nutraceutical properties was related to the high genetic variability among genotypes.

## Practical applications

Brazil is the world's largest producer, consumer and exporter of acerola, with commercial orchards distributed all over the country. According to the Brazilian Ministry of Agriculture, Livestock and Supply, about eighteen registered varieties of acerola have been produced in the country. Among them are the varieties developed by Breeding Programs at the Brazilian Agricultural Research Corporation (Embrapa). Despite the great diversity of studies about acerola composition, only a few studies have focused on analyzing specific varieties. Therefore, limited information is currently available on the profile of metabolites of commercial interest in acerola varieties, such as sugars, organic acids and some phenolics. This study showed that acerola nutraceutical properties was highly dependent on the genotype.

## KEYWORDS

bioactive compounds, *Malpighia emarginata* DC, polyphenols, São Francisco Valley

## 1 | INTRODUCTION

Acerola (*Malpighia emarginata* DC.) is a tropical fruit originated from Central America, which has high economic importance mainly due to its high contents of ascorbic acid, carotenoids and phenolic compounds that have nutraceutical properties and make acerola a super fruit (Chang et al., 2019; Delva & Schneider, 2013; Prakash & Baskaran, 2018; Xu et al., 2020). Indeed, studies have shown that ascorbic acid and several phenolics belonging to the groups of flavanols, flavonols and anthocyanins are the main compounds responsible for the bioactive properties in acerola (Mezadri et al., 2008; Nascimento et al., 2018; Oliveira et al., 2012; Prakash & Baskaran, 2018; Vasavilbazo-Saucedo et al., 2018). These bioactive properties have stimulated acerola consumption either as fresh fruit or processed products such as pulp, juice, and ice cream (Belwal et al., 2018; Chang et al., 2019; Mariano-Nasser et al., 2017).

Brazil is considered the world's largest producer, consumer and exporter of acerola, with commercial cultivation spread over almost all regions of the country. In the Northeast region, the edaphoclimatic conditions characterized as tropical semi-arid make it possible to harvest acerola several times throughout the year. The São Francisco Valley (SFV) is located in the Northeast of Brazil and is the largest producer of acerola, accounting for more than 25% of the national production (Belwal et al., 2018; IBGE, 2017). In the SFV, up to eight harvests per year are made possible with the use of irrigation, where the main genotypes cultivated are "Junko," "Flor Branca," "BRS Sertaneja," "Costa Rica," "Okinawa," "Nikki," "Coopama N° 1," and "BRS Cabocla" (Ribeiro & Freitas, 2020; Souza et al., 2013). In addition to Brazil, acerola is also cultivated in Mexico, China, and some parts of South East Asia and India. Moreover, a considerable demand for acerola products exists in the United States of America, Japan, and Europe due to its high vitamin C content. This demand is attended mainly by acerola processed products such as pulp and clarified juice due to the fact that fresh acerolas have short postharvest life (Belwal et al., 2018; Xu et al., 2020).

According to the Brazilian Ministry of Agriculture, Livestock and Supply, about eighteen registered varieties of acerola have been cultivated in the country (Ministério da Agricultura and Pecuária e Abastecimento (MAPA), 2018). However, there is a great diversity of wild varieties that may present characteristics of interest to the fresh market and processing industries (Oliveira et al., 2012). In this context, studies have been carried out to identify new acerola varieties with nutraceutical properties of economic interest (Ritzinger et al., 2018). Pioneering studies to improve acerola quality in Brazil began in the 1970s and were carried out by Japanese immigrant cooperatives in the North of the country, especially in the State of Pará. However, it was only in the 1980s that acerola breeding programs were created across the country in several institutions, such as the Brazilian Agricultural Research Corporation (Embrapa) (Souza et al., 2013). The varieties launched by Embrapa breeding programs are always named "BRS." Among the Brazilian varieties of acerola are BRS Sertaneja, BRS Cabocla, BRS 235 Apodi, BRS 236 Cereja, BRS 237 Roxinha, BRS 238 Frutacor, and BRS 366 Jaburu. These varieties

were developed for high sugar and ascorbic acid contents, which are important quality parameters for both fresh fruit consumption and processing industry (Araújo et al., 2007; Mariano-Nasser et al., 2017; Oliveira et al., 2012).

Acerola composition is determined by genotype and growing conditions (Hanamura et al., 2008). Despite the great diversity of studies about acerola composition, only a few studies have focused on analyzing specific varieties. Previous studies have analyzed total phenolic content (TPC), total anthocyanins, ascorbic acid, in vitro antioxidant capacity (AOX), and some phenolics in acerola varieties growing in Brazil, Vietnam and Japan (Hanamura et al., 2008; Mariano-Nasser et al., 2017; Oliveira et al., 2012; Souza et al., 2014). New studies are required to characterize different classes of phenolic compounds and other plant metabolites of interest such as sugars and organic acids in acerola varieties.

The objectives of this study were to analyze the individual phenolic compounds, organic acids, sugars, and the in vitro AOX in seven Brazilian varieties of acerola fruit produced under tropical semi-arid conditions.

## 2 | MATERIAL AND METHODS

### 2.1 | External standards for high performance liquid chromatography and reagents

External standards for malic, tartaric, citric, formic and succinic acids, glucose, fructose, maltose, and rhamnose were obtained from Química Vetec (Rio de Janeiro, RJ, Brazil). Trolox (6-hydroxy-2,5,7,8-tetramethylchromate-2-carboxylic acid), 2,2-diphenyl-1-picrylhydrazil (DPPH), 2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), TPTZ (2,3,5-triphenyltetrazolium chloride), and the external standards of the phenolics chlorogenic acid, syringic acid, gallic acid, *p*-coumaric acid, *trans*-caftaric acid, caffeic acid, hesperidin, naringenin, procyanidin B1, procyanidin B2, catechin, epicatechin and malvidin-3,5-diglucoside, cyanidin 3,5-diglucoside and pelargonidin 3,5-diglucoside were purchased from Sigma-Aldrich (St. Louis, MO, USA). Cyanidin 3-rhamnoside was obtained from ACMEC Biochemical (China). Procyanidin A2, epicatechin gallate, epigallocatechin gallate, kaempferol 3-glucoside, quercetin 3-glucoside, quercetin 3-rutinoside (rutin), myricetin, petunidin 3-glucoside, delphinidin 3-glucoside, peonidin 3-glucoside, delphinidin 3-glucoside, malvidin 3-glucoside, cyanidin 3-glucoside, pelargonidin 3-glucoside came from Extrasynthese (Genay, France). *Cis*-resveratrol and *trans*-resveratrol were obtained from Cayman Chemical Company (Ann Arbor, MI, USA). The ultrapure water was obtained using a Marte Científica purification system (São Paulo, SP, Brazil).

