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BIOACTIVE CONTENT OF SIX PASSION FRUIT GENOTYPES CULTIVATED IN SOUTHERN BRAZIL

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Abstract

Passion fruit production in Brazil is concentrated in tropical regions, however, recently production has expanded to regions with temperate climate. Cultivar performance in different climate and soil can lead to variation in the contents of bioactive compounds in the juice and rind of the fruit. This study characterized the bioactive content of passion fruit rind and juice of six passion fruit genotypes (‘Catarina Roxo’, ‘Catarina’, ‘Urussanga’, ‘BRS Gigante Amarelo’, ‘BRS Rubi do Cerrado’, and ‘BRS Sol do Cerrado’) cultivated in southern Brazil. Phenolic, flavonoid, anthocyanin, carotenoid, and ascorbic acid contents and the antioxidant potential of each fruit portion from each genotype were evaluated. Fruit composition varied with genotype and evaluated tissue. Bioactive compound contents were greatest in the rind of ‘Urussanga’ and ‘Catarina’, whereas the juice of ‘BRS Sol do Cerrado’ and ‘Catarina Roxo’ had the greatest bioactive content. Given cultivar and tissue variability for bioactive content, postharvest use of passion fruit will determine the choice of cultivar to obtain a product with maximum bioactive compounds. Passion fruit genotypes evaluated in this study have shown to be potential sources of bioactive compounds. Fruit rind has the potential to be explored in the scientific and technological scope, due to its high amounts of phenolic compounds and antioxidant activity.

Keywords: Antioxidants. Fruit Rind. Juice. *Passiflora* spp. Phytochemicals.

1. Introduction

Passion fruit is cultivated in tropical regions and in Brazil approximately 550 thousand tons of passion fruit are produced yearly in approximately 51 thousand hectares (IBGE 2019). Passion fruit cultivation has expanded to new regions within Brazil but there is little information on their implementation in such location including Rio Grande do Sul state, where average temperatures are low, and frost may occur during the winter (Weber et al. 2017; Barreto et al. 2019).

Passion fruit species vary regarding fruit weight, diameter, color, rind thickness, taste, juice volume, acidity, and, consequently, the quantity of residues generated by the passion fruit processing industry. Such residues can be utilized into manufactured products and therefore possess potential commercial applications (Ayala-Zavala et al. 2011; Nascimento et al. 2012; Lopez-Vargas et al. 2013; Silva et al. 2014; Coqueiro et al. 2016).

The main cultivated passion fruit species are sweet passion fruit (*Passiflora alata* Curtis), purple passion fruit (*Passiflora edulis* Sims.), and yellow passion fruit (*Passiflora edulis* Sims.). Passion fruit is consumed mainly fresh or as juice. Yellow passion fruit, the most cultivated fruit in Brazil, is predominantly utilized in juice processing (Meletti 2011) and this results in a large amount of waste because about 50% of the fruit weight is represented by the rind and seeds (Weber et al. 2016), which are usually discarded after processing.

Bioactive compounds extracted from passion fruit juice and from passion fruit processing residues may be applied to pharmaceutical, cosmetics, chemical, and food industries (Oliveira et al. 2009). Processing passion fruit rind into a powder enables it to be mixed with other ingredients such as flours and to be added to baked goods, juices, and vitamins (Cazarini et al. 2014; Silva et al. 2014; Coqueiro et al. 2016). As a result, it contributes to add value to byproducts and impart functional potential to food (Zeraik et al. 2010; Coqueiro et al. 2016).

Passion fruit pulp and rind are rich in compounds that may provide significant benefits to human health (Zeraik et al. 2012; Pertuzatti et al. 2015; Araújo et al. 2018). Fruit bioactive content includes fibers and antioxidant compounds, and their consumption has been associated with reduction of chronic-degenerative diseases (Rufino et al. 2010; Chen et al. 2012).

Commercial passion fruit varieties are rich in bioactive compounds, including vitamin C, carotenoids, and phenolic compounds (Zeraik et al. 2010). These compounds may be affected by several factors, such as the genotype, edaphoclimatic conditions, cultivation system, and postharvest processing (Pertuzatti et al. 2015; Botelho et al. 2016).

In this study fruit of six passion fruit cultivars were separated into juice and rind and each fruit part from each cultivar was evaluated for its bioactive composition.

