Phytochemical Compounds and Antioxidant Activity of the Pulp of Two Brazilian Passion Fruit Species: *Passiflora Cincinnata* Mast. And *Passiflora Edulis* Sims

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\textbf{ABSTRACT}

About 600 species of *Passiflora* are described around the world, of which 120 are native to Brazil. In the present work, the phytochemical compounds were analyzed by high-performance liquid chromatography, and the antioxidant activities (AOX) were measured in the pulp of *P. edulis* and *P. cincinnata* species. The *P. edulis* presented a higher bioactive content and AOX when compared to *P. cincinnata*. Citric and malic acids were the main organic acids found. The principal component analysis-PCA associated the highest values of quercetin-3-glucoside, hesperidin, \textit{trans}-caftaric acid, chlorogenic acid, caffeic acid, \textit{p}-coumaric acid, \textit{trans}-resveratrol, rutin, procyanidin-B2, epigallocatechin-gallate and epicatechin-gallate, to *P. cincinnata*. The *P. edulis* was associated with higher values of total phenolic, vitamin C, total carotenoids, AOX (DPPH\textsuperscript{b}, ABTS\textsuperscript{c} and FRAP), \textit{cis}-resveratrol, naringenin, kaempferol-3-glucoside, myricetin and procyanidin-B1. *P. cincinnata*, although not a commercial species such as *P. edulis*, presented phenolic compounds and antioxidant activity in acceptable values, including the high values of quercetin 3-glucoside. The present study contributes to the knowledge of the physical-chemical composition of the *Passiflora* species.

\textbf{KEYWORDS}

Passion fruit; phenolic compounds; organic acids; HPLC

\section*{Introduction}

Passion fruit is a tropical fruit belonging to the family *Passifloraceae*. The name was given by Spanish missionaries to South America who used the exotic flower to describe and explain their religious convictions while trying to convert the indigenous habitants to Christianity. The most well-known types of this fruit are the purple and yellow passion fruits, *Passiflora edulis* Sims (Wijeratnam, 2016).

Around the world, approximately 600 species of *Passiflora* are described, of which 120 are native to Brazil (Ayres et al., 2017). Among Brazilian passion fruit species, yellow passion fruit (*Passiflora edulis* Sims) is the most cultivated and appreciated due to its flavor and aroma (Rotili et al., 2013). Besides in Brazil, *P. edulis* species have also been cultivated with economic significance in countries such as Ecuador, Colombia, Peru, Indonesia, and Kenya. The yellow passion fruit represents over 95% of the production for juice extraction (Wijeratnam, 2016).

The genus *Passiflora* is traditionally used in the treatment of anxiety and as an antidepressant. Yellow passion fruit leaf extracts (*P. edulis*) have been shown to have antidepressant activity in rats similar to the effects of the commercial drugs Nortriptyline and Fluoxetine; this effect has been
attributed to its phytochemical compounds, such as flavonoids (Ayres et al., 2017). Seed extracts from *P. edulis* have also shown antitumor activity and antioxidant activity associated with fatty acids present in this seed (Mota et al., 2018). Peels of *P. edulis* are rich in pectin and their flours can be used to replace some colloids used in the production of processed foods (Coelho et al., 2018a, 2016).

The passion fruit species *Passiflora cincinnata* Mast. popularly known in Brazil as “maracujá-do-mato”, “maracujá-da-caatinga”, “maracujá-mochila” or “maracujá-tubarão” is native to the Caatinga, an exclusive biome of Brazil (Lavor et al., 2018). *Passiflora cincinnata* Mast., synonyms: *Passiflora corumbaensis* Barb. Rodr., *Passiflora perlubata* Killip or *Passiflora cincinnati* var. minor Hoehne, is a species of plant in the *Passifloraceae* family belonging to the *Passiflora* genus. It is a vigorous plant of grooved stems. Its leaves are palmate, digitate, with 3–5 lobes, split ones. The flowers, with 10 cm of diameter, have roughened and curled cilia on corona filaments, ringed or snail-shaped with hair, white striped and alternate purple striped on the base. The fruit is ovoid, with 5 × 3 cm, and seeds measuring 0.5 cm long (Costa et al., 2015). The fruit has a greenish rind and white pulp, having a higher acidity content than *P. edulis*. The *P. cincinnata* is a species resistant to pests and agricultural diseases and has been used in the genetic improvement of new varieties of passion fruit (Siebra et al., 2018), such as cv. ‘BRS Sertão Forte’ (*P. cincinnata*), recently created by the Brazilian Agricultural Research Corporation (Embrapa) breeding program (Silva et al., 2020). It has also been used in the production of handmade jams and juices (Azoubel et al., 2011). Extracts from the leaves, peel, and seeds of *P. cincinnata* have been shown to have in vitro antimicrobial and anti-inflammatory activities, with these activities being attributed to its phenolic compounds (Lavor et al., 2018; Siebra et al., 2018).

Most of the studies that characterize bioactive compounds in the pulp from the Brazilian passion fruit have evaluated *P. edulis* species. The main bioactive compounds found were trans-β-carotene, cis-carotene and β-cryptoxanthin carotenoids (Pertuzatti et al., 2015; Wondracek et al., 2011), and the phenolics quercetin-3-glucoside, quercetin-3,7-dihexoside, luteolin-8-C-(2-rhamnosyl)-hexoside, quercetin-3-(6-acetyl) glucosyl-2-synaptic acid, quercetin-7-glucoside, and kaempferol-3-glucoside (Medina et al., 2017). Some studies have also mentioned the presence of vitamin C (ascorbic acid) (Pertuzatti et al., 2015) and antioxidant activity (measured by DPPH and ABTS methods) in the pulp of *P. edulis*. (Ramaiya et al., 2013; Rotili et al., 2013). *Passiflora cincinnata* Mast cv. ‘BRS Sertão Forte’, a recent variety resultant from the genetic improvement of the species *P. cincinnata*, presented isoquercetin (quercetin 3-glucoside) and caftaric acid as the main phenolics present in its pulp (Silva et al., 2020). The present work had the objective of quantifying phenolic compounds, to determine the profile of organic acids and to measure the in vitro antioxidant activity of pulp both the Brazilian passion fruits *P. cincinnata* Mast. and *P. edulis* Sims, for comparison purposes.

