Comparison of the physicochemical properties and biological compounds of acerola fruit varieties grown in Vietnam through the various maturation stages

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ABSTRACT

The objective of the present study was to find the changes in physicochemical properties, bioactive compounds, and antioxidant activity of acerola fruits under different cultivars (i.e., Brazilian acerola (*Malpighia emarginata* D.C) and sour acerola (*Malpighia glabra* L.)) and maturation stages (unripe, half-ripe, and ripe). For any species, the study found an increase in total soluble solid and a* value, whereas there was a decrease in the content of bioactive compounds (i.e., polyphenols, flavonoids, vitamin C), total acidity, and antioxidant activity, which followed the maturation development of fruits. Briefly, the unripe acerola fruits (Brazillan cultivar) were an excellent source of vitamin C (32.97 mg/g) and phenolic content (25.62 mg GAE/g).

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1. Introduction

The tropical fruit like acerola is not only high in ascorbic acid but also a source of phenolic compounds and flavonoids. Hence, this fruit is being used as a nutritional dietary supplement for enhancing immune response, antioxidant capability, and dietary requirements. (Hanamura et al., 2005). Besides being a functional material good for human health, acerola could be used as an ingredient for making various delicious food and beverage products such as nectar, jam, powder, fermented drinks, and ice cream (Hoang et al., 2022). Acerola fruits are extensively grown in some regions of Vietnam's Mekong Delta. The yield of this fruit is noticeably high in Tien Giang province.

There are two major acerola fruit cultivars in Vietnam: Malpighia glabra L. (Vietnamese called it sour acerola fruit) and Malpighia emarginata D.C. (Vietnamese called it Brazilian acerola fruit). The raw material characteristics are one of the most important factors influencing the final product's quality. The previous studies about pomegranate (Al-Maiman & Ahmad, 2002), mango (Barbosa-Gamez et al., 2017), and mulberry (Mahmood et al., 2012) revealed the phytochemical compositions, bioactive compounds, and bio-functions of fruit modified during the maturation period. On the other hand, these attributes were affected by the plant cultivar (Ribeiro & Freitas, 2020). However, there has not been any available information about the impact of both factors on the physicochemical properties of acerola fruit varieties grown in Vietnam.

2. Material and Methods

2.1. Materials

The two varieties of acerola, including sour acerola fruits (SAF) and Brazilian acerola fruits (BAF), were purchased from cooperative gardeners in Go Cong town, Tien Giang province, during the summer of 2022. The fruits were not damaged, moldy, or rotten. Acerola was collected, washed, and drained: After pretreatment, both materials were divided into 3 different maturity levels, such as unripe, half-ripe, and ripe, based on their visual appearance (Tables 1 & 2). All samples were packed into plastic bags and stored in a freezer until used for analysis. The sampling was carried out in 3 replications, where each iteration was performed with 200 g (approximately 45 fruits).

Table 1. Experimental design-matrix encoding the independent variables

Maturity	Brazilian acerola (*Malpighia emarginata* D.C).		Sour acerola (*Malpighia glabra* L.)	
Unripe				
Half-ripe				
Ripe				

Table 2. Organoleptic properties of acerola fruit at the different maturity indexes and varieties

Maturity	Brazilian acerola (*Malpighia emarginata* D.C).	Sour acerola (*Malpighia glabra* L.)
Unripe	Bold greenness	Bright greenness
	Hard	Hard
	Sour	Quite Sour
	Uncharacteristic aroma	Uncharacteristic aroma
Half-ripe	Orange yellow	Orange yellow
	Semi-soft	Semi-soft
	Sour and a little sweet	Little sour and a little sweet
	Uncharacteristic aroma	Uncharacteristic aroma
Ripe	Redness	Redness
	Juicy	Juicy
	Sweet and little sour	Sweet and little sour
	A quite characteristic aroma	Strong aroma

2.2. Chemical

The chemicals used for this assay were Na_2CO_3 ≥ 99,5%, $AlCl_3$, CH_3COONa, NaOH, Methanol 100%, Iodine, Starch, (Xilong, China); Gallic acid 99%, Quercetin (95%), Ascorbic acid, Folin - Ciocalteu 99.5% (Sigma Aldrich, USA); 2.2-diphenyl-1-picrylhydrazyl (DPPH) and 2.2'-azisbonis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium (ABTS) (TCI, Japan).