2. Material and Methods

Fruits were harvested from passionfruit vines grown on espaliers at the Centro Agropecuário da Palma (CAP), at Universidade Federal de Pelotas (UFPel), located in Capão do Leão, RS, Brazil. The region has a humid subtropical climate with hot summers, considered “Cfa” in Köppen climate classification. The mean temperature and mean annual rainfall during cultivation were 18.6ºC and 1,844.3 mm, respectively.

The soil is moderately deep with medium texture at the A horizon and clay texture at the B horizon, and therefore classified as red-yellow clay soil. The soil consisted of 13% clay, 1.5% organic matter, 4% aluminum saturation, 61% base saturation, cation exchange capacity at pH 7 of 7.9 $cmol_c/dm^3$, 50.4 mg/dm^3 of P-Mehlich, 65 mg/dm^3 of K and pH 5.0. Fertilization was carried out according to the Manual of Fertilization and Liming for the States of Rio Grande do Sul and Santa Catarina (ROLAS, 2004), applying bovine manure at planting, increasing doses of nitrogen (Urea) every 15-20 days until flowering, followed by higher doses of phosphorus (simple superphosphate) and potassium (potassium chloride) divided into five plots, based on soil analysis. Liming was performed with dolomitic limestone (PRNT 85%) performed according to the Shoemaker-McLean-Pratt (SMP) index method, raising the pH to 6.0, according to Rolas (2004).

‘Catarina Roxo’ (Epagri), purple rind; ‘Catarina’ (Epagri), yellow rind; BRS Gigante Amarelo, yellow rind; BRS Rubi do Cerrado, yellow rind; and BRS Sol do Cerrado, yellow rind were all sour passion fruit (*Passiflora edulis* Sims.) while ‘Urussanga’ (Epagri), yellow rind was the only sweet passion fruit (*Passiflora alata* Curtis) type.

The experimental design was completely randomized, with four replications. Twenty ripe fruits from every treatment were harvested. Fruits were washed, the pulp was separated from the rind and the juice was strained, packaged in plastic bags and frozen at -20ºC until analysis. The rind was oven dried at 60°C for 24 hours until the humidity content reached 10%. Then, it was ground using an industrial blender so that the powder had uniform particle size of 1 mm. Ground samples were stored in brown paper bags at room temperature (24°C) until analysis.

For the analyses of phenolic compounds, flavonoids, and antioxidant capacity, either 2 g dry and ground rind or 2 mL of juice were extracted with 20 mL methanol. The mixture was homogenized by ultraturrax (7,500 rpm) for 1 min and centrifuged at 9,900 x *g* for 15 min at 15ºC. The supernatant was collected in 15 mL polypropylene tubes.

Total phenolic compound content was determined according to the methodology proposed by Singleton and Rossi (1965) and results were expressed as mg gallic acid equivalent (GAE) per 100 g fresh weight. Total flavonoid content was determined by spectrophotometry (Zhishen et al. 1999) and results were expressed as mg catechin equivalent per 100 g fresh weight. Total anthocyanin content was determined according to the methodology proposed by Lees and Francis (1972) and results were expressed as mg cyaniding-3-glucoside equivalent per 100 g fresh weight. L-Ascorbic acid content was determined by high performance liquid chromatography (HPLC), using a Shimadzu HPLC system equipped with an automatic injector and a UV-Vis detector (254 nm), following a method adapted from Vinci et al. (1995) and results were expressed as mg L-Ascorbic acid equivalent per 100 g fresh weight. Carotenoid content was determined using the modified AOAC (2005) method 970.64 and results were expressed as mg β-carotene equivalent per 100 g fresh weight. Antioxidant potential was determined by the method proposed by Brand-Williams et al. (1995), with the use of the free radical *2,2*-diphenyl-*1*-picrylhydrazyl (DPPH) and results were expressed as percentage (%) of DPPH radical remaining.

Data were submitted to an analysis of variance (ANOVA). When the effect of the treatment was significant means were compared by Tukey's test ($p \leq 0.05$). To determine the correlation between the measured variables antioxidant potential, anthocyanin, ascorbic acid, carotenoids, flavonoids, and phenolic compounds, Pearson's correlation coefficients were calculated ($p \leq 0.05$).