**Material and Methods**

**Raw Material**

The passion fruits *P. cincinnata* and *P. edulis* were harvested at the experimental farm of the Brazilian Agricultural Research Corporation (EMBRAPA Semiárido), Petrolina, PE, Brazil (09º09’ S and 40º22’ W). The average rainfall of the region is 1.78 mm, concentrated in the period from January to April in 2016, the year of the study. The average monthly temperature was 26°C, relative humidity between 50 and 70%, average insolation of 2800 hours/year, with evaporation around 2000 mm/year. The soil of the harvested area is red-yellow Latosol type. The fruits were sanitized in chlorine solution at 50 ppm, cut, and the pulp was manually extracted, packed in polyethylene bags, and kept in a freezer (−20°C) until analysis. For each species of passion fruit, three replications were analyzed, where each replicate corresponded to the mixed pulp of 30 fruits randomly collected from 15 plants.
**Chemicals**

Folin-Ciocalteu reagent, ethanol, hexane, potassium persulfate, ferric chloride hexahydrate, phosphoric acid and potassium phosphate monobasic were purchased from Merck (Darmstadt, Germany). Trolox (6-hydroxy-2,5,7,8-tetramethylecrocromate-2-carboxylic acid), and the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2-azino-bis-3-ethylbenzthiazoline-6-sulfonic acid (ABTS) radicals, and 2,3,5-triphenyltetrazolium chloride (TPTZ) were supplied by Sigma-Aldrich (St. Louis, MO, USA). Methanol and isopropanol from J.T. Baker (Phillipsburg, NJ, USA). Ultrapure water was obtained in a Marte Científica purification system (São Paulo, SP, Brazil). Rhamnose and succinic acid were obtained from Sigma-Aldrich (St. Louis, MO, USA). External standards of glucose, fructose, tartaric acid, citric acid, lactic acid, acetic acid, and malic acid were obtained from Merck (Darmstadt, Germany).

**Classical Analysis and Color Measurement by CIEL*a*b* System**

To obtain basic analytical characteristics of the samples, classical pH analyses (potentiometer B 474 Micronal (Brazil)) were carried out; soluble solids (°Brix) (digital refractometer HI 96801 Hanna, USA), titratable acidity (TA), humidity, and ashes, following the methodologies described in (AOAC, 1998). Color analysis was also conducted using a MiniScan EZ digital colorimeter (Hunterlab, USA) and CIE Lab L*, a* and b* system, where L* denotes lightness and ranges from 0 (black) to 100 (white), and a* and b* denote opponent dimensions, ranging from green (-) to red (+) and from blue (-) to yellow (+), respectively.

**Total Bioactive Content – Total Phenolic Content, Total Carotenoids, and Vitamin C**

The total phenolic content of the samples was measured by the colorimetric method with Folin-Ciocalteu according to Singleton and Rossi (1965). Gallic acid was used as standard and the total phenolic concentrations in samples were expressed as mg of gallic acid equivalents (GAE)/kg. One gram of fresh pulp was mixed with 4 mL of methanol 50% v/v using vortex for 2 min. The mixture was centrifuged (4000 × g 5 min, 24°C) and the supernatant was removed. One aliquot of the extract was used for quantification of the total phenolic content and assays of the antioxidant activity.

Total carotenoids were determined according to the method described in AOAC (1998). The extraction of the carotenoids was by liquid-liquid extraction with hexane as the organic phase. Fifty mL of ultrapure water, 10 g of passion fruit pulp, 30 mL of isopropanol and 10 mL of hexane were added to a separatory funnel and the mixture was stirred and allowed to stand for 30 min. The organic phases of two extractions were mixed, 0.2 g of sodium sulfate, 5 mL of acetone was added, and the volume was topped up to 50 mL with hexane. The absorbance was read at 450 nm in the spectrophotometer, and the results expressed in mg of β-carotene per kg of the fresh pulp.

The vitamin C (ascorbic acid) was determined according to Ramaiya et al. (2013), using a direct titration method. Ascorbic acid was used as the standard. The passion fruit pulp (25 mL) was titrated against iodine solution until the endpoint blue-black color developed.

**Simultaneous Analysis of Organic Acids and Sugars by HPLC-DAD-RID**

Simultaneous analyses of the organic acids and sugars were performed using an HPLC system model Agilent 1260 Infinity LC (Agilent Technologies, Santa Clara, CA, USA) coupled to a DAD-Diode Arrangement Detector (G1315D model) and RID-Refractive Index Detector (G1362A model). This procedure was carried out according to the chromatographic conditions previously described by Coelho et al. (2018b). A 500 µL aliquot of fresh pulp was diluted in 4500 µL of ultrapure water, filtered through a 0.45 µm nylon membrane (Chromafil® Xtra, Macherey-Nagel – Germany), and a volume of 10 µL was injected into a column. The column used was that of Agilent Hi-Plex H (300 × 7.7 mm) ion exchange with internal particles of 8.0 µm protected by a PL Hi-Plex
H (5 × 3 mm) guard column (Agilent Technologies). The temperature of the column compartment was maintained at 70°C, and RID flow cell at 50°C. The flow was used 0.5 mL/min with a run time of 20 min. The phase was H2SO4 4.0 mmol L⁻¹. For the determination of tartaric, malic, lactic, succinic, citric, and acetic acids, detection was made in the DAD at 210 nm. For glucose and fructose sugars, detection was made in the RID. Data were processed using OpenLAB CDS ChemStation Edition™ software (Agilent Technologies, USA).

**Extraction and Quantification of the Individual Phenolic Compounds by RP-HPLC/DAD**

The phenolic compounds of the passion fruit fresh pulp were extracted by liquid-liquid extraction (LLE), following the methodology described by Burin et al. (2014). An aliquot of 5 mL of the pulp was extracted twice with 10 mL of ethyl acetate under agitation for 5 min (vortex mixer). The organic phases of two extractions were combined and evaporated in a rotatory evaporator with controlled temperature (35 ± 1°C). The remaining residue was re-dissolved in 2 mL of methanol 50% v/v.

Phenolic compounds were identified and quantified using an Agilent 1260 Infinity LC System liquid chromatograph coupled to DAD. The column used was Zorbax Eclipse Plus RP-C18 (100 × 4.6 mm, 3.5 μm) and the pre-column was Zorbax C18 12.6 × 4.6 mm, 5 μm (Zorbax, USA). The oven temperature was 35°C and the injection volume was 20 μL. The solvent flow was 0.8 mL min⁻¹. The new 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 where solvent A was a solution of phosphoric acid 0.1 M (pH = 2.0) and solvent B was methanol acidified with 0.5% H3PO4. Identification and quantification of the compounds were made by comparison with external standards (Dutra et al., 2018; Padilha et al., 2017). External standards of gallic acid, syringic acid, p-coumaric acid, chlorogenic acid, trans-caftaric acid, caffeic acid, hesperidin, naringenin, procyanidin B1, catechin, epicatechin and procyanidin B2 from Sigma-Aldrich (St. Louis, MO, USA). Epigallocatechin, epicatechin gallate, procyanidin A2 quercetin 3-glucoside, rutin (quercetin 3-rutinoside), kaempferol 3-glucoside, myricetin came from Extrasynthese (Genay, France). Trans-resveratrol and cis-resveratrol were obtained from Cayman Chemical Company (Michigan, EUA).

**In Vitro Antioxidant Activity by ABTS, DPPH and FRAP Methods**

*In vitro* antioxidant activity was determined by free radical sequestration with ABTS⁺⁺, 2,2-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) and DPPH⁺ (2,2-diphenyl-2-picrylhydrazyl) (Kim et al., 2002; Re et al., 1999). The Trolox analytical standard (100–1500 μmol L⁻¹) was used to build the calibration curves and the results were expressed as Trolox equivalents per kg of pulp (mmol TEAC kg⁻¹). Absorbance measurement was performed with a spectrometer model UV 2000A (Instrutherm, Brazil).