2.3. Analytical method

2.3.1. Moisture content

The samples were weighed and dried in an oven (Memmert UM200, Atmosafe, Germany) at 105^{0}C until the weight remained constant. The samples were cooled in a desiccator untill cool and weighed. Moisture content was measured according to the formula:

$$MC = \frac{m1 - m2}{m1} \times 100\%$$

Where: MC is moisture content (%); m1 is the sample weight before drying (g); m2 is the sample weight after drying (g).

2.3.2. Ascorbic acid measurement

The procedure was carried out according to Pathy (2018). Weigh 10 g of the crushed sample dissolved in distilled water and makeup to 100 mL. Add 2 drops of 0.2% HCl to stabilize the sample for 10 min. Take 10 mL of the diluted sample, add 2 drops of the saturated starch solution, and titrate with the 0.01 N iodine solution. Ascorbic acid content was calculated according to the formula:

$$X\ (mg/g) = \frac{V \times V_1\ x\ 0.88}{V_2\ x\ m\ x}$$

Where: V: mL of 0.01 N I_2 that used for titration, V_1: volume of sample solution used in the experiment, V_2: volume of sample solution taken to determine vitamin C content, 0.88: The mg of vitamin C corresponds to 1 mL of 0.01 N I_2 solution, m: sample mass (g).

2.3.3. Total phenolic content (TPC)

The antioxidant components in acerola fruits were extracted with methanol using a modified version of the Xu et al. (2008) method. One g of the crushed acerola fruit was weighed into a 50 mL falcon tube. The extraction procedure was performed with 9 mL of 80% methanol for 30 min at room temperature 29 - 31°C, in a dark condition. Next, the sample was filtered through a filter paper to collect the solution.

The TPC measurement is referenced according to Lim et al. (2007). In a test tube, 0.3 mL diluted acerola fruit solution was vortexed with 1.5 mL Folin-Ciocalteu 10%. Samples were allowed to stand for 5 min in a darkened area. The mixture was then mixed thoroughly with 1.2 mL of 7.5% Na_2CO_3 and left for 30 min. The samples were tested for optical density (OD) by using a UV-Visible Spectrophotometer (V730, Germany) at a wavelength of 765 nm. The standard curve was carried out using gallic acid and TPC was performed as mg gallic acid equivalent (GAE)/g.

$$TPC = \frac{(y - b)\ x\ V\ x\ df}{a\ x\ m\ x\ 1000}$$

Where y: OD value of sample. a and b are the coefficient in the standard curve. V: volume of extracted solution (mL). DF: dilution factor. m: sample mass (g). 1/1000: the coefficient converts from µg/g to mg/g.

2.3.4. Total flavonoid content (TFC)

The TFC measurement is referenced according to Do et al. (2014). The aliquot of 2 mL of extract was mixed well with 0.1 mL of 10% AlCl3 solution and 0.1 mL of 0.1 mM CH3COOK solution. After that, the samples were kept at room temperature for 30 min in dark condition. The total flavonoid content was measured by using a spectrophotometer (UV-Visible Spectrophotometer, V730, Germany) at a wavelength of 415 nm. The standard curve was carried out using quercetin solution and TFC was performed as mg quercetin equivalent (QE)/g

$$TFC = \frac{(y - b)\ x\ V\ x\ df}{a\ x\ m\ x\ 1000}$$

Where y: OD value of sample. a and b are the coefficient in the standard curve. V: volume of extracted solution (mL). DF: dilution factor. m: sample mass (g). 1/1000: the coefficient converts from µg/g to mg/g.