3. Results and Discussion

Contents of total phenolic compounds found in passion fruit and rind (ranged from 118.6 to 192.3 mg GAE 100 g^{-1}) did not differ (p≤0.05) among 'Catarina Roxo', 'Catarina', 'BRS Gigante Amarelo', and 'Urussanga' genotypes, and were higher than those found in 'BRS Sol do Cerrado' and 'BRS Rubi do Cerrado' genotypes (Table 1).

Table 1. Phenolic, flavonoid, and anthocyanin contents of passion fruit juice and rind.

Genotypes	Phenolic compounds[1]		Flavonoids[2]		Anthocyanins[3]	
	Rind	Juice	Rind	Juice	Rind	Juice
Catarina Roxo	192.3±10.8^{a}	36.7±5.4^{bc}	48.5±4.1^{ab}	5.0±1.2^{a}	3.5±0.1^{c}	nd
Gigante Amarelo	173.3±10.3^{a}	28.3±2.0^{bc}	39.4±3.3^{bc}	3.7±1.0^{ab}	5.5±0.5^{b}	nd
Urussanga	190.4±20.7^{a}	49.1±8.0^{a}	56.0±3.4^{a}	2.9±1.2^{b}	9.1±0.7^{a}	nd
Rubi do Cerrado	118.6±14.9^{b}	26.1±2.4^{c}	31.0±2.3^{c}	3.1±1.1^{ab}	5.6±1.3^{b}	nd
Catarina	175.4±19.0^{a}	27.9±5.0^{bc}	54.0±9.8^{a}	5.0±1.2^{a}	7.2±1.2^{ab}	nd
Sol do Cerrado	128.8±26.9^{b}	36.7±5.4^{bc}	62.0±10.0^{a}	3.7±1.0^{ab}	7.4±0.5^{ab}	nd

Means followed by the same lowercase letter within a column do not differ from each other based on Tukey's test ($p \leq 0.05$). nd = not detected. [1]mg gallic acid equivalent 100 g^{-1} fresh weight (fw); [2] mg catechin equivalent 100 g^{-1} fw; [3] mg cyanidin-3-glycoside equivalent 100 g^{-1} fw.

Phenolic compound variation among passion fruit varieties depends on genetic and environmental factors as well as their interaction (Herrera 2012). Previous studies also reported variation in the phenolic contents of different passion fruit genotypes (Ramaiya et al. 2013; Casierra-Posada and Jarma-Orozco 2016). Ideal temperature for passion fruit cultivation ranges from 23°C to 27°C (Andrade Neto et al. 2015). Fruit evaluated in this study came from plants grown under summer months temperature ranging from 22°C to 25°C and winter months temperature ranging from 12 °C to 15 °C (Barreto et al. 2019). At lower temperature and higher altitude fruit production is delayed and fruit development takes longer (Fischer et al. 2018), which in turn may affect phenolic compound metabolism (Malheiro et al. 2015).

Higher amounts of phenolic compounds found in passion fruit rind than in juice, direct a potential application of this residue into a product with health promoting appeal to due to the phenolics' capacity of preventing various processes associated with oxidative stress (Chandrasekhar et al. 2019).

Cazarin et al. (2014) studied *Passiflora edulis* Sims. passion fruit produced in Torre de Pedra, São Paulo and found contents of total phenolic compounds which ranged from 206 to 253 mg GAE 100 g^{-1} rind (fresh weight). It's possible that the drying process at 60ºC for 24 h may have led to the degradation of phenolics, which explains the low contents found in this study (118 to 192 mg GAE 100 g^{-1}). On the other hand, other studies with passion fruit grown in the states of Santa Catarina, Paraná, and Pernambuco found even lower total phenolic contents ranging from 20 to 83 mg GAE 100 g^{-1} fresh weight in passion fruit pulp (Kuskpski et al. 2006; Melo et al. 2008; Rotili et al. 2013).

The highest content of phenolic compounds was found in the juice extracted from the 'Urussanga' genotype, which belongs to the group of sweet passion fruits (Table 1). Likewise, Cohen et al. (2008a) also found higher contents of phenolic compounds in sweet passion fruits than in sour ones ranging from 46 to 60 mg GAE 100 g^{-1}; similar contents were observed in the current study. There seems to be a correlation between sugars and phenolic compounds. Positive correlation between glucose, fructose, and total sugar with the content of phenolic compounds has already been reported in passion fruit juice (Ramaiya et al. 2012).