The ABTS⁺⁺ radical was formed through the reaction of 7 mM ABTS in 140 mM potassium persulfate for 16 hr in the absence of light. The solution was then diluted in ethanol until absorbance reached 0.700 ± 0.05. The ABTS⁺⁺ radical scavenging activity of the samples was determined through the rate of decay in the absorbance at 734 nm determined at time t = 0 min and at time t = 6 min after the addition of samples.

The DPPH⁺ method of the samples was assessed through the rate of decay in the absorbance at 517 nm. A solution of DPPH⁺ (1.0 mmol L⁻¹) was prepared in ethanol and diluted to an absorbance of 0.900 ± 0.050 (100 μmol L⁻¹). The absorbance of the DPPH⁺ solution was determined at time t = 0 min and 30 min after the addition of sample.

The FRAP method was used as described by Rufino et al. (2006). The FRAP reagent was prepared in 300 mmol L⁻¹ acetate buffer (pH 3.6), TPTZ (2,4,6-tris (2-pyridyl) -s-triazine) 10 mmol L⁻¹ in a solution of HCl 40 mmol L⁻¹ and 20 mmol FeCl₃. The fresh pulp (90 μL) and 270 μL of distilled water were mixed with 2.7 mL of FRAP reagent. They were subsequently mixed in a tube and incubated for 30 min in a thermodigester block for tubes (Bioplus IT-2002 (Barueri, SP, Brazil)). Absorbance (595 nm) was measured in a spectrophotometer. The standard curve was created with
ferrous sulfate (100–2000 µmol L\(^{-1}\)), and the results were expressed in mmol Fe\(^{2+}\) per kg of the passion fruit pulp (mmol Fe\(^{2+}\) kg\(^{-1}\)).

**Statistical Analysis**

All the analyses were carried out in triplicate and the results were expressed as average ± standard deviation of the values obtained. To evaluate the behavior of the phenolic profile, total carotenoids, vitamin C and antioxidant activity in relation to the *Passiflora* species, the application of multivariate statistics was carried out using principal component analysis (PCA) with pretreatment of the data for normalization and scaling. The program SPSS Inc., version 17.0 (Chicago, IL, USA) was utilized.

**Results and Discussion**

**Basic Analysis and Color**

The results of the classic analysis and color of the passion fruit pulp from the species *P. edulis* and *P. cincinnata* are shown in Table 1. The values of pH, Brix degree (°Brix) and titratable acidity (TA) in *P. edulis* pulp were 2.87, 12.23 and 6.28%, respectively. In the *P. cincinnata* pulp, the values were 2.74, 13.16 and 8.41% for pH, °Brix and TA, respectively. In general, the results obtained for pH and °Brix showed few differences between the two passion fruit species evaluated. The values of TA in passion fruit *P. cincinnata* was higher than in *P. edulis*.

The values of pH, °Brix and TA found in the present study for passion fruit *P. edulis* agree with other studies that have analyzed the pulp of passion fruit from several other species, such as *P. edulis* (Purple), *P. edulis* (Frederick), *P. maliformes*, *P. quadrangularis*, *P. edulis* (Pink) and *P. edulis* Flavicarpa. In these species, pH values varied from 2.6 to 3.54, TA of 1.19–5.5% and °Brix of 10.1–16.8 (Chen et al., 2018; Dias et al., 2011; Ramaiya et al., 2013; Silva et al., 2000). Based on these values, the titratable acidity of passion fruit *P. cincinnata* (8.41%) was considered high.

Brazilian legislation establishes that commercial pulp from the passion fruit must have a pH between 2.7 and 3.8, and °Brix greater than 11 (Brasil, 2000). Based on this, the values of pH and

| Analysis                              | *Passiflora edulis* Sims | *Passiflora cincinnata* Mast. |
|---------------------------------------|--------------------------|-----------------------------|
| Classical analysis                    |                          |                             |
| pH                                    | 2.87 ± 0.05              | 2.74 ± 0.03                 |
| Soluble Solids (°Brix)                | 12.23 ± 0.05             | 13.16 ± 0.05                |
| Titratable acidity % (TA)             | 6.28 ± 0.01              | 8.41 ± 0.02                 |
| Ratio °Brix/TA                         | 1.95 ± 0.01              | 1.56 ± 0.01                 |
| Humidity %                            | 85.95 ± 0.28             | 85.19 ± 0.20                |
| Soluble ash %                         | 0.84 ± 0.10              | 0.76 ± 0.03                 |
| Insoluble ash %                       | 0.14 ± 0.12              | 0.05 ± 0.01                 |
| Total ash %                           | 0.98 ± 0.23              | 0.81 ± 0.27                 |
| Color CIELAB                          |                          |                             |
| L*                                    | 62.27 ± 0.57             | 75.35 ± 0.27                |
| a*                                    | 15.65 ± 1.26             | -2.1 ± 0.24                 |
| b*                                    | 97.63 ± 2.76             | 26.02 ± 1.41                |
| Organic acids by HPLC (g 100 g\(^{-1}\)) |                          |                             |
| Citric acid                           | 3.87 ± 0.80              | 6.85 ± 0.25                 |
| Malic acid                            | 1.60 ± 0.29              | 1.66 ± 0.05                 |
| Succinic acid                         | 0.08 ± 0.03              | 0.17 ± 0.05                 |
| Sugars by HPLC (g 100 g\(^{-1}\))    |                          |                             |
| Glucose                               | 1.27 ± 0.17              | 0.11 ± 0.04                 |
| Fructose                              | 0.01 ± 0.01              | 0.02 ± 0.01                 |

The results are expressed as mean ± standard deviation (n = 3). ND – not detected. L* = lightness, a* = red-green hue, b* = yellow-blue hue.
*Brix of the two evaluated species meet the requirements of Brazilian legislation for the commercialization of pulp.

The values of humidity and total ash in *P. edulis* pulp were 85.95 and 0.98%, respectively. For the *P. cincinnata* pulp, the humidity and total ash presented values of 85.15 and 0.81%, respectively. In the pulp of *Passiflora foetida*, 76% humidity content and 1.7% total ash have been reported (Song et al., 2018).

Regarding the color measured by the CIE L*a*b* system, the pulp of the passion fruit *P. edulis* presented values of L* = 62.27, a* = 15.65 and b* = 97.63. The pulp of passion fruit *P. cincinnata* showed values of L* = 75.35, a* = −2.1 and b* = 26.02. Considering that positive values of b* corresponding to yellow, and negative values of a* corresponding to green, it can be observed that in the pulp of *P. edulis* the yellow color predominates, and in *P. cincinnata* there was a slightly greenish color, as it can see in Figure 1. The color of the pulp of passion fruit species is usually associated with the presence of compounds such as anthocyanins, carotenoids, and yellow flavonoids (Silva et al., 2014; Wondracek et al., 2011).