### 2.2 | Acerola varieties and environmental conditions

Acerola varieties were produced in an experimental area in the SFV, Petrolina, PE, Brazil (latitude 09°08'S; longitude 40°18'W; altitude

365.5 m). In this region, the climate is classified as BSh, characterized as a tropical semi-arid, according to the Köppen classification. The soil is classified as dystrophic Yellow Argisol (Santos et al., 2018). During fruit growth and development, the average daily temperature was 25°C, precipitation was 0.2 mm, relative humidity was 72.9%, evapotranspiration was 4.24 mm, and solar radiation was 17.00 MJ/m<sup>2</sup> d<sup>-1</sup>, determined by the weather station of the experimental area.

The fruit were harvested in the morning, at red ripe maturity stage, characterized by red skin color. The varieties analyzed in this study were BRS 235 (Apodi), BRS 236 (Cereja), BRS 237 (Roxinha), BRS 238 (Frutacor), BRS 366 (Jaburu), BRS Sertaneja, and BRS Cabocla. The plants were five years old and were spaced by 4.0 and 3.5 meters between lines and plants, respectively. The plants were daily irrigated for one hour with 8 mm of water. Fertilization and phytosanitary treatment were carried out according to technical recommendations (Ritzinger et al., 2003). The experiment followed a randomized complete block design. Each variety was composed by three blocks and each block by 10 plants. A total of 20 fruit were harvested per plant for quality analyzes, as described below.

### 2.3 | Soluble solids, acidity, pH, ascorbic acid, and skin color

Soluble solids (SS) were determined in juice samples with a digital refractometer model PAL-1 (Atago, São Paulo, Brazil). Titratable acidity (TA) was performed with a Titrino Plus automatic titrator (Metrohm, São Paulo, Brazil). AT results were expressed as percent of malic acid present in the juice. The analyses followed the methodologies described in AOAC (2016).

Total ascorbic acid content was determined by the Tillmans method, using 2,6-dichlorophenol-indophenol, following the methodology described by Strohecker and Henning (1967).

The skin color was analyzed with a colorimeter model CR-400 (Konica Minolta, Japan). The color values were expressed in the CIELAB system, with determination of the parameters luminosity (*L\**), *a\** and *b\** coordinates, chroma (*C\**) and hue angle (*h*).

### 2.4 | Determination of TPC and in vitro AOX

A total of 5 g of flesh and skin were macerated in 20 ml of absolute ethanol for 24 hr at room temperature, in the absence of light. After that, the extracts were centrifuged, filtered and immediately frozen at -23°C until analysis.

The total content of phenolic compounds was determined by the Folin-Ciocalteu spectrophotometric method (Singleton & Rossi, 1965). The results were expressed as mg of gallic acid equivalents (mg GAE) g<sup>-1</sup> of fresh fruit. All absorbance readings were performed using a UV-vis 2000A spectrophotometer (Instrutherm, Brazil).

The in vitro AOX was evaluated by ferric reducing antioxidant power (FRAP), as well as by free radical scavenging by ABTS [2,2-azi-

nobis-(3-ethylbenzthiazoline-6-sulfonic acid)], and DPPH (1,1-diphenyl-2-picrylhydrazyl), following the methods described in the literature (Kim et al., 2002; Re et al., 1999; Rufino et al., 2006). Calibration curves were obtained with the analytical standard Trolox for ABTS and DPPH methods, and ferrous sulfate for the FRAP method. The results were expressed as Trolox equivalents per kilogram of flesh and skin (mmol TE kg<sup>-1</sup>) or mmol of Fe<sup>2+</sup> per kilogram of flesh and skin (mmol Fe<sup>2+</sup> kg<sup>-1</sup>) for the ABTS and DPPH or FRAP, respectively.

The ABTS+ radical was formed by the reaction between 140 mmol of potassium persulfate with 7 mmol ABTS solution, which as incubated in the dark at 25°C for 16 hr. The radical was then diluted in absolute ethanol (final absorbance of 0.70 ± 0.05) and quantified at 734 nm. Later, 300-μl aliquot of the extract was transferred to 2,700 μl of the radical and the readings were carried out 6 min after adding the sample in the dark.

A solution containing 100 μmol/L of DPPH in ethanol p.a. was prepared and stored in amber glass at 20°C. An aliquot of 2.9 ml of this solution was mixed with 100 μl of extract and incubated in the dark at 20°C for 30 min. The AOX was assessed through the degradation rate in at 517 nm.

The FRAP reagent was prepared by adding 300 mmol/L of acetate buffer (pH 3.6), 10 mmol/L of TPTZ (2,4,6-tris (2-pyridyl)-s-triazine), 40 mmol/L of HCl and 20 mmol/L of FeCl<sub>3</sub>. An aliquot of 90 μl of extract and 270 μl of ultrapure water were mixed with 2,700 μl of FRAP reagent. The final solution was then mixed and incubated for 30 min in a thermodigester block (Bioplus IT-2002, SP, Brazil). The samples were analyzed at 595 nm.

### 2.5 | High performance liquid chromatography analyses of individual phenolic compounds, organic acids and sugars

Individual phenolic compounds were measured from an extract prepared with 5 g of pulp and skin, and 20 ml of ethanol 70%, followed by sonication (20 min, 35 kHz, 25°C) and centrifugation at 3,000 g by 10 min. The procedure was repeated two times and extracts were filtered with a 0.45-μm nylon filter (Millex Millipore, SP, Brazil). Organic acids and sugars were measured from water-soluble fruit extract. Five grams of pulp and skin were homogenized with 20-ml of ultra-pure water (5 min) using a mini Turrax apparatus (Tecnal, SP, Brazil). After centrifugation, the supernatant was filtered with a 0.45-μm nylon filter.

All analyses by high performance liquid chromatography (HPLC) were performed on an Agilent 1260 Infinity LC liquid chromatograph system (Agilent Technologies, CA, USA), coupled to a refractive index detector-RID (model G1362A) and a diode array detector-DAD (model G1315D). Data processing was on OpenLAB CDS ChemStation Edition software (Agilent Technologies, CA, USA).

The individual phenolic compounds were determined by RP-HPLC/DAD, using the method describe by Padilha et al. (2017), with adaptations accomplished by Dutra et al. (2018). The column and pre-column used were a Zorbax Eclipse Plus RP-C18 (100 × 4.6 mm,

3.5  $\mu\text{m}$ ) and a Zorbax C18 (12.6  $\times$  4.6 mm, 5  $\mu\text{m}$ ), respectively (Agilent Technologies). The sample volume injected was 20  $\mu\text{l}$  and the oven temperature was maintained at 35°C. The solvent flow was 0.8 ml/min. The gradient used in the separation was 0–5 min: 5% B; 5–14 min: 23% B; 14–30 min: 50% B; 30–33 min: 80% B, in which solvent A is a phosphoric acid solution (pH 2.0) and solvent B is methanol acidified with  $\text{H}_3\text{PO}_4$  0.5%. Quantification of individual polyphenols was performed by comparison with external standards. All calibration curves showed good linear regression ( $r^2 > .998$ ), LOD < 0.17 mg/L and LOQ < 1.41 mg/L. The confirmation of the quantified compounds found in the present study was accomplished by checking the spectral peak purity using the threshold test (purity factor  $\geq 950$ ), and by comparing the UV spectrum of the sample peak with that obtained in the external standard (Figures S1 and S2, respectively).