2.3.5. DPPH assay

The DPPH reagent was used for antioxidant activity determination (Phuong et al., 2020) The aliquot of 0.2 mL of extract was added to 4 mL of 0.1 mM DPPH solution. After vortexing, the samples were left for 30 min in dark condition. The antioxidant activity was determined by using a spectrophotometer (UV-Visible Spectrophotometer, V730, Germany) at a wavelength of 517 nm. The standard curve was prepared using solutions of ascorbic acid (AA) and antioxidant activity was expressed as mg AAE (ascorbic acid equivalent)/g.

$$DPPH = \frac{(y - b)\ x\ V\ x\ df}{a\ x\ m\ x \times 1000}$$

Where y: OD value of sample. a and b are the coefficient in the standard curve. V: volume of extracted solution (mL). DF: dilution factor. m: sample mass (g). 1/1000: the coefficient converts from µg/g to mg/g.

2.3.6. ABTS assay

The ABTS assay was used for antioxidant activity determination (Phuong et al., 2020). The aliquot of 80 µL of the extract was added to 3.2 mL of ABTS working solution. After shaking well, the samples were left for 5 min in a dark condition. The antioxidant activity was determined by using a spectrophotometer (UV-Visible Spectrophotometer, V730, Germany) at a wavelength of 734 nm. The standard curve was prepared using solutions of ascorbic acid (AA) and antioxidant activity was expressed as mg AAE/g.

$$ABTS = \frac{(y - b)\ x\ V\ x\ df}{a\ x\ m\ x \times 1000}$$

Where y: OD value of sample. a and b are the coefficient in the standard curve. V: volume of extracted solution (mL). DF: dilution factor. m: sample mass (g). 1/1000: the coefficient converts from µg/g to mg/g.

2.3.7. Color measurement

The color parameters were performed and expressed in the color space CIE L*a*b* by using a handheld chroma meter (Konica Minolta, CR-400, Japan). Where, L* indicated the bright from darkness (zero value) to lightness (positive value), a* indicated the color from greenness (-a*) to redness (+a*), and b* indicated the color from blueness (-b*) to yellowness (+b*).

2.3.8. Physicochemical properties

The total soluble solid (TSS) was determined by a hand-held refractometer (ATAGO 0.0 ~ 33.0%, Japan). The titration procedure with 0.1 N NaOH and 1% phenolphthalein as an indicator was used to determine the total acidity (TA). The fruit size such as weight and length were evaluated by using an electronic balance (FX-1200i, A&D, Japan) and digital caliper (150 mm, Miyutoyo, Japan), respectively. The pH was measured using a pH meter (Hanna, HI2210-02, Romania).

2.3.9. Statistical analysis

The methods such as One way-ANOVA and least significant difference (LSD) which were applied by using software JMP version 13 with P = 0.05.

3. Results and Discussion

3.1. Physicochemical properties parameter

Regarding morphological characteristics, the shape of the acerola fruit was different under the various cultivars (Table 1). For example, the Brazilian acerola had a long, round shape with three lobes (zones) and a surface with sharp notches, while the sour acerola had a round, smooth, glossy surface with three lobes (zones). Besides, the current study found a development of the fruit size during maturation progression (Table 3). Herein, the diameter expanded gradually from 1.64 to 1.87 mm (BAF) and from 1.64 to 1.85 mm (SAF), while the weight of fruit increased continuously from 5.08 to 5.95 g (BAF) and from 4.40 to 4.63 g (SAF). However, the statistical analysis showed no different significance among the samples at $P > 0.05$ for both attributes.

On the other hand, the current study obtained different statistical significance for color properties among fruits under the various maturation stages. Table 3 displayed an a* value that increased dramatically from -16.74 to 44.34 (BAF) and from -13.14 to 47.72 (SAF), where a* indicated the red tones at a positive value and the green tones at a negative value. Moreover,

Table 3 also performed the highest value of b* at half-ripe fruit; herein, b* indicated the yellow tones at a positive value and the blue tones at a negative value. Another study about the acerola (Malpighia punicifolia L) also recorded that b* had the peak value (12.13) at an immature stage, while a* (25.97) was achieved at the mature stage (Vendramini & Trugo, 2000).