**Organic Acids and Sugars**

The values obtained for organic acids and sugars from the fresh pulp of the passion fruit species *P. edulis* and *P. cincinnata* are shown in Table 1. The major organic acids quantified in the pulp were citric and malic acids, and succinic acid in small amounts. The values of citric and malic acids in the pulp of *P. edulis* were 3.87 and 1.60 g 100 g⁻¹, respectively. In the *P. cincinnata* pulp, the values of citric and malic acid were 6.85 and 1.66 g 100 g⁻¹, respectively. The values of succinic acid were 0.08 and 0.17 g 100 g⁻¹ in the pulp of *P. edulis* and *P. cincinnata*, respectively. The profile and values of organic acids in fruit pulp depend on many factors, such as type of fruit, variety, and maturation stage. Citric acid with values ranging from 0.03 to 5.15 g 100 g⁻¹ and malic acid (0.01–2.18 g 100 g⁻¹) are the main organic acids present in the pulp of various fruits such as melon, cashew, acai, peach, orange and lemon (Flores, Hellín & Phenol, 2012; Scherer et al., 2008). In the yellow passion fruit pulp *P. edulis* flavicarpa and the passion fruit *P. foetida*, citric and malic acids were also the main detected organic acids (Oliveira et al., 2014; Song et al., 2018). Based on the values obtained for organic acids in the present study, the pulp from the passion fruit species *P. edulis* and *P. cincinnata* were found to be high in acidity, mainly because of the high amount of citric acid.

![Passiflora edulis](image1)

![Passiflora cincinnata](image2)

*Figure 1.* Visual appearance of Brazilian passion fruit pulp taken from *Passiflora edulis* Sims. and *Passiflora cincinnata* Mast.
Regarding sugars, the values obtained for glucose and fructose in the pulp of *P. edulis* were 1.27 and 0.01 g 100 g⁻¹, respectively. The *P. cincinnata* pulp had values of 0.11 and 0.02 g 100 g⁻¹ for glucose and fructose, respectively. Glucose and fructose are the main sugars present in the passion fruit pulp of several species such as *P. edulis* (yellow), *P. edulis* (Purple), *P. edulis* (Frederick), *P. maliformes*, *P. quadrangularis*, *P. edulis* (pink) and *P. edulis* flavicarpa (Ramaiya et al., 2013). The glucose and fructose values in the passion fruit pulp used in the present study agree with those obtained by Song et al. (2018), in passion fruit pulp *P. foetida*.

**Total Bioactive Content – Total Phenolics, Total Carotenoids and Vitamin C**

A number of studies have associated the bioactivity content of passion fruit fresh pulp with phenolic compounds, carotenoids, and ascorbic acid (Medina et al., 2017; Pertuzzati et al., 2015; Ramaiya et al., 2013; Song et al., 2018; Wondracek et al., 2011).

The results for total phenolics measured with Folin-Ciocalteu, total carotenoids and vitamin C (ascorbic acid) obtained in the fresh pulp from *P. edulis* and *P. cincinnata* are presented in Table 2. Total phenolics presented values of 365 and 476.1 mg kg⁻¹ for *P. cincinnata* and *P. edulis*, respectively. For total carotenoids, expressed as β-carotene, the values were 18.7 and 0.9 mg kg⁻¹ for the *P. edulis* and *P. cincinnata*, respectively. Ascorbic acid values were 264.2 and 176.1 mg kg⁻¹ for the pulp of *P. edulis* and *P. cincinnata*, respectively. Studies evaluating the total phenolic content of passion fruit pulp by the Folin-Ciocalteu method have reported values ranging from 277 to 600 mg

| Compounds mg kg⁻¹ FW | *Passiflora edulis* Sims. | *Passiflora cincinnata* Mast. |
|-----------------------|--------------------------|-------------------------------|
| **FLAVANOLS**         |                          |                               |
| (+)-Catechin           | 3.08 ± 0.18              | 1.64 ± 0.02                   |
| (-)-Epicatechin        | 0.02 ± 0.01              | 0.02 ± 0.01                   |
| (-)-Epigallocatechin gallate | 0.51 ± 0.30      | 3.06 ± 0.28                   |
| (-)-Epicatechin gallate | ND                      | 0.15 ± 0.03                   |
| Procyanidin A2         | ND                       | ND                            |
| Procyanidin B1         | 0.44 ± 0.04              | 0.12 ± 0.02                   |
| Procyanidin B2         | 0.52 ± 0.04              | 1.40 ± 0.02                   |
| **FLAVONOLS**         |                          |                               |
| Kaempferol 3-glucoside | 0.34 ± 0.03              | 0.20 ± 0.05                   |
| Myricetin              | 0.81 ± 0.10              | 0.40 ± 0.02                   |
| Rutin                  | 0.04 ± 0.01              | 0.08 ± 0.00                   |
| Quercetin 3-glucoside  | 0.34 ± 0.02              | 39.1 ± 2.95                   |
| **FLAVANONES**        |                          |                               |
| Hesperidin             | 2.74 ± 0.19              | 4.58 ± 0.44                   |
| Naringenin             | 0.46 ± 0.04              | 0.14 ± 0.07                   |
| **STILBENES**         |                          |                               |
| trans-Resveratrol      | 0.22 ± 0.02              | 0.24 ± 0.03                   |
| cis-Resveratrol        | 2.32 ± 0.12              | 1.64 ± 0.08                   |
| **PHENOLIC ACIDS**    |                          |                               |
| Gallic acid            | 0.40 ± 0.03              | 0.30 ± 0.03                   |
| Caffeic acid           | 1.04 ± 0.1               | 1.34 ± 0.12                   |
| p-Coumaric acid        | 0.42 ± 0.02              | 1.0 ± 0.08                    |
| Chlorogenic acid       | 1.06 ± 0.1               | 1.74 ± 0.16                   |
| Syringic acid          | 1.16 ± 0.09              | 1.18 ± 0.20                   |
| trans-Caftaric acid    | 0.58 ± 0.06              | 1.42 ± 0.15                   |
| **TOTAL BIOACTIVE CONTENT** |                       |                               |
| Total carotenoids§     | 18.7 ± 1.0               | 0.9 ± 0.1                     |
| Vitamin C (ascorbic acid) | 264.2 ± 2.4            | 176.1 ± 3.2                   |
| Total phenolics§       | 476.1 ± 9.1              | 365 ± 46.8                    |

The results are expressed as mean ± standard deviation (*n* = 3). ND – not detected. §Total phenolics measured with Folin–Ciocalteu expressed as mg kg⁻¹ equivalent to gallic acid. *Total carotenoids expressed as mg kg⁻¹ equivalent to β-carotene.*
kg\(^{-1}\) in the *P. edulis* (yellow), *P. edulis* (purple), *P. edulis* (Frederick), *P. maliformes*, *P. quadrangularis*, *P. edulis* flavicarpa and *P. glandulosa* Cav. species (Chen et al., 2018; Ramaiya et al., 2013; Song et al., 2018). For vitamin C (L-ascorbic acid) in several *Passiflora* species, values varying from 23 to 577 mg kg\(^{-1}\) are described (Pertuzatti et al., 2015; Ramaiya et al., 2013; Rotili et al., 2013). Based on this, the total phenolic and vitamin C contents of the pulp of *P. edulis* and *P. cincinnata* were considered to be within normality. The content of carotenoids present in passion fruit pulp depends on many variables, including the crop system, climatic factors, and fruit maturation (Pertuzatti et al., 2015; Vianna-Silva et al., 2008). Wondracek et al. (2011) evaluated 14 individual carotenoids in the pulp of four Brazilian passion fruit species (*P. nitida*, *P. cincinnata*, *P. setacea* and *P. edulis*) and mentioned that the trans-\(\beta\)-carotene was present in all species, with cis-\(\zeta\)-carotene being the main carotenoid found in *P. edulis* (6.2–12.1 mg kg\(^{-1}\)), followed by trans-\(\zeta\)-carotene (5.4–12.1 mg kg\(^{-1}\)) and trans-\(\beta\)-carotene (2.6–3.8 mg kg\(^{-1}\)), all associated with the yellow color of the pulp. Concerning *P. cincinnata*, only trans-\(\beta\)-carotene (0.03 mg kg\(^{-1}\)) and violaxanthin (0.02 mg kg\(^{-1}\)) were present in small amounts.