Organic acids and sugars were simultaneously determined by HPLC-DAD/RID (Coelho et al., 2018). An Agilent Hi-Plex H ion exchange column (300  $\times$  7.7 mm) with internal particles of 8.0  $\mu\text{m}$  was used and protected by a PL Hi-Plex H pre-column (5  $\times$  3 mm) (Agilent Technologies, CA, USA). The sample volume injected was 10  $\mu\text{l}$  and the solvent flow was 0.6 ml/min. The mobile phase was a 4 mM/L  $\text{H}_2\text{SO}_4$  solution. The column oven temperature was maintained at 70°C. Organic acids were detected by DAD 210 nm and sugars by RID. All quantified compounds showed calibration curves with  $R^2 > .996$ . The limits of detection and quantification (LOD and LOQ, respectively) for all evaluated compounds were LOD < 0.027 g/L and LOQ < 0.102 g/L, respectively.

## 2.6 | Statistical analysis

The results were presented as means with standard deviations. Data were submitted to analysis of variance (one-way ANOVA) and means were compared by Tukey's test ( $p < .05$ ), using R version 4.0.2 (R Core Team, Vienna, Austria). Principal component analysis (PCA) was performed with the SPSS statistical package version 20.0 (SPSS, Chicago, USA).

## 3 | RESULTS AND DISCUSSION

### 3.1 | Physicochemical analyses

The results of the physicochemical analyses are shown in Table 1. Average fruit weight ranged from 3.84 to 8.02 g in the varieties "BRS 238" and "BRS 237," respectively. pH values varied from 2.93 in "BRS 236" to 3.54 in "BRS 366." SS content ranged from 8.40% to 10.35% in "BRS 366" and "BRS 238," respectively. Regarding TA, the values ranged from 0.99% to 1.93% of malic acid in "BRS 366" and "BRS Sertaneja," respectively. According to Delva and Schneider (2013), acerola is a very acidic fruit, with an average weight of 2 to 15 g, pH ranging from 3.60 to 3.70, SS of 7.7% to 9.2% and TA from 1.04% to 1.87% in ripe fruit. In addition, the values obtained for average

fruit weight, pH, SS and TA in the acerola varieties evaluated in our study also agree with those reported by Oliveira et al. (2012) for ripe fruit of "BRS 235," "BRS 236," "BRS 237," and "BRS 238" cultivated in Limoeiro do Norte, Brazil, which is also under tropical semi-arid climate conditions. The physicochemical quality of acerola fruit observed in our study is similar to the physicochemical quality reported in previous studies for "Flor Branca," "Junko," and "Florida Sweet" acerolas (Freitas & Ribeiro, 2020; Souza et al., 2014).

Acerola SS and acidity are highly influenced by the maturity stage, representing the sugars and organic acids contents in the fruit, respectively. These primary metabolites are responsible for the sweet and acid taste in the fruit (Xu et al., 2020).

Regarding fruit color, measured by the CIE  $L^*a^*b^*$  system, acerola genotypes showed color values ranging from  $L^* = 33.18$  to 42.22,  $a^* = 36.14$  to 46.2 and  $b^* = 12.95$  to 29.98. Considering that positive values of  $a^*$  correspond to red, and positive values of  $b^*$  correspond to yellow, the red color on the fruit predominated in all genotypes. In acerola, the red color is usually associated with the presence of pigments such as anthocyanins and carotenoids in ripe fruit (Delva & Schneider, 2013; Vasavilbazo-Saucedo et al., 2018).

Although quality standards required for the international market are still not well established, buyers demand acerola fruit with SS content equal or higher than 7% in Europe, 7.5% in Japan, and about 1% of ascorbic acid in Europe and the United States (Delva & Schneider, 2013). In that case, all new Brazilian varieties analyzed in our study met the quality requirements for the international market (Table 1).

### 3.2 | Organic acids and sugars

The results obtained for organic acids and sugars in new Brazilian varieties of acerola are shown in Table 1. Organic acids play important roles on fruit metabolic processes during growth, ripening and senescence, affecting fruit susceptibility to microorganisms, as well as participating in the synthesis of other metabolic compounds and determining fruit flavor (Delva & Schneider, 2013).

In our study, ascorbic acid was the main acid observed in all varieties, presenting average values ranging from 1.18 to 2.43 g 100  $\text{g}^{-1}$ , with higher values in "BRS 235" (2.13 g 100  $\text{g}^{-1}$ ), "BRS Sertaneja" (2.32 g 100  $\text{g}^{-1}$ ) and "BRS 236" (2.43 g 100  $\text{g}^{-1}$ ). Previous studies have shown that ripe "BRS 235," "BRS 236," "BRS 237," and "BRS 238" acerolas produced in other Brazilian regions have ascorbic acid values ranging from 1.20 to 1.64 g 100  $\text{g}^{-1}$ , with higher values in "BRS 235" and "BRS 236," which also corroborate with the results observed in our study (Mariano-Nasser et al., 2017; Oliveira et al., 2012). These results also suggest that acerolas produced in the SFV can have higher ascorbic acid content than acerolas produced in other regions in Brazil. Indeed, the high light intensity and temperature during the whole year in the SFV can play an important role on increasing ascorbic acid synthesis in acerola fruit (Lee & Kader, 2000; Oliveira et al., 2012; Souza et al., 2013). In that case, acerolas produced in the SFV can have higher acceptance in the national and international

**TABLE 1** Physicochemical attributes, organic acids, and sugars of the Brazilian varieties of acerola cultivated in the São Francisco Valley, Brazil