The report of several authors also obtained the external appearance color of acerola fruit transferred from green to red (Batista-Silva et al., 2018; Ribeiro & Freitas, 2020). The reason could come from the change in pigment compounds such as β-carotene, cryptoxanthin, lutein, and violaxanthin (Mezadri et al., 2005). The research on acerola fruit planted in Brazil (Lima et al., 2005) and *Maclura tricuspidata* (Kim et al., 2019) pointed out that the enhancement of carotenoid concentration in fruit pulp during the ripening period was considerable. In addition, the increase in the action of the chlorophyllase enzyme caused chlorophyll degradation (Nassur et al., 2015).

Generally, TSS, total acidity, and pH of both acerola fruit cultivars changed during ripening. (Table 3). Herein, the TSS increased slightly from 7.10% to 7.93% (BAF), and from 8.00% to 8.30% (SAF); due to the action of an enzyme promoted during the maturation process, which leads to the hydrolysis of starch and polysaccharides into simple sugar (Kulkarni & Aradhya, 2005). Whereas TA dropped slightly from 1.63% to 1.02% (BAF), and from 0.91 to 0.76% (SAF). Organic acid can be used as a material for fruit's respiration during maturation, leading to a reduction in the acidity of fruit (Mini, 2017). In comparison with the various studies, the behavior of soluble solids and acidity in fruit during ripening showed variation among the different fruits. For example, TSS of mango (Nassur et al., 2015; Barbosa-Gamez et al., 2017) and *Bunchosia glandulifera* fruit (Blank et al., 2018) amplified during the growth of fruit, whereas TSS seems unchanged for pomegranate (Al-Maiman & Ahmad, 2002). TA of mango (Nassur et al., 2015; Barbosa-Gamez et al., 2017) and pomegranate fruits (Al-Maiman & Ahmad, 2002) decreased during ripeness, while TA increased for *Bunchosia glandulifera* fruit (Blank et al., 2018). The pH value of BAF lower than SAF for any maturation index. The pH changed from 3.13 to 3.09 (BAF), and from 3.43 to 3.38 (SAF) from unripe to ripe.

Table 3. Effect of maturity indexes and acerola fruit varieties on the physicochemical properties of fruits

Attributes	Varieties					
	Brazilian acerola (*Malpighia emarginata* D.C)			Sour acerola (*Malpighia glabra* L.)		
	Unripe	Half-ripe	Ripe	Unripe	Half-ripe	Ripe
TSS (%)	$7.10^{d} \pm 0.08$	$7.60^{c} \pm 0.14$	$7.93^{b} \pm 0.05$	$8.00^{b} \pm 0.08$	$8.10^{b} \pm 0.08$	$8.30^{a} \pm 0.08$
TA (%)	$1.63^{a} \pm 0.04$	$1.21^{b} \pm 0.03$	$1.02^{c} \pm 0.02$	$0.91^{d} \pm 0.15$	$0.86^{d} \pm 0.11$	$0.76^{e} \pm 0.28$
pH	$3.13^{c} \pm 0.02$	$3.08^{d} \pm 0.01$	$3.09^{d} \pm 0.02$	$3.36^{b} \pm 0.01$	$3.43^{a} \pm 0.02$	$3.38^{b} \pm 0.00$
Diameter (mm)	$1.64^{a} \pm 0.32$	$1.80^{a} \pm 0.23$	$1.87^{a} \pm 0.32$	$1.64^{a} \pm 0.25$	$1.70^{a} \pm 0.17$	$1.85^{a} \pm 0.26$
Weight (g)	$5.08^{b} \pm 0.31$	$5.89^{a} \pm 0.15$	$5.95^{a} \pm 0.08$	$4.40^{c} \pm 0.24$	$4.63^{c} \pm 0.13$	$4.74^{b} \pm 0.05$
L*	$44.94^{cd} \pm 1.80$	$60.82^{b} \pm 3.65$	$40.8^{d} \pm 2.66$	$68.18^{a} \pm 1.04$	$65.42^{ab} \pm 2.19$	$47.92^{c} \pm 2.98$
a*	$-16.74^{f} \pm 0.41$	$27.14^{c} \pm 0.59$	$44.34^{b} \pm 0.64$	$-13.14^{e} \pm 0.55$	$11.27^{d} \pm 1.37$	$47.72^{a} \pm 1.34$
b*	$34.00^{b} \pm 0.82$	$44.86^{a} \pm 1.26$	$34.17^{b} \pm 3.84$	$42.66^{a} \pm 2.13$	$44.06^{a} \pm 0.72$	$40.59^{a} \pm 1.96$
Moisture content (%)	$93.92^{f} \pm 0.02$	$94.22^{e} \pm 0.06$	$94.64^{d} \pm 0.14$	$92.27^{c} \pm 0.02$	$91.40^{b} \pm 0.04$	$91.08^{a} \pm 0.04$