In a study by Pertuzatti et al. (2015), 5 individual carotenoids from yellow passion fruit pulp *P. edulis* harvested from organic and conventional crop systems were evaluated, where \(\beta\)-cryptoxanthin (139–250 mg kg\(^{-1}\)) was the main quantified compound, followed by \(\beta\)-carotene (0.6–0.8 mg kg\(^{-1}\)).

In the present work, the pulp of the yellow passion fruit *P edulis* Sims. presented higher values of total carotenoids (18.7 mg kg\(^{-1}\)) than *P. cincinnata* (0.9 mg kg\(^{-1}\)), corroborating the study by Wondracek et al. (2009).

**Individual Phenolic Compounds**

The profiles of phenolic compounds quantified by HPLC analysis of the passion fruit fresh pulp studied are shown in Table 2. Among the 21 phenolic compounds analyzed, 7 were flavanols, 4 flavonols, 2 flavanones, 6 phenolic acids and 2 stilbenes. Chromatograms obtained from the analysis of phenolic compounds by RP-HPLC-DAD of the extracts (LLE) of the pulp of *P. edulis* and *P. cincinnata* can be observed in Figure 2a,b, respectively.

**Flavonoids: Flavanols, Flavonols and Flavanones**

The major quantified flavanols in the pulp of *P. edulis* and *P. cincinnata* were catechin> epigallocatechin gallate> procyanidin B2 and procyanidin B1. The major quantified flavonols were quercetin-3-glucoside> myricetin> kaempferol-3-glucoside. Comparing the two species studied in relation to quantified flavanols, *P. edulis* presented higher values of catechin (3.08 mg kg\(^{-1}\)) and procyanidin B1 (0.44 mg kg\(^{-1}\)), while *P. cincinnata* had higher values of epigallocatechin gallate (3.06 mg kg\(^{-1}\)) and procyanidin B1 (1.40 mg kg\(^{-1}\)). In relation to flavanones, *P. cincinnata* showed a high amount of quercetin-3-glucoside (39.1 mg kg\(^{-1}\)) when compared to *P. edulis* (0.34 mg kg\(^{-1}\)). For the myricetin, kaempferol-3-glucoside and rutin flavonol, the pulp from the two species presented low values, varying from 0.04 to 0.81 mg kg\(^{-1}\).

Few studies in the literature have analyzed passion fruit pulp in relation to several families of phenolic compounds. Medina et al. (2017) analyzed phytostrophanes and phenolic compounds in the passion fruit pulp *Passiflora edulis* Sims f. *edulis* (gualupa), where the main phenolics quantified were anthocyanin cyanidin 3-glucoside (189.2 mg 100 g\(^{-1}\) DW), and the flavonols quercetin-3-glucoside (166.9 mg 100 g\(^{-1}\) DW), quercetin-3,7- hexoside (57.9 mg 100 g\(^{-1}\) DW), luteolin-8-C-(2-O-rhamnosyl) hexoside (44.42 mg 100 g\(^{-1}\) DW), quercetin-3-O-(6-acetyl) glycosyl-2-synapic acid (42 mg 100 g\(^{-1}\) DW), quercetin 7-glucoside (32.7 mg 100 g\(^{-1}\) DW) and kaempferol-3-glucoside (32.9 mg 100 g\(^{-1}\) DW). Rotta et al. (2019) evaluated the flavanols quercetin-3-glucoside and rutin in the fresh pulp of the *P. edulis*, *P. alata* and *P. ligulares*, where quercetin 3-glucoside was only present in *P. edulis* (0.42 mg kg\(^{-1}\)), and rutin in the pulp of *P. edulis* (0.23 mg kg\(^{-1}\)) and *P. alata* (0.29 mg kg\(^{-1}\)).
In relation to the quantified flavanones, the pulp of *P. edulis* presented values of 0.46 and 2.74 mg kg$^{-1}$ for naringenin and hesperidin, respectively (Table 2). *P. cincinnata* presented values of 0.14 and 4.58 mg kg$^{-1}$ for naringenin and hesperidin, respectively.

Few studies have analyzed hesperidin and naringenin in passion fruit pulp. Shanmugam et al. (2018) evaluated the Brazilian passion fruit pulp *P. subpeltata* and did not find naringenin. Usually naringenin and hesperidin are the major phenolic compounds in citrus fruits such as oranges, lemons, tangerines and grapefruit, reaching values of 1162 and 1674 mg kg$^{-1}$, respectively (Zhao et al., 2017).
Non-flavonoids: Phenolic Acids and Stilbenes

The results obtained for phenolic acids and stilbenes in passion fruit fresh pulp are presented in Table 2. The values of trans-resveratrol and cis-resveratrol in the pulp of *P. edulis* were 0.22 and 2.32 mg kg\(^{-1}\) respectively; and in *P. cincinnata* pulp, these were 0.24 and 1.64 mg kg\(^{-1}\) respectively. Trans and cis resveratrol stilbenes have been widely studied for their health benefits to consumers, where grapes and grape-derived beverages have been the main source studied for these compounds. The values obtained for these stilbenes in the pulp of *P. edulis* and *P. cincinnata* agree with those mentioned in the literature for juices and wines cultivated in the same region as the studied passion fruit (Dutra et al., 2018); this confers merit on this species as bioactive compounds of nutritional interest.

In relation to phenolic acids, the main compounds present in terms of quantity were caffeic acid, chlorogenic acid and syringic acid in values from 1.06 to 1.74 mg kg\(^{-1}\). Gallic acid, p-coumaric acid and trans-caftaric acid, with values ranging from 0.30 to 1.42 mg kg\(^{-1}\) were also detected. In a study by Rotta et al. (2019), the pulp of *P. edulis* presented hydroxybenzoic acid (0.12 mg kg\(^{-1}\)), chlorogenic acid (0.18 mg kg\(^{-1}\)), vanillic acid (0.43 mg kg\(^{-1}\)), caffeic acid (0.06 mg kg\(^{-1}\)), coumaric acid (0.24 mg kg\(^{-1}\)) and trans-cinnamic acid (0.37 mg kg\(^{-1}\)). For the pulp of passion fruit *P. subpeltata*, they detected the presence of cinnamic acid (0.01 mg kg\(^{-1}\)), ferulic acid (0.05 mg kg\(^{-1}\)) and vanillic acid (0.05 mg kg\(^{-1}\)). The values obtained for phenolic acids in the pulp of *P. edulis* and *P. cincinnata* in the present work are higher than reported in other studies for passion fruit pulp *P. edulis* (Rotta et al., 2019) and *P. subpeltata* (Shanmugam et al., 2018); however, these compounds were present in small amounts in both studies.