Analysis	Acerola varieties							
	"BRS 235" Apodi	"BRS 236" Cereja	"BRS 237" Roxinha	"BRS 238" Frutacor	"BRS 366" Jaburu	"BRS Sertaneja"	"BRS Cabocla"	
Average fruit weight (g)	5.39 ± 0.03 bc	6.01 ± 0.36 b	8.02 ± 0.37 a	3.84 ± 0.23 d	4.42 ± 0.31 c	6.19 ± 0.70 b	4.09 ± 0.59 cd	
pH	3.27 ± 0.14 bc	2.93 ± 0.01 d	3.07 ± 0.01 cd	3.40 ± 0.15 ab	3.54 ± 0.07 a	2.96 ± 0.01 d	3.14 ± 0.15 bcd	
Soluble solids (SS, °Brix)	9.80 ± 0.30 abcd	10.25 ± 0.65 a	8.70 ± 0.50 de	9.10 ± 0.80 bcde	8.40 ± 0.50 e	8.50 ± 0.80 e	8.95 ± 0.01 cde	
Titrateable acidity (TA, % malic acid)	1.48 ± 0.03 cd	1.92 ± 0.04 a	1.28 ± 0.02 de	1.59 ± 0.08 bc	0.99 ± 0.01 f	1.93 ± 0.21 a	1.37 ± 0.01 cde	
SS/TA ratio	6.63 ± 0.34 b	5.34 ± 0.44 cd	6.79 ± 0.28 b	5.72 ± 0.79 bc	8.48 ± 0.46 a	4.40 ± 0.90 d	6.53 ± 0.07 bc	
L*	34.23 ± 0.26 fg	33.18 ± 0.36 g	35.27 ± 0.58 ef	33.64 ± 1.22 fg	44.22 ± 0.15 a	37.70 ± 0.60 cd	40.91 ± 0.90 b	
a*	39.93 ± 0.12 cde	37.60 ± 0.23 def	36.14 ± 0.71 f	36.94 ± 2.40 ef	46.20 ± 0.70 a	41.11 ± 1.14 bc	41.81 ± 0.17 bc	
b*	15.76 ± 0.06 de	12.95 ± 0.52 g	13.69 ± 0.72 fg	14.05 ± 1.67 fg	29.98 ± 0.35 a	20.19 ± 1.26 c	23.59 ± 0.97 b	
Chroma	42.93 ± 0.13 def	39.77 ± 0.39 fg	38.64 ± 0.91 g	39.52 ± 2.84 fg	55.07 ± 0.39 a	45.80 ± 1.57 cd	48.00 ± 0.63 bc	
Hue	21.54 ± 0.02 de	19.00 ± 0.59 f	20.73 ± 0.62 ef	20.77 ± 1.03 ef	32.98 ± 0.71 a	26.14 ± 0.79 c	29.42 ± 0.90 b	
<i>Organic acids g 100 g<sup>-1</sup></i>								
Malic acid	1.01 ± 0.03 ab	1.05 ± 0.01 a	0.89 ± 0.02 b	0.46 ± 0.02 d	0.99 ± 0.09 ab	1.10 ± 0.01 a	0.72 ± 0.04 c	
Succinic acid	0.05 ± 0.01 c	0.09 ± 0.01 ab	0.05 ± 0.00 c	0.09 ± 0.01 ab	0.05 ± 0.0 c	0.05 ± 0.01 c	0.06 ± 0.02 bc	
Ascorbic acid <sup>1</sup>	1.67 ± 0.02 cd	2.43 ± 0.06 a	1.44 ± 0.02 def	1.90 ± 0.16 bc	1.18 ± 0.05 f	2.32 ± 0.03 a	1.46 ± 0.1 def	
Total quantified organic acids	2.73 ± 0.06	3.57 ± 0.08	2.38 ± 0.04	2.45 ± 0.18	2.22 ± 0.01	3.47 ± 0.03	2.24 ± 0.16	
<i>Sugars g 100 g<sup>-1</sup></i>								
Fructose	1.60 ± 0.02 b	1.23 ± 0.00 e	1.49 ± 0.07 bc	1.87 ± 0.08 a	1.52 ± 0.04 bc	1.54 ± 0.02 bc	1.27 ± 0.13 de	
Glucose	1.36 ± 0.01 d	1.44 ± 0.00 cd	1.36 ± 0.04 d	1.83 ± 0.08 a	1.44 ± 0.03 cd	1.52 ± 0.02 bc	1.24 ± 0.06 e	
Maltose	0.09 ± 0.00 bc	0.13 ± 0.00 a	0.07 ± 0.00 e	0.10 ± 0.00 ab	0.08 ± 0.00 de	0.10 ± 0.00 ab	0.06 ± 0.00 ef	
Total quantified sugars	3.06 ± 0.03	2.80 ± 0.01	2.92 ± 0.11	3.80 ± 0.16	3.04 ± 0.07	3.17 ± 0.04	2.57 ± 0.19	

Note: The results are expressed as mean ± standard deviation (n = 3). Means followed by the same letter in the row are statistically equal according to Tukey's test at 5% of error probability.

<sup>1</sup>Ascorbic acid quantified by Tillmans's method. Tartaric, citric and formic acids, and sugar rhamnose were not detected on HPLC.

markets due to the fact that ascorbic acid content is one of the most important parameters required for fruit nutraceutical properties and consumption (Belwal et al., 2018).

Malic acid has been reported to be second most abundant acid in acerolas, which is responsible for more than 30% of the total organic acids content in the fruit (Delva & Schneider, 2013; Prakash & Baskaran, 2018; Righetto et al., 2005). In our study, malic was also the second most predominant acid in all acerola genotypes, with values ranging from 0.46 to 1.10 g 100 g<sup>-1</sup> in "BRS 238" and "BRS Sertaneja," respectively. The acerola varieties also presented succinic acid at lower concentrations from 0.05 to 0.09 g 100 g<sup>-1</sup>. Although our study found no detectable amounts of tartaric, citric and formic acids in all genotypes, previous studies have reported that ripe acerola can have an average of 0.38 g 100 g<sup>-1</sup> of malic acid and 0.002 g 100 g<sup>-1</sup> of tartaric and citric acids, depending on the genotype (Righetto et al., 2005).

As for the quantified sugars, the sum of the average values of fructose, glucose and maltose in the varieties ranged from 2.57 to 3.80 g 100 g<sup>-1</sup> (Table 1). The most abundant sugars observed in acerola fruit were fructose and glucose, both at similar proportions. The varieties that had the highest contents of fructose and glucose were "BRS 235," "BRS 238," and "BRS Sertaneja." In the study by Righetto et al. (2005), mean values of 3.33 and 0.88 g 100 g<sup>-1</sup> were reported for fructose and glucose in ripe acerola juice, respectively. Although few studies have characterized individual sugars in acerolas, these are important variables to establish the sweetness and sensory attributes of the fruit. The use of SS alone to estimate the sweetness of acerola is not appropriated, because there are high concentrations of organic acids and other compounds that make up the SS content in the fruit.

Acerola sensory and nutritional quality is closely correlated with the concentration of soluble sugars, organic acids, and secondary metabolites. These compounds play important roles on maintaining fruit quality and nutritive value (Xu et al., 2020).

Previous studies that characterized individual organic acids and sugars in the Brazilian varieties of acerola were not found. In our study, the concentrations of organic acids and sugars were statistically different among acerola varieties. Considering that all genotypes were cultivated under the same environmental conditions, the observed differences are possibly due to the genetic variability among genotypes.