Flavonoid content in passion fruit rind ranged from 31.0 to 62.0 mg catechin 100 g^{-1}. 'BRS Sol do Cerrado', 'Urussanga', 'Catarina', and 'Catarina Roxo' genotypes had higher flavonoid content than both 'BRS Rubi do Cerrado' and 'BRS Gigante Amarelo' genotypes (Table 1). In oven dried peel of passion fruit, was found a flavonoid concentration of 35.13 mg equivalent of quercetin 100 g^{-1} (Morais et al. 2015). The content of flavonoids found in passion fruit rind in this study was higher than those reported by Morais et al. (2015), with the exception of Rubi do Cerrado. Flavonoid content in passion fruit juice varied from 2.9 to 5.0 mg catechin 100 g^{-1} and 'Catarina Roxo' and 'Catarina' genotypes had the highest content in relation to 'Urussanga' (Table 1). Similar values were found by Cohen et al. (2008b), who found values between 3.0 to 4.73 mg 100 g^{-1} of flavonoids in the passion fruit pulp.

Anthocyanins were not detected in passion fruit juice of the evaluated genotypes. The highest anthocyanin contents were found in the rind of 'Urussanga', 'BRS Sol do Cerrado', and 'Catarina' genotypes (Table 1). Kuskoski et al. (2006) also did not find anthocyanins in passion fruit juice, what is expected, since the fruit flesh of all genotypes are yellow, which indicates the presence of carotenoids, not anthocyanins (Acero et al. 2019). On the other hand, the peel of some passion fruits, as in the case of 'Catarina Roxo' has red / purple colors which is usually associated with the accumulation of anthocyanins. Throughout fruit development occurs degradation of chlorophyll and synthesis of pigments, such as yellow carotenoids and purple anthocyanins in the rind (Silva et al. 2008).

Contents of ascorbic acid in the rind were higher in 'Catarina', 'Urussanga' and 'BRS Gigante Amarelo' genotypes (Table 2). Ascorbic acid content of passion fruit juice varied from 5.1 (Catarina) to 9.7 mg of L-ascorbic acid 100 g^{-1} (Catarina Roxo) (Table 2). Ascorbic acid is a very labile compound susceptible degradation by heat and oxidation and is usually utilized as quality control marker.

Table 2. Ascorbic acid and carotenoid contents and antioxidant potential of passion fruit juice and rind.

Genotypes	Ascorbic acid[1]		Carotenoids[2]		Antioxidant potential[3]	
	Rind	Juice	Rind	Juice	Rind	Juice
Catarina Roxo	7.0±1.3^{b}	9.7±2.1^{a}	2.5±0.3^{b}	8.8±2.2^{bc}	49.1±2.9^{b}	12.7±1.3^{ab}
Gigante Amarelo	6.8±3.0^{b}	6.7±1.8^{bc}	2.3±0.2^{b}	11.0±2.7^{b}	52.2±2.8^{ab}	10.7±1.5^{b}
Urussanga	9.9±2.6^{ab}	5.9±2.6^{bc}	19.8±5.7^{a}	5.0±1.4^{c}	62.9±2.5^{a}	7.3±1.7^{c}
Rubi	8.9±0.6^{ab}	6.6±2.5^{bc}	1.9±0.1^{b}	9.6±2.9^{bc}	33.1±3.5^{c}	11.2±1.4^{b}
Catarina	12.1±1.4^{a}	5.1±1.1^{c}	3.7±1.4^{b}	10.1±1.6^{b}	54.2±2.7^{ab}	10.9±1.5^{b}
Sol do Cerrado	2.7±0.4^{c}	8.2±2.0^{ab}	1.6±0.1^{b}	18.1±0.7^{a}	48.7±2.9^{b}	13.9±1.3^{a}

Means followed by the same lowercase letter within a column do not differ from each other based on Tukey's test ($p \leq 0.05$). [1] mg L-ascorbic acid equivalent 100g^{-1} fresh weight (fw); [2] mg β-carotene equivalent 100 g^{-1} fw. [3] % of DPPH radical remaining.