**Figure 3.** In vitro antioxidant activity of the pulp of two Brazilian passion fruit species. Antioxidant activities measured with DPPH\(^{•}\) and ABTS\(^{•+}\) expressed as mmol kg\(^{-1}\) equivalent to Trolox. Antioxidant activity measured with FRAP expressed as mmol Fe\(^{2+}\) kg\(^{-1}\). Bar averages, followed by equal letters, do not differ from each other by the Tukey test at 5% of error probability.
**In Vitro Antioxidant Activity**

In Figure 3, the results of the antioxidant activities (AOX) of the passion fruit fresh pulp as measured with ABTS** and DPPH* are expressed as equivalent to Trolox per kilogram of fresh pulp (mmol TE kg⁻¹). The results of the AOX by the FRAP method are expressed as Fe²⁺ equivalent per kilogram of fresh pulp (mmol Fe²⁺ kg⁻¹). With the free radical sequestration methods, *P. edulis* pulp had mean values of 1.47 and 1.43 mmol TE kg⁻¹ for ABTS** and DPPH*, respectively. *P. cincinnata* pulp had mean values of 1.25 and 1.07 mmol TE kg⁻¹ for ABTS** and DPPH*, respectively. With the FRAP method, the pulp of *P. edulis* and *P. cincinnata* presented average values of 5.92 and 4.50, respectively. In general, the pulp of passion fruit *P. edulis* had higher values of AOX than *P. cincinnata*.

The antioxidant activity of a sample depends on the method used in the measurement as well as the composition of the sample in relation to the profile of antioxidant substances. In the present study, except for the high quercetin 3-glucoside values in *P. cincinnata*, the two types of pulp studied presented a close profile for phenolic compounds; however, the highest values of AOX in *P. edulis* may be associated with its higher total bioactive content – total phenolics, total carotenoids and ascorbic acid (see Table 2). Other works in the literature have also associated the total phenolic content of passion fruit pulp directly to the AOX analysis by DPPH* and ABTS** methods (Ramaiya et al., 2013; Rotta et al., 2019; Septembre-Malaterre et al., 2016).

In a study by Ramaiya et al. (2013), the antioxidant activities (DPPH*) were measured in fresh pulp of several *Passiflora* species, where the values obtained were: *P. edulis* (yellow) (0.52 mmol TE kg⁻¹), *P. edulis* (purple), *P. edulis* (Frederick) (0.93 mmol TE kg⁻¹), *P. maliformes* (1.69 mmol TE kg⁻¹), *P. quadrangulares* (0.92 mmol TE kg⁻¹), *P. edulis* (pink) (0.78 mmol TE kg⁻¹) and *P. edulis* flavicarpa (0.75 mmol TE kg⁻¹). According to Rotta et al. (2019), the AOX values for the fresh pulp from the passion fruits *P. edulis*, *P. alata* and *P. ligulares* ranged from 5.75 to 8.10 mmol TE kg⁻¹ (DPPH* and ABTS**). Based on this, the antioxidant activities of the pulp of *P. edulis* Sims and *P. cincinnata* Mast were considered within the normal range.

**Principal Component Analysis (PCA)**

One of the ways to differentiate samples in relation to the profile of a number of compounds is by means of multivariate analysis of variance (MANOVA) using Principal Component Analysis (Granato et al., 2018). In the present study, a PCA was obtained between the total bioactive content, phenolic profile, and antioxidant activity in relation to the pulp from the passion fruits *P. edulis* and *P. cincinnata*, as shown in Figure 4. The principal components 1 and 2 (PC1 and PC2, respectively) explained 97.9% of the variance of components in the experiment, where PC1 explained 67.4% and PC2 30.5%. The analysis factor (loadings > 0.70) showed that the separation of the passion fruit species *P. edulis* and *P. cincinnata* occurred in PC1 (PC1 > 0; loading = 0.97). The variables associated with *P. cincinnata* (PC1 > 0; loadings > 0.70) were quercetin-3-glucoside, hesperidin, trans-caftaric acid, chlorogenic acid, caffie acid, p-coumaric acid, trans-resveratrol, rutin, procyanidin B2, epigallocatechin-gallate and epicatechin-gallate. The variables associated with *P. edulis* (PC1 < 0; loadings > 0.70) were total phenolic, vitamin C, total carotenoids, DPPH*, ABTS**, FRAP, cis-resveratrol, naringenin, kaempferol 3-glucoside, myricetin and procyanidin B1.

Based on the results of PCA, the differences in chemical profiles between the two species of passion fruit studied are evident. The species that presented the highest antioxidant activity was *P. edulis*, and, using by PCA, the compounds strongly correlated with antioxidant activities (DPPH*, ABTS** and FRAP) had the highest values of total phenolics, total carotenoids and vitamin C (ascorbic acid) present in the pulp of this species of passion fruit (Table 2). The results obtained in the present work corroborate with other studies that have mentioned that phenolic compounds, carotenoids and ascorbic acid are the main bioactive compounds present in the pulp of *Passiflora* (Medina et al., 2017; Pertuzatti et al., 2015; Ramaiya et al., 2013; Rotta et al., 2019; Wondracek et al., 2011).
The PCA proved to be a technique capable of differentiating the two species of passion fruit by virtue of their chemical profiles, even when the differences in the values of the measured compounds were apparently close (see Table 2).

*P. cincinnata*, although not a commercial species such as *P. edulis*, presented phenolic compounds and antioxidant activity in acceptable values, especially the high values of quercetin 3-glucoside. The present study highlights that *P. cincinnata* is a Brazilian native species that needs to be better explored. The results of the phenolic profile obtained in the present study for *P. cincinnata* Mast, corroborate those obtained recently by Silva et al. (2020) for the cv. ‘BRS Sertão Forte’, variety resulting from the genetic improvement of the species *Passiflora cincinnata* Mast, where quercetin 3-glucoside (isoquercetin) was the main phenolic found.

**Conclusions**

Pulp from the passion fruit species *P. edulis* Sims and *P. cincinnata* Mast. presented chemical profiles agreeing with those mentioned for other *Passiflora* species in the literature. The pulp of passion fruit *P. edulis* presented higher total bioactive content and antioxidant activity when compared to *P. cincinnata*. In relation to organic acids, the main quantified compounds were citric and malic acids, and in small quantities succinic acid, where *P. cincinnata* showed high values of citric acids when compared to other *Passiflora* species. The PCA differentiated between the pulp of the two species of passion fruit, associating the highest values of quercetin-3-glucoside, hesperidin, *trans*-caftaric acid, chlorogenic acid, caffeic acid, *p*-coumaric acid, *trans*-resveratrol, rutin, procyanidin B2, epigallocatechin-gallate and epicatechin-gallate to *P. cincinnata*. The *P. edulis* was associated with higher values of total phenolic, vitamin C, total carotenoids, antioxidant activity (DPPH*, ABTS** and FRAP), *cis-*
resveratrol, naringenin, kaempferol-3-glucoside, myricetin and procyanidin B1. *P. cincinnata*, although not a commercial species such as *P. edulis*, presented phenolic compounds and antioxidant activity in acceptable values, especially the high values of quercetin 3-glucoside.