All data are the mean ± SD of three replicates. The data within a row followed by the same superscript letter (a, b, c) are not statistically significant difference. TSS: total soluble solid; TA: total acidity.

3.2. Bioactive compounds and antioxidant activity

As fruit maturity progressed, this study observed the reduction of bioactive compounds such as vitamin C, polyphenols, and flavonoids in acerola fruit. There were significant differences ($P < 0.05$) in these attributes among varieties, wherein the unripe fruit had the highest value, and the ripe fruit had the lowest value (Table 4). For instance, the vitamin C content of the unripe fruit of BAF was the highest at 32.97 mg/g, which was significantly different compared to the ripe fruits (17.89 mg/g). Similarly, unripe fruit of SAF had a vitamin C content (18.95 mg/g) greater than ripe fruit (13.23 mg/g). Similarly, the significantly highest TPC was 25.62 mg/g for the unripe fruit of the Brazilian variety, while the ripe fruit of the sour variety had the lowest value (12.97 mg/g). The degradation of polyphenols may be affected by the actions of some enzymatic browning (e.g., polyphenol oxidase) during the development of fruit. Another reason is that phenolic compounds may be used as substrates for the biosynthesis of different compounds (Kulkarni & Aradhya, 2005). Likewise, the deterioration of TFC during ripening also obtained from 0.092 to 0.063 mg/g (BAF) and from 0.064 to 0.062 (SAF). Moreover, Table 4 showed the content of vitamin C, TPC, and TFC in BAF was 2 times higher than that in SAF within a ripeness index. As a result of this phenomenon, the antioxidant activity of BAF was stronger compared to that of SAF. The antioxidant activity of the unripe fruit of BAF was 0.19 mg/g (DPPH assay) and 26.17 mg/g (ABTS assay), while its value reached 0.15 mg/g (DPPH assay) and 15.05 mg/g (ABTS assay) for SAF.

The loss of TPC and vitamin C as well as antioxidant activity in acerola fruit samples from unripe to fully ripe stages is consistent

with various fruits such as *Maclura tricuspidata* (Kim et al., 2019), mango (Barbosa-Gamez et al., 2017), and pomegranate (Al-Maiman & Ahmad, 2002). However, the different studies obtained an increase in TFC and TPC in mulberry pulp (Mahmood et al., 2012), and *Cudrania tricuspidata* (Shin et al., 2015), *Bunchosia glandulifera* (Blank et al., 2018) during ripeness progression. It could be concluded that there is no general pattern for the variation of biological compounds and antioxidant activity of fruit during the ripening period. The change in these properties belongs to the horticultural condition and genotype type (Mahmood et al., 2012; Barbosa-Gamez et al., 2017).

The vitamin C content and TPC of acerola fruit samples in the current study are higher than in previous studies. For acerola fruit (*Malpighia emarginata* DC) samples planted in Brazil, the vitamin C content of fresh pulp from immature to mature ranged from 2424 to 957 mg/100 g (de-Assis et al., 2001), 1900 - 970 mg/100 g (Righetto et al., 2005). The other studies on acerola fruits (*Malpighia glabra* L.) verified their antioxidant activity of 959.1 mg/100 g (DPPH assay), and 1198.9 mg/100 g (ABTS assay), total phenolics of 1055.9 mg/100 g (Kuskosk et al., 2005). These data are different compared to our results due to the different weather conditions, farming techniques, and locations.