### 3.3 | Individual phenolic compounds quantified by HPLC

The nutraceutical role of phenolic compounds is related to the ability of these substances to neutralize free radicals and reduce oxidative damage in the organism, which could trigger degenerative and pathological processes in humans (Granato et al., 2018).

The profile of phenolic compounds in the new Brazilian varieties of acerola is shown in Table 2. A total of 31 phenolic compounds

were analyzed by RP-HPLC/DAD and presented as mg/kg of fresh fruit weight.

#### 3.3.1 | Flavonoids

According to the results, total phenolics quantified in HPLC was different among genotypes. The varieties "BRS 237" (845.89 mg/kg), "BRS 236" (816.11 mg/kg) and "BRS 235" (810.19 mg/kg) had the highest total phenolics. The anthocyanin cyanidin 3-rhamnoside was the most abundant phenolic compound present in acerolas, with concentrations ranging from 149.93 to 682.26 mg/kg, which represented 49% to 84% of total phenolics observed in the fruit. The highest cyanidin 3-rhamnoside concentrations were observed in the varieties "BRS 235" (682.26 mg/kg), "BRS 236" (666.40 mg/kg), "BRS 237" (663.90 mg/kg), and "BRS 238" (501.88 mg/kg).

Although some studies show cyanidin 3-rhamnoside and pelargonidin 3-rhamnoside as the most abundant anthocyanins in ripe acerolas, other studies show the presence of malvidin 3,5-diglucoside and cyanidin 3-glucoside (Belwal et al., 2018; Delva & Schneider, 2013). In the study by Xu et al. (2020), the anthocyanins cyanidin, delphinidin-3 $\beta$ -D-glucoside, phloretin and peonidin were identified in ripe acerolas. However, the varieties analyzed in these previous studies were not described, which may explain the different results presented in the literature. In addition, only a few studies have quantified individual anthocyanins in acerolas by comparison with external standards. In the study by Oliveira et al. (2012), cyanidin 3-rhamnoside and pelargonidin 3-rhamnoside were the major anthocyanins present in ripe acerolas. However, in this study only cyanidin was quantified and the values for each variety were 52.52 mg 100 g<sup>-1</sup> DW for "BRS 235," 148 mg 100 g<sup>-1</sup> DW for "BRS 236," 241.1 mg 100 g<sup>-1</sup> DW for "BRS 237," and 104.87 mg 100 g<sup>-1</sup> DW for "BRS 238." In addition, according to this study, the total content of anthocyanins in fresh fruit were 64.9 mg/kg for "BRS 235," 91.2 mg/kg for "BRS 236," 173.0 mg/kg for "BRS 237," and 74.2 mg/kg for "BRS 238." Anthocyanins are known to be a class of important flavonoids responsible for the development of the red color in ripe acerola. Indeed, studies have shown that ripening is associated with increasing anthocyanin synthesis and concentration in acerola fruit (Oliveira et al., 2012; Vasavilbazo-Saucedo et al., 2018; Xu et al., 2020).

In our study, the profile of flavanols was statistically different among genotypes. The major flavanols present in most of the varieties were catechin, epicatechin gallate and procyanidin A2. Catechin was the only flavanol present in all varieties, ranging from 6.63 to 25.06 mg/kg in "BRS Sertaneja" and "BRS Cabocla," respectively. Epicatechin was only present in "BRS 235" (0.03 mg/kg). Epicatechin gallate was not detected only in "BRS Cabocla" and was present at concentrations of 2.5 and 7.2 mg/kg in "BRS Sertaneja" and "BRS 235," respectively. Procyanidin A2 was not detected in "BRS Cabocla," but ranged from 5.22 to 9.28 mg/kg in "BRS 366" and "BRS 235," respectively. The highest concentration of procyanidin B1 and

TABLE 2 Individual phenolic compounds of the Brazilian varieties of acerola cultivated in the São Francisco Valley, Brazil

Phenolic compounds (mg/kg)	Acerola varieties						
	"BRS 235" Apodi	"BRS 236" Cereja	"BRS 237" Roxinha	"BRS 238" Frutacor	"BRS 366" Jaburu	"BRS Sertaneja"	"BRS Cabocla"
<b>Flavanols</b>							
(+)-Catechin	8.40 ± 0.30 c	7.98 ± 0.04 c	7.60 ± 0.35 c	12.49 ± 4.12 bc	6.80 ± 0.20 c	6.63 ± 1.30 c	25.06 ± 2.47 a
(-)-Epicatechin	0.03 ± 0.01	ND	ND	ND	ND	ND	ND
(-)-Epicatechin gallate	7.20 ± 0.70 a	5.04 ± 0.49 c	4.37 ± 0.18 cd	5.51 ± 0.98 bc	3.19 ± 0.15 dc	2.50 ± 0.64 e	ND
Procyanidin A2	9.28 ± 0.53 a	8.26 ± 0.16 abc	6.28 ± 1.81 bcd	5.51 ± 1.24 cd	5.22 ± 0.72 d	9.02 ± 1.31 ab	ND
Procyanidin B1	6.40 ± 0.15 b	2.20 ± 1.35 b	0.89 ± 0.05 b	ND	ND	1.27 ± 0.05 b	17.75 ± 6.97 a
Procyanidin B2	4.17 ± 0.37 ab	3.47 ± 0.11 ab	3.47 ± 0.11 ab	8.10 ± 5.66 a	2.49 ± 0.56 b	ND	ND
<b>Flavanones</b>							
Kaempferol 3-glucoside	4.05 ± 0.10 cd	7.08 ± 1.04 ab	8.05 ± 0.08 a	8.30 ± 1.94 a	ND	3.44 ± 0.42 d	6.02 ± 1.26 b
Quercetin 3-glucoside	24.67 ± 1.18 b	32.15 ± 2.10 a	32.88 ± 1.37 a	23.66 ± 1.87 b	13.14 ± 2.31 c	15.55 ± 2.57 cd	ND
Rutin	1.69 ± 0.67 cd	1.94 ± 0.14 bc	1.61 ± 0.19 d	ND	ND	0.62 ± 0.05 d	4.75 ± 3.43 ab
Isorhamnetin	35.83 ± 1.82 cd	45.27 ± 2.54 a	47.01 ± 0.79 a	20.78 ± 4.41 e	39.45 ± 8.81 bc	46.74 ± 2.22 a	28.47 ± 3.77 de
<b>Flavanones</b>							
Naringenin	2.25 ± 0.14 c	13.35 ± 3.75 ab	17.28 ± 0.18 a	5.13 ± 2.87 c	4.34 ± 0.89 c	11.94 ± 1.24 b	4.58 ± 1.49 c
Hesperidin	10.23 ± 0.40 cd	13.62 ± 1.27 bcd	14.90 ± 0.02 bc	19.50 ± 5.50 abc	ND	25.94 ± 0.20 ab	32.62 ± 13.80 a
<b>Anthocyanins</b>							
Cyanidin 3-rhamnoside	682.26 ± 7.01 a	666.40 ± 2.95 a	663.90 ± 0.44 a	501.88 ± 31.80 b	149.93 ± 8.30 d	282.05 ± 2.05 c	157.56 ± 2.56 d
<b>Phenolic acids</b>							
Caffeic acid	ND	ND	ND	ND	0.74 ± 0.23 b	1.10 ± 0.12 b	2.89 ± 1.69 a
trans-Caftaric acid	3.42 ± 0.57 ab	ND	ND	ND	ND	3.68 ± 0.52 ab	4.52 ± 1.11 a
Chlorogenic acid	3.23 ± 0.12 ab	2.90 ± 0.07 abc	2.95 ± 0.12 abc	1.68 ± 0.07 c	3.84 ± 1.42 a	2.36 ± 0.22 bc	1.97 ± 0.11 bc
<b>Stilbene</b>							
trans-Resveratrol	3.08 ± 0.23 ab	3.73 ± 0.29 a	3.85 ± 0.18 a	3.52 ± 0.25 a	2.34 ± 0.40 b	3.06 ± 0.93 ab	ND
Total phenolics quantified in HPLC	810.19 ± 3.03 a	816.11 ± 2.98 a	845.89 ± 34.90 a	631.13 ± 55.90 b	237.02 ± 29.50 d	419.55 ± 4.66 c	295.19 ± 18.60 d
Total phenolic content <sup>1</sup>	14,738 ± 40 de	19,775 ± 630 bc	13,080 ± 140 e	15,483 ± 990 cde	11,884 ± 550 e	25,903 ± 971 a	16,096 ± 500 bcd