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**Disclosure Statement**

The authors declare that there are no conflicts of interest regarding the publication of this article.

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**Ethical Approval**

This article does not contain any studies with human participants or animals performed by any of the authors.

**Literature Cited**

AOAC. Association of Official Analytical Chemists. 1998. Official methods of analysis. 16 ed. AOAC International, Rockville, MD, Washington.  
Ayres, A.S.F.S.J., W.B. Santos, D.D. Junqueira-Ayres, G.M. Costa, F.A. Ramos, L. Castellanos, J.S.F. Alves, L. Asth, I. U. Medeiros, S.M. Zucolotto, et al. 2017. Monoaminergic neurotransmission is mediating the antidepressant-like effects of *Passiflora edulis* Sims to *Edulis*. Neurosci. Lett. 660:79–85. doi: 10.1016/j.neulet.2017.09.010.  
Azoubel, P.M., A.J.B. Araújo, S.B. de Oliveira, and M.R. Amorim. 2011. Restructuring *Passiflora cincinnata* fruit pulp: Influence of hydrocolloids. Ciência e Tecnologia de Alimentos 31(1):160–166. doi: 10.1590/S0101-20612011000100023.  
Brasil. 2000. Instrução normativa n°1, de 7 de janeiro de 2000. Estabelece o Regulamento Técnico Geral para fixação dos Padrões de Identidade e Qualidade para polpa de fruta. Diário Oficial da República Federativa do Brasil, Seção 1, p. 261.  
Burin, V.M., N.E. Ferreira-lima, C.P. Panceri, and M.T. Bordignon-luiz. 2014. Bioactive compounds and antioxidant activity of *Vitis vinifera* and *Vitis labrusca* grapes: Evaluation of different extraction methods. Microchem. J. 114:155–163. doi: 10.1016/j.microc.2013.12.014.  
Chen, S., N. Yu, S. Yang, B. Zhong, and H. Lan. 2018. Identification of Telosma mosaic virus infection in *Passiflora edulis* and its impact on phytochemical contents. Virol. J. 15(168):1–8. doi: 10.1186/s12985-018-1084-6.  
Coelho, E.M., L.C. Azevêdo, A.C. Viana, I.G. Ramos, R.G. Gomes, M. Dos Santos Lima, and M.A. Umsza-Guez. 2018a. Physico-chemical properties, rheology and degree of esterification of passion fruit (*Passiflora edulis* f.flavicarpa) peel flour. J. Sci. Food Agric. 98(1):166–174. doi: 10.1002/jsfa.8451.  
Coelho, E.M., C.V. da Silva Padilha, G.A. Miskinis, A.G.B. de Sá, G.E. Pereira, L.C. de Azevêdo, and M. Dos Santos Lima. 2018b. Simultaneous analysis of sugars and organic acids in wine and grape juices by HPLC: Method validation and characterization of products from northeast Brazil. J. Food Comp. Anal. 66:160–167. doi: 10.1016/j.jfca.2017.12.017.  
Coelho, E.M., R.G. Gomes, B.A.S. Machado, R.S. Oliveira, M. Dos Santos Lima, L.C. Azêvedo, and M.A. Umsza-Guez. 2016. Passion fruit peel flour – Technological properties and application in food products. Food Hydrocoll. 62:158–164. doi: 10.1016/j.foodhyd.2016.07.027.  
Costa, E.C.S., T.S. Nunes, and J.I.M. Melo. 2015. Flora da Paraíba, Brasil: Passifloraceae *sensu stricto*. Rodriguésia 66 (1):271–284. doi: 10.1590/2175-7860201566117.  
Dias, T.J., L.F. Cavalcante, J.L.O. Freire, J.A.M. Nascimento, M.Z.B. Cavalcante, and G.P. Santos. 2011. Qualidade química de frutos do maracujazeiro-amarelo em solo com biofertilizante irrigado com águas salinas. Revista Brasileira de Engenharia Agrícola e Ambiental 15(3):229–236. doi: 10.1590/S1415-43662011000300002.
Dutra, M.C.P., L.L. Rodrigues, D. Oliveira, G.E. Pereira, and L.M. Dos Santos. 2018. Integrated analyses of phenolic compounds and minerals of Brazilian organic and conventional grape juices and wines: Validation of a method for determination of Cu, Fe and Mn. Food Chem. 269:157–165. doi: 10.1016/j.foodchem.2018.07.014.

Flores, P., P. Hellin, and J. Fenoll. 2012. Determination of organic acids in fruits and vegetables by liquid chromatography with tandem-mass spectrometry. Food Chem. 132(2):1049–1054. doi: 10.1016/j.foodchem.2011.10.064.

Granato, D., P. Putnik, D.B. Kovacevic, J.S. Santos, V. Calado, R.S. Rocha, A.G. Da Cruz, B. Jarvis, O.Y. Rodionova, and A. Pomerantsev. 2018. Trends in chemometrics: food authentication, microbiology, and effects of processing. Comp. Rev. Food Sci. Food Safety 17(3):663–677. doi: 10.1111/1541-4337.12341.

Kim, Y.K., Q. Guo, and L. Packer. 2002. Free radical scavenging activity of red ginseng aqueous extracts. Toxicology 172(2):149–156. doi: 10.1016/S0300-483X(01)00585-5.

Lavor, E.M., A.E.B.P. Leal, A.W.C. Fernandes, F.P.R.A. Ribeiro, J.M. Barbosa, M.G. Silva, R.B.A. Teles, L.F.S. Oliveira, J. C. Silva, L.A. Rolim, et al. 2018. Ethanol extract of the aerial parts of Passiflora cincinnata Mast. (Passifloraceae) reduces nociceptive and inflammatory events in mice. Phytomedicine. 47:58–68. doi: 10.1016/j.phymed.2018.04.052.

Medina, S., J.C. González, F. Ferreres, J.L. Londoño, C.J. Cartagena, A. Guy, T. Durand, J.M. Galano, and A.G. Izquierdo. 2017. Quantification of phytoprostanols – Bioactive oxylipins – And phenolic compounds of Passiflora edulis Sims shell using UHPLC-QqQ-MS/MS and LC-IT-DAD-MS/MS. Food Chem. 229:1–8. doi: 10.1016/j.foodchem.2017.02.049.

Mota, N.S.R.S., M.R. Kviecinski, R.C. Zeferino, D.A. Oliveira, L.C. Bretanha, S.R.S. Ferreira, G.A. Micke, D.W. Filho, R. C. Pedrosa, and F. Ourique. 2018. In vivo antitumor activity of by-products of Passiflora edulis f. flavicarpa Deg. Rich in medium and long chain fatty acids evaluated through oxidative stress markers, cell cycle arrest and apoptosis induction. Food Chem. Toxicol. 118:557–565. doi: 10.1016/j.fct.2018.06.010.

Oliveira, G.A., F. de Castilhos, C.M.G.C. Renard, and S. Boreau. 2014. Comparison of NIR and MIR spectroscopic methods for determination of individual sugars, organic acids and carotenoids in passion fruit. Food Res. Int. 60:154–162. doi: 10.1016/j.foodres.2013.10.051.