Table 4 also displayed the phenolic content in acerola fruit is higher than that of apples (1.97 mg/100 g), blackberries (3.01 mg/100 g), oranges (0.75 mg/100 g), and pomegranates (1.33 mg/100 g), soursop (54.8 mg/100 g), pineapple (38.1 mg/100 g), sweetsop (81.7 mg/100 g), jackfruit (29.0 mg/100 g) (Ruiz-Torralba et al., 2018; Almeida et al., 2011). Likewise, the vitamin C content in acerola fruit is higher than kiwi (0.92 mg/100 g), orange (0.59 mg/100 g), lime (0.29 mg/100 g), apple (0.04 mg/100 g), soursop (3.3 mg/100 g), pineapple (13.0 mg/100 g), sweetsop (29.6 mg/100 g), jackfruit (1.2 mg/100 g) (Almeida et al., 2011; Mieszczakowska-Frąc et al., 2021).

Table 4. Effect of maturity indexes and varieties on the antioxidant compounds in acerola fruits

Characteristic	Varieties					
	Brazilian acerola (*Malpighia emarginata* D.C)			Sour acerola (*Malpighia glabra* L.)		
	Unripe	Half-ripe	Ripe	Unripe	Half-ripe	Ripe
Vitamin C (mg/g)	$32.97^{a} \pm 0.04$	$21.82^{b} \pm 0.12$	$17.89^{d} \pm 0.3$	$18.95^{c} \pm 0.29$	$17.34^{d} \pm 0.37$	$13.23^{e} \pm 0.32$
TPC (mg GAE/g)	$25.62^{a} \pm 0.3$	$18.57^{b} \pm 0.19$	$16.31^{c} \pm 0.43$	$15.65^{c} \pm 0.34$	$13.68^{d} \pm 0.46$	$12.97^{d} \pm 0.29$
TFC (mg QE/g)	$0.092^{a} \pm 0.008$	$0.063^{b} \pm 0.002$	$0.057^{bc} \pm 0.001$	$0.064^{b} \pm 0.001$	$0.065^{b} \pm 0.001$	$0.062^{b} \pm 0.002$
DPPH (mg AAE/g)	$0.19^{a} \pm 0.01$	$0.16^{b} \pm 0.01$	$0.13^{c} \pm 0.01$	$0.15^{d} \pm 0.01$	$0.11^{e} \pm 0.01$	$0.06^{f} \pm 0.01$
ABTS (mg AAE /g)	$26.17^{a} \pm 1.06$	$17.72^{b} \pm 0.77$	$14.95^{c} \pm 0.45$	$15.05^{c} \pm 0.25$	$9.59^{d} \pm 0.24$	$6.71^{e} \pm 0.45$

All data are the mean ± SD of three replicates. All attributes are present under mg/g fresh weight. The data within a row followed by the same superscript letter (a, b, c) are not statistically significant difference. TPC: total phenolic content; TFC: total flavonoid content; DPPH: 2.2-diphenyl-1-picrylhydrazyl; ABTS: 2.2'-azisbonis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium.

3.3. Correlation among color properties, bioactive compound, and antioxidant

For Brazilian cultivars, Table 5 provided that TSS had a positive correlation with diameter (r = 0.99), weight (r = 0.94), and moisture content (r = 0.98); in contrast, it had a negative correlation with pH (r = -0.99) and TA (r = -0.86). Table 5 also revealed the positive correlation between vitamin C and polyphenols (r = 0.99), vitamin C and TFC (r = 0.99), and polyphenols and flavonoids (r = 0.99). On the other hand, Table 5 displayed a significant correlation between the bioactive compounds and antioxidant activity. All coefficient correlations had a positive value (i.e., r > 0.83), which means the decrease in bioactive compounds leads to a decline in antioxidant activity. Vitamin C was the major compound that contributed to the antioxidant activity of acerola fruit, followed by polyphenols and other compounds (Mezadri et al., 2008). Table 5 also stated a negative correlation between the L*, a*, and b* with bioactive compounds or antioxidant activity for any cultivar. Most of the coefficient correlation values range from -0.99 to -0.93 (a*) and are lower than 0.5 (L* and b*). Regardless of sour cultivar, Table 6 demonstrated a positive correlation between bioactive compounds and antioxidant activity with r value from 0.83 to 0.99.