Total carotenoid content of fruit rind varied from 1.6 (Sol do Cerrado) to 19.8 mg equivalent β-carotene 100 g^{-1} (Urussanga) (Table 2). Rind of 'Urussanga' genotype had the highest carotenoid content of all genotypes meanwhile 'Urussanga' juice had the lowest carotenoid content (along with Rubi and Catarina Roxo) (Table 2). Sepúlveda et al. (1996) observed 1.57 to 3.22 mg equivalent β-carotene 100 g^{-1} in passion fruit (*Passiflora edulis*) and that the harvest season influences carotenoid content, with fruit grown during winter months yielding greater carotenoid content than those grown during summer months. Therefore, the cultivation of passion fruit in the southern colder regions has the potential to yield juices with more intense colors and higher contents of carotenoids.

The rind of ‘Urussanga’, ‘Catarina’, and ‘BRS Gigante Amarelo’ genotypes had the highest antioxidant capacity (Table 2). Cazarin et al. (2014) found yellow passion fruit antioxidant capacity measured as inhibition % of the radical DPPH ranging from 46.4% and 29.6%, similar to the ones of the ‘BRS Rubi do Cerrado’ and ‘BRS Sol do Cerrado’ genotypes (Table 2).

Regarding the antioxidant capacity of the juice, ‘BRS Sol do Cerrado’ and ‘Catarina Roxo’ genotypes had the highest values, whereas the ‘Urussanga’ genotype had the lowest ones (Table 2). It is possible that the highest antioxidant potential found in passion fruit rind may be in part due to anthocyanins do not present in the fruit juice (Zeraik 2010).

Positive and strong correlation was observed between phenolic content and antioxidant potential (r=0.8092), positive and moderate correlations were observed between both flavonoid (r=0.6108) and carotenoid (r=0.5406) contents with antioxidant potential, and positive and low correlation was observed between anthocyanin and antioxidant potential (r=0.4084) in passion fruit rind (Table 3). In addition, antioxidant potential of fruit rind was negatively correlated with ascorbic acid content (r= - 0.4121) (Table 3).

Table 3. Pearson's correlation coefficients (r) comparison of variables measured in passion fruit juice.

	Ascorbic acid	Carotenoid	Flavonoid	Phenolic compounds	Antioxidant potential
Ascorbic acid	1.0000	0.3435	0.5331*	0.1674	0.6748*
Carotenoid		1.0000	0.4723*	-0.1801	0.7094*
Flavonoid			1.0000	0.0705	0.4765*
Phenolic				1.0000	-0.2324
Antioxidant potential					1.0000

* Significant at $p \leq 0.05$.

In passion fruit juice the antioxidant potential was positively correlated with ascorbic acid (r=0.6748), carotenoid (r=0.7094), and flavonoid contents (r=0.4765) (Table 3). No significant correlation was observed between phenolic compounds and antioxidant potential in passion fruit juice. On the other hand, passion fruit rind antioxidant potential was more strongly correlated with total phenolic content (r=0.8092). Melo et al. (2008) and Rotili et al. (2013) had found a weak correlation between fruit phenolic content and antioxidant capacity. However, many other authors have shown a strong positive correlation between total phenolic content and the antioxidant capacity of fruits (Leja et al. 2003; Abdille et al. 2005; Kuskoski et al. 2006; Gruz et al. 2011). The variation observed for the correlation coefficients indicate that the overall antioxidant capacity of the fruit may be better explained from the added contributions from all the different components with antioxidant properties instead of their isolated impact.

Table 4. Pearson's correlation coefficients (r) comparison of variables measured in passion fruit rind.

	Anthocyanin	Ascorbic acid	Carotenoid	Flavonoid	Phenolic compounds	Antioxidant potential
Anthocyanin	1.0000	-0.0373	0.5857*	0.4879*	-0.0587	0.4084*
Ascorbic acid		1.0000	0.0341	-0.6746*	-0.1799	-0.4121*
Carotenoid			1.0000	0.2796	0.3588	0.5406*
Flavonoid				1.0000	0.3028	0.6108*
Phenolic					1.0000	0.8092*
Antioxidant potential						1.0000

* Significant at $p \leq 0.05$.

4. Conclusions

Differences in contents of bioactive compounds were genotype and tissue dependent and therefore postharvest use of passion fruit will determine the choice of cultivar to obtain a product with maximum bioactive compounds.

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