Note: The results are expressed as mean ± standard deviation (n = 3). Means followed by the same letter in the row are statistically equal according to Tukey's test at 5% of error probability.

<sup>1</sup>Total phenolic content by Folin-Ciocalteu spectrophotometric method. The compounds epigallocatechin gallate, myricetin, cyanidin 3-glucoside, pelargonidin 3-glucoside, petunidin 3-glucoside, malvidin 3-glucoside, peonidin 3-glucoside, delphinidin 3-glucoside, malvidin 3,5-diglucoside, cyanidin 3,5-diglucoside, pelargonidin 3,5-diglucoside, cis-resveratrol, p-coumaric acid, gallic acid, syringic acid, and cis-resveratrol were not detected on HPLC. ND, not detected.

procyanidin B2 were observed in “BRS Cabocla” (17.75 mg/kg) and “BRS 238” (8.10 mg/kg), respectively.

In the study by Mezadri et al. (2008), the flavanols epicatechin, epigallocatechin gallate and procyanidin B1 were analyzed in six samples of frozen acerola pulps. According to the results, epicatechin was not detected, epigallocatechin gallate was present in two samples (0.74 and 0.79 mg/L) and procyanidin B1 was present in all samples, ranging from 1.38 to 1.53 mg/L. Nascimento et al. (2018) analyzed eight phenolic compounds by HPLC/DAD in lyophilized acerolas harvested at three maturity stages (variety not described) and observed that the content of phenolic compounds gradually increased from green to ripe acerola. In this study, lyophilized fruit had 8.71 mg/g of catechin and 7.04 mg/g of epicatechin.

In relation to flavonols, the compounds isorhamnetin > quercetin 3-glucoside > kaempferol 3-glucoside > rutin (quercetin 3-rutinoside) were present in all acerola varieties (Table 2). Regarding isorhamnetin, the varieties that showed the highest concentrations were “BRS 237” (47.01 mg/kg), “BRS Sertaneja” (46.74 mg/kg), and “BRS 236” (45.27 mg/kg). The varieties that stood out in relation to quercetin 3-glucoside were “BRS 237” (32.88 mg/kg) and “BRS 236” (32.15 mg/kg). In the study by Oliveira et al. (2012), dehydrated ripe acerolas of the varieties “BRS 235,” “BRS 236,” “BRS 237,” and “BRS 238” showed quercetin concentrations in the range between 12.81 to 33.49 mg 100 g<sup>-1</sup> DW, being the highest concentration observed in “BRS 238” acerola. Mezadri et al. (2008) observed levels of rutin in frozen ripe acerolas ranging from 0.58 to 1.60 mg/kg, which are lower than the levels observed in our study that were 7.09 mg/kg for “BRS 238,” 4.99 mg/kg for “BRS 366” and 4.75 mg/kg for “BRS Cabocla.” In our study, “BRS 238” stood out for presenting the highest content of kaempferol 3-glucoside (15.38 mg/kg). Accordingly, other studies have also shown the presence of kaempferol in dehydrated ripe acerola at the concentration of 14.26 mg/kg DW (Bataglion et al., 2015).

The flavanones naringenin and hesperidin were present in all acerola varieties, with the exception of “BRS 366” that had no detectable amount of hesperidin. The varieties with the highest levels of naringenin were “BRS 237” (17.28 mg/kg), “BRS 236” (13.35 mg/kg) and “BRS Sertaneja” (11.94 mg/kg). The varieties with the highest levels of hesperidin were “BRS Cabocla” (36.62 mg/kg), “BRS Sertaneja” (25.94 mg/kg) and “BRS 238” (19.50 mg/kg). Other studies that have analyzed flavanones in acerola fruit were not found in the literature. According to Oroion and Escheriche (2015) flavanones are bioactive compounds commonly found in citrus fruit such as oranges, lemons and tangerines. In addition, Tabart et al. (2009) have also mentioned that naringenin and hesperidin have in vitro antioxidant activity, which can have an important role on increasing acerola bioactive properties.

### 3.3.2 | Phenolic acids and stilbenes

Among the phenolic acids evaluated, chlorogenic acid was the only one present in all genotypes, ranging from 1.68 to 3.84 mg/kg. The

varieties that presented the highest chlorogenic acid content were “BRS 366” and “BRS 235,” with 3.84 and 3.23 mg/kg, respectively. Nascimento et al. (2018) also analyzed phenolic acids in acerola fruit, observing caffeic acid, gallic acid, and ellagic acid at concentrations of 8.71, 5.36, and 2.53 g/kg, respectively. In our study, *trans*-caftaric acid was observed at higher concentrations in “BRS 235” (7.25 mg/kg) and “BRS 366” (5.97 mg/kg), whereas caffeic acid was observed at higher concentrations in “BRS Cabocla” (2.89 mg/kg) and “BRS Sertaneja” (1.10 mg/kg). Other studies have also reported the presence of chlorogenic acid at 11.52 mg/kg, as well as *p*-coumaric and ferulic acids at smaller concentrations in ripe acerola (Cruz et al., 2019; Mezadri et al., 2008; Xu et al., 2020).