Table 5. Pearson's correlation coefficient among the color properties, bioactive compounds, and antioxidant activity in Brazilian acerola

	TSS	TA	Diameter	Weight	pH	Moisture content	L*	a*	b*	TPC	TFC	Vit C	DPPH	ABTS
TSS	1.00													
TA	-0.99	1.00												
Diameter	0.99	-0.99	1.00											
Weight	0.94	-0.97	0.96	1.00										
pH	-0.86	0.90	-0.90	-0.98	1.00									
Moisture content	0.98	-0.95	0.96	0.85	-0.73	1.00								
L*	-0.08	-0.02	0.00	0.27	-0.44	-0.29	1.00							
a*	0.99	-1.00	0.99	0.98	-0.92	0.94	0.05	1.00						
b*	0.13	-0.23	0.21	0.46	-0.62	-0.08	0.98	0.26	1.00					
TPC	-0.96	0.98	-0.98	-0.99	0.96	-0.88	-0.19	-0.99	-0.39	1.00				
TFC	-0.94	0.97	-0.97	-0.99	0.98	-0.85	-0.25	-0.98	-0.45	0.99	1.00			
Vit C	-0.98	0.99	-0.99	-0.99	0.95	-0.91	-0.13	-0.99	-0.33	0.99	0.99	1.00		
DPPH	-0.97	0.94	-0.94	-0.82	0.70	-0.99	0.33	-0.93	0.13	0.86	0.83	0.89	1.00	
ABTS	-0.99	0.99	-0.99	-0.98	0.92	-0.94	-0.06	-0.99	-0.27	0.99	0.98	0.99	0.92	1.00

TSS: total soluble solid; TA: total acidity; TPC: total phenolic content; TFC: total flavonoid content; DPPH: 2.2-diphenyl-1-picrylhydrazyl; ABTS: 2.2'-azisbonis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium.

Table 6. Pearson's correlation coefficient among the color properties, bioactive compounds, and antioxidant activity in sour acerola

	TSS	TA	Diameter	Weight	pH	Moisture content	L*	a*	b*	TPC	TFC	Vit C	DPPH	ABTS
TSS	1.00													
TA	-0.99	1.00												
Diameter	1.00	-0.99	1.00											
Weight	0.92	-0.94	0.88	1.00										
pH	0.11	-0.16	0.02	0.48	1.00									
Moisture content	-0.90	0.92	-0.85	-1.00	-0.54	1.00								
L*	-0.98	0.97	-0.99	-0.83	0.10	0.79	1.00							
a*	1.00	-0.99	0.99	0.95	0.19	-0.93	-0.96	1.00						
b*	-0.79	0.82	-0.73	-0.97	-0.69	0.98	0.65	-0.84	1.00					
TPC	-0.89	0.91	-0.84	-0.99	-0.56	0.99	0.77	-0.92	0.99	1.00				
TFC	-0.95	0.96	-0.91	-0.99	-0.43	0.99	0.86	-0.97	0.95	0.99	1.00			
Vit C	-0.99	0.99	-0.97	-0.97	-0.24	0.95	0.94	-0.99	0.87	0.94	0.98	1.00		
DPPH	-0.99	0.99	-0.97	-0.98	-0.28	0.96	0.93	-0.99	0.88	0.95	0.99	0.99	1.00	
ABTS	-0.92	0.94	-0.88	-0.99	-0.48	0.99	0.83	-0.95	0.97	0.99	0.99	0.97	0.98	1.00

TSS: total soluble solid; TA: total acidity; TPC: total phenolic content; TFC: total flavonoid content; DPPH: 2.2-diphenyl-1-picrylhydrazyl ; ABTS: 2.2'-azisbonis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium.

4. Conclusions

The total acidity, a* value, bioactive compounds, and antioxidant activity of the Brazilian acerola varieties were higher than the sour acerola variety. The content of these parameters decreased gradually according to the fruit's maturation development, excess a* value. The unripe Brazilian acerola fruit had the highest bioactive compounds and antioxidant activity. This sample can be used as material for the extraction of bioactive compounds or as a functional ingredient to improve the antioxidant activity of foodstuffs.

Conflict of interest

The authors declare no conflict of interest.

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