Padilha, C.V.S., G.A. Miskinis, M.E.A.O. De Souza, G.E. Pereira, D. Oliveira, M.T. Bordignon-Luiz, and M.D.S. Lima. 2017. Rapid determination of flavonoids and phenolic acids in grape juices and wines by RP-HPLC/DAD: Method validation and characterization of commercial products of the new Brazilian varieties of grape. Food Chem. 228:106–115. doi: 10.1016/j.foodchem.2017.01.137.

Pertuzzatti, P.B., M. Sganzerla, A.C. Jacques, M.T. Barcia, and R.C. Zambiasi. 2015. Carotenoids, tocopherols and ascorbic acid content in yellow passion fruit (Passiflora edulis) grown under different cultivation systems. LWT - Food Sci. Technol. 64(1):259–263. doi: 10.1016/j.lwt.2015.05.031.

Ramaiya, S.D., J.S. Bujang, M.H. Zakaria, W.S. King, and M.A.S. Sahirir. 2013. Sugars, ascorbic acid, total phenolic content and total antioxidant activity in passion fruit (Passiflora) cultivars. J. Sci. Food Agric. 93(5):1198–1205. doi: 10.1002/jsfa.5876.

Re, R., N. Pellegrini, A. Protegente, A. Pannala, M. Yang, and C. Rice-Evans. 1999. Antioxidant activity applying an improved ABTS** radical cationdecolorization assay. Free Radic. Biol. Med. 26(9–10):1231–1237. doi: 10.1016/S0891-5849(98)00315-3.

Rotili, M.C.C., J.A. Vorpogel, G.C. Braga, O.J. Kuhn, and A.B. Salibe. 2013. Atividade antioxidante, composição química e conservação do maracujá-amarelo embalado com filme PVC. Revista Brasileira De Fruticultura 35(4):942–952. doi: 10.1590/S0100-29452013000400004.

Rotta, E.M., C.A. Rodrigues, I.C.S.F. Jardim, L. Maldaner, and J.V. Visentainer. 2019. Determination of phenolic compounds and antioxidant activity in passion fruit pulp (Passiflora spp.) using a modified QuEChERS method and UHPLC/MS/MS. Food Sci. Technol. 100:397–403.

Rufino, M.D.S.M., R.E. Alves, E.S. de Brito, S.M. de Morais, C.D.G. Sampaio, J. Pérez-Jiménez, and F.D. Saura-colixto. 2006. Metodologia científica: Determinação da atividade antioxidante total em frutos pelo método de redução do ferro (FRAP). Comunicado Técnico Embrapa 125:1–4.

Scherer, R., A.C.P. Rybka, and H.T. Godoy. 2008. Determinação simultânea dos ácidos orgânicos tartárico, málico, ascórbico e cítrico em polpas de acerola, açaí e caju e avaliação da estabilidade em sucos de caju. Química Nova 31(5):1137–1140. doi: 10.1590/S0100-40422008000500039.

Septembre-Malaterre, A., G. Stanislas, E. Douraguia, and M.P. Gonthier. 2016. Evaluation of nutritional and antioxidant properties of the tropical fruit’s banana, litchi, mango, papaya, passion fruit and pineapple cultivated in Réunion French Island. Food Chem. 212:225–233. doi: 10.1016/j.foodchem.2016.05.147.

Shanmugam, S., I.A. Gomes, M. Denadai, B.S. Lima, A.A.S. Araújo, N. Narain, M.T.S.L. Neta, M.R. Serafini, L.J. Júnior, and P. Thangaraj. 2018. UHPLC-QqQ-MS/MS identification, quantification of polyphenols from Passiflora subpeltata fruit pulp and determination of nutritional, antioxidant, α-amylase and α-glucosidase key enzymes inhibition properties. Food Res. Int. 108:611–620. doi: 10.1016/j.foodres.2018.04.006.

Siebra, A.L.A., L.R. Oliveira, A.O.B.P.B. Martins, D.C. Siebra, R.S. Albuquerque, I.C.S. Lemos, G.A. Delmondes, S. R. Tintino, F.G. Figueredo, J.G.M. da Costa, et al. 2018. Potentiation of antibiotic activity by Passiflora cincinnata Mast. front of strains Staphylococcus aureus and Escherichia coli. Saudi J. Biol. Sci. 25(1):37–43. doi: 10.1016/j.sjbs.2016.01.019.
Silva, G.S., G.S.C. Borges, C.D.P.C. Castro, S.T. Aidar, A.T.B. Marques, S.T. de Freitas, A.C.P. Rybka, and H. R. Cardarelli. 2020. Physicochemical quality, bioactive compounds and in vitro antioxidant activity of a new variety of passion fruit cv. BRS Sertão Forte (*Passiflora cincinnata* Mast.) from Brazilian Semi-arid region. Sci. Hortic. 272:109595. doi: 10.1016/j.scienta.2020.109595.

Silva, L.M.R., E.A.T. Figueiredo, N.M.P.S. Ricardo, I.C.P. Vieira, R.W. Figueiredo, I.M. Brasil, and C.L. Gomes. 2014. Quantification of bioactive compounds in pulp and by-products of tropical fruits from Brazil. Food Chem. 143 (398–404):2014.

Silva, T.V., E.D. Resende, A.P. Viana, R.C.C. Rosa, S.M.F. Pereira, L.A. Carlos, and L. Vitorazi. 2000. Influência dos estádios de maturação na qualidade do suco de maracujá-amarelo. Revista Brasileira De Fruticultura 27(3):472–475. doi: 10.1590/S0100-29452005000300031.

Singleton, V.L., and J.A. Rossi. 1965. Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid reagents. Am. J. Enol. Vitic. 16:144–158.

Song, Y., X.-Q. Wei, M.-Y. Li, X.-W. Duan, Y.-M. Sun, R.-L. Yang, X.-D. Su, R.-M. Huang, and H. Wang. 2018. Nutritional composition and antioxidant properties of the fruits of a Chinese Wild *Passiflora foetida*. Molecules 23 (2):459. doi: 10.3390/molecules23020459.

Vianna-Silva, T., E.D. Resende, A.P. Viana, R.C. Carrielo, S.M.F. Pereira, L.A. Carlos, and L. Vitorazi. 2008. Influência dos estádios de maturação sobre as características físicas dos frutos de maracujá-amarelo. Bragantia 67(2):521–525. doi: 10.1590/S0006-87052008000200029.

Wijeratnam, S.W. 2016. Passion Fruit. Encyclop. Food Health 230–243. doi: 10.1016/B978-0-12-384947-2.00521-3.

Wondracek, D.C., F.G. Faleiro, S.M. Sano, R.F. Vieira, and T.S. Agostini-Costa. 2011. Composição de carotenoides em *Passifloras* do Cerrado. Revista Brasileira De Fruticultura 33(4):1222–1228. doi: 10.1590/S0100-29452011000400022.

Zhao, Z., S. He, Y. Hu, Y. Yang, B. Jiao, Q. Fang, and Z. Zhou. 2017. Fruit flavonoid variation between and within four cultivated Citrus species evaluated by UPLC-PDA system. Sci. Hortic. 224:93–101. doi: 10.1016/j.scienta.2017.05.038.