Regarding stilbenes, *trans*-resveratrol and *cis*-resveratrol were analyzed in our study. However, only *trans*-resveratrol was detected in most of the varieties, with the exception of BRS Cabocla. The concentrations of *trans*-resveratrol in acerola fruit ranged from 2.34 to 3.85 mg/kg in the varieties “BRS 366” and “BRS 237,” respectively. These results show for the first time the present of *trans*-resveratrol in acerola fruit, which is known to play an important role on fruit nutraceutical properties. The levels of *trans*-resveratrol obtained in the present study are similar to those found in grapes and wines (Lucena et al., 2010; Padilha et al., 2019), which are known as important sources of this compound.

The phenolic profile differences among acerola genotypes have been mainly attributed to the genetic diversity, as well as the environmental conditions (Hanamura et al., 2008; Xu et al., 2020). In general, there are a limited number of studies analyzing different classes of phenolic compounds in specific acerola varieties. Our study shows for the first time a complex and diverse composition of phenolic compounds in different acerola genotypes. Considering the large diversity of acerola genotypes and cultivation conditions (Ritzinger et al., 2018), future studies should be accomplished to better understand the phenolic profile of different genotypes cultivated under different environmental conditions.

## 3.4 | TPC and in vitro AOX

The TPC, measured with Folin-Ciocalteu reagent, is shown in Table 2. There were significant differences ( $p < .05$ ) for the TPC among the Brazilian varieties of acerola. The TPC ranged from 13,080 to 25,903 mg/kg, being the highest concentrations observed in “BRS Sertaneja” (25,903 mg/kg) and “BRS 236” (19,775 mg/kg). The studies of Souza et al. (2014), Oliveira et al. (2012), and Mariano-Nasser et al. (2017) have also shown that TPC of ripe acerola can reach values of 26,310 mg/kg for “BRS 366,” 9,142–9,690 mg/kg for “BRS 235,” 10,990–24,280 mg/kg for “BRS 236,” 10,210–16,680 mg/kg for “BRS 237,” and 9,310–10,238 mg/kg for “BRS 238,” which are in agreement with the concentrations observed in our study.

The in vitro AOX is other analysis that can be used to characterize acerola bioactive properties (Mezadri et al., 2008; Nascimento et al., 2018; Oliveira et al., 2012; Xu et al., 2020). The antioxidant activity of phenolic compounds and ascorbic acid is based on the



transfer of hydrogen atoms or electrons to free radicals, as well as the reduction of transition metals (Granato et al., 2018). In our study, the AOX of acerola varieties was determined by radical scavenging methods with DPPH and ABTS, and by the FRAP method. In our study, the AOX of Brazilian acerola varieties was determined by radical scavenging methods with DPPH and ABTS, and by the FRAP method. The results were expressed as Trolox equivalents per kilogram of fresh skin and pulp ( $\text{mmol TE kg}^{-1}$ ) and  $\text{mmol of Fe}^{2+}$  per kilogram of fresh skin and pulp ( $\text{mmol Fe}^{2+} \text{ kg}^{-1}$ ).

The AOX results obtained for the acerola varieties are shown in Figure 1. Based on the DPPH method, the AOX values ranged from 138.1 to 200.0  $\text{mmol TE kg}^{-1}$ , being the highest values observed in "BRS Sertaneja" (200.0  $\text{mmol TE kg}^{-1}$ ), "BRS 237" (186.2  $\text{mmol TE kg}^{-1}$ ), and "BRS 235" (170.3  $\text{mmol TE kg}^{-1}$ ). Based on the ABTS method, the AOX values ranged from 135.7 to 208.3  $\text{mmol TE kg}^{-1}$ , being the highest values observed in "BRS Sertaneja" (208.2  $\text{mmol TE kg}^{-1}$ ), and "BRS 236" (167.3  $\text{mmol TE kg}^{-1}$ ). Based on the FRAP method, the AOX values ranged from 293.3 to 535.4  $\text{mmol Fe}^{2+} \text{ kg}^{-1}$ , being the highest values observed in "BRS Sertaneja" (535.1  $\text{mmol Fe}^{2+} \text{ kg}^{-1}$ ), "BRS 366" (440.6  $\text{mmol Fe}^{2+} \text{ kg}^{-1}$ ), and "BRS 238" (425.7  $\text{mmol Fe}^{2+} \text{ kg}^{-1}$ ).

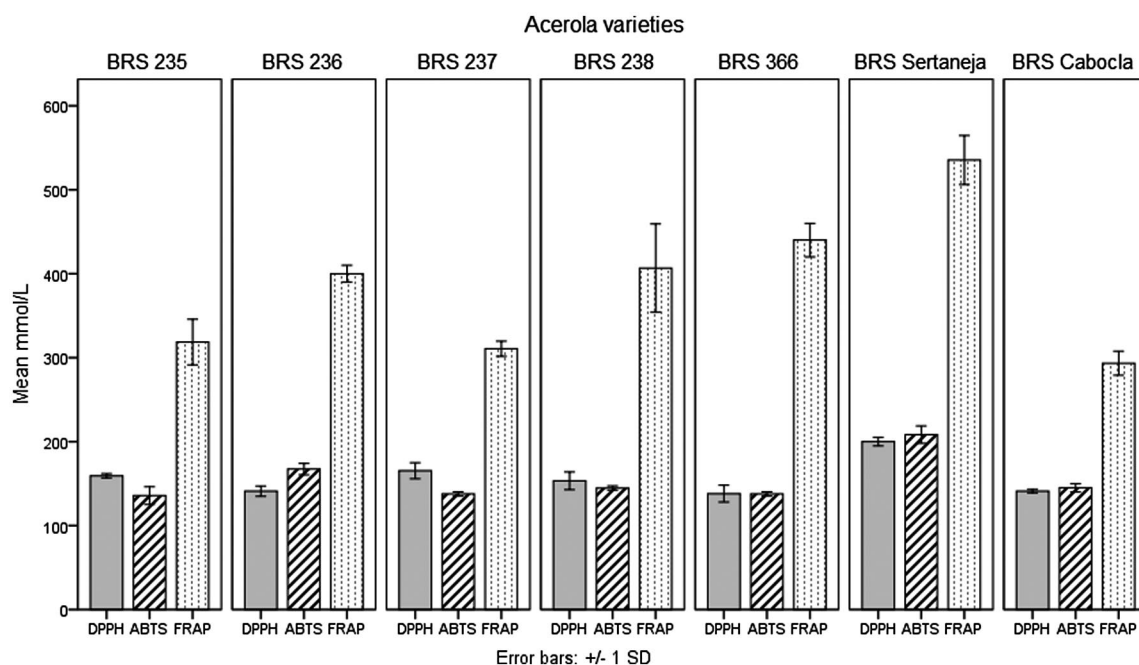
Previous studies that analyzed acerolas AOX with the ABTS method have shown values of 42.4  $\text{mmol TE kg}^{-1}$  in "BRS 366" (Souza et al., 2014), 91.4  $\text{mmol TE kg}^{-1}$  in "BRS 235," 105.6  $\text{mmol TE kg}^{-1}$  in "BRS 236," 75.6  $\text{mmol TE kg}^{-1}$  in "BRS 237," and 59.8  $\text{mmol TE kg}^{-1}$  in "BRS 238" (Oliveira et al., 2012). In the study by Xu et al. (2020), the AOX of ripe acerolas was about 70  $\text{mmol TE kg}^{-1}$  with both DPPH and ABTS methods. In general, the AOX of green acerolas is higher than red ripe acerolas, which is mostly explained by the higher ascorbic acid content in less mature fruit (Cruz et al., 2019; Oliveira

et al., 2012; Xu et al., 2020). These studies have also shown higher AOX due to higher concentrations of ascorbic acid and phenolic compounds in acerola fruit.

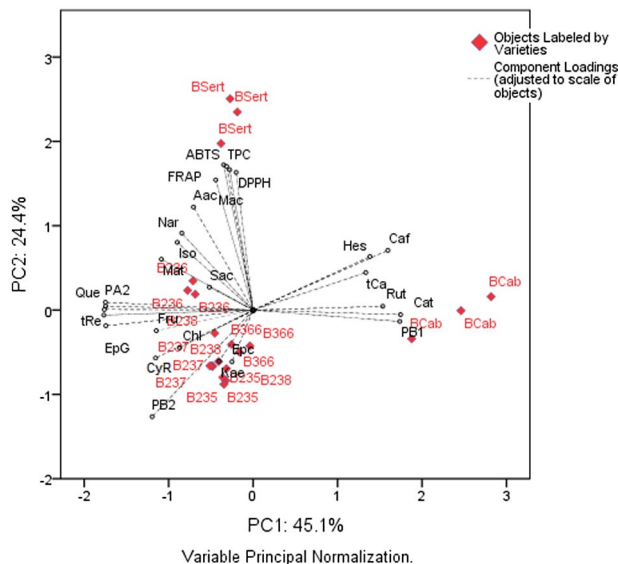
In the present study, the AOX values obtained in the Brazilian varieties of acerola were higher than those reported in other studies, demonstrating that these varieties have also higher nutraceutical properties. These results are explained by the fact that acerola breeding programs in Brazil are focusing on developing new varieties with higher bioactive compounds and nutraceutical properties (Ritzinger et al., 2018).

### 3.5 | PCA of acerola genotypes and nutraceutical properties

Acerola genotypes and nutraceutical properties were subjected to PCA (Figure 2). According to the results, PC1 and PC2 explained 69.5% of the total variance of the experiment, where PC1 explained most of the variance with 45.1%. PC1 separated the variety "BRS Cabocla" from the others with a positive loading ( $\text{PC1} > 0$ ), and PC2 separated the variety "BRS Sertaneja" from the others with a positive loading ( $\text{PC2} > 0$ ). The factor analysis adopted to determine the variables responsible for the separations was the component loading  $\geq 0.70$ . The separation of "BRS Cabocla" occurred due to its higher concentrations of caffeic acid, trans-caftaric acid, catechin, procyanidin B1, rutin and hesperidin, and lower values of epicatechin gallate, procyanidin A2, quercetin, trans-resveratrol, and glucose, compared to the other varieties. The separation of "BRS Sertaneja" occurred due to its higher values of malic acid, ascorbic acid, TPC, and AOX determined by DPPH, ABTS, and



**FIGURE 1** Antioxidant capacity of the Brazilian varieties of acerola planted in the São Francisco Valley, Brazil. DPPH and ABTS, antioxidant capacity equivalent to  $\text{mmol Trolox kg}^{-1}$  FW. FRAP, antioxidant capacity equivalent to  $\text{mmol Fe}^{2+} \text{ kg}^{-1}$  FW



**FIGURE 2** Principal components analysis. Acerolas: BScert, BRS Sertaneja; BScab, BRS Cabocla; B235, BRS 235; B236, BRS 236; B237, BRS 237; B238, BRS 238; B366, BRS 366. Aac, ascorbic acid; Caf, caffeic acid; Cat, catechin; Chl, chlorogenic acid; CyR, cyanidin 3-rhamnoside; DPPH, ABTS, and FRAP, antioxidant capacity; Epc, epicatechin; EpG, epicatechin gallate; Fru, fructose; Glu, glucose; Hes, hesperidin; Iso, isorhamnetin; Kae, kaempferol; Mac, malic acid; Mat, maltose; Nar, naringenin; PA2, procyanidin A2; PB1, procyanidin B1; PB2, procyanidin B2; Que, quercetin 3-glucoside; Rut, rutin; Sac, succinic acid; tCa, trans caftaric acid; TPC, total phenolic content; tRe, trans-resveratrol

FRAP, compared to the other varieties. The other varieties did not show high component weights that could indicate differences related to the nutraceutical properties analyzed in our study. The PC2 strongly correlated the AOX (DPPH, ABTS, and FRAP) with the TPC, which corroborates with previous studies showing strong correlation between the AOX and the TPC in ripe acerolas (Mezadri et al., 2008; Nascimento et al., 2018; Oliveira et al., 2012; Xu et al., 2020).

## 4 | CONCLUSIONS

The Brazilian varieties of acerola showed high levels of ascorbic and malic acids, as well as small quantities of succinic acid. The highest levels of ascorbic and malic acids were observed in “BRS Sertaneja.”

The main sugars observed in the fruit of all acerola genotypes were glucose and fructose. Cyanidin 3-rhamnoside was the most abundant phenolic compound present in acerola, representing between 49% and 84% of total phenolics, which showed the highest concentration in the varieties BRS 235 (Apodi), BRS 236 (Cereja) and BRS 237 (Roxinha). Quercetin 3-glucoside, isorhamnetin, catechin, procyanidin A2, naringenin, hesperidin, chlorogenic acid, and trans-resveratrol were phenolic compounds also present in most of the varieties.

All acerola genotypes had high AOX, with the highest value observed in “BRS Sertaneja.”

Acerola composition is highly determined by the genotype.

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## CONFLICT OF INTEREST

The authors declared that they have no conflict of interest.

## AUTHOR CONTRIBUTIONS

**Ianca Carneiro Ferreira:** Conceptualization; Formal analysis; Investigation. **Vagner Pereira da Silva:** Formal analysis. **João Claudio Vilvert:** Formal analysis; Writing-original draft. **Flávio de França Souza:** Data curation; Investigation. **Sérgio Tonetto de Freitas:** Conceptualization; Writing-review & editing. **Marcos dos Santos Lima:** Conceptualization; Methodology; Project administration; Writing-original draft.

## DATA AVAILABILITY STATEMENT

Research data are not shared.

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#### SUPPORTING INFORMATION

Additional Supporting Information may be found online in the Supporting Information section.

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