ISSN 0100-2945
DOI: http://dx.doi.org /10.1590/0100-29452019452
Revista Brasileira de Fruticultura

Processing

Physical-chemical and chemical characterization of *Passiflora cincinnata* Mast fruits conducted in vertical shoot positioned trellis and horizontal trellises system

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Abstract - *Passiflora cincinnata* Mast. or Caatinga passion fruit is widely cultivated in the northeastern semi-arid regions of Goiás, Minas Gerais, and Bahia. The system of cultivation and field management of the *Passiflora* species affects the physicochemical quality of its fruits. In this study, we evaluated the chemical and physico-chemical characteristics of the fruits of 2 progenies (CPEF2220 and CBAF2334) of *P. cincinnata* species using the vertical and horizontal trellis system. Fruits were collected from the plants at their physiological maturation stage and tested for the fruit skin color and texture and the pH, total soluble solids, titratable acidity, pulp acidity ratio, and the contents of flavonoids, anthocyanins, and polyphenols in the seedless fruit pulp. The experimental design was completely randomized in a 2 x 2 factorial scheme (progenies x conduction system) performed in 3 replications using 4 plants in each. The analysis of variance and the means were compared using the Tukey's test at 5% probability. The results revealed that the CBAF2334 fruits presented with greener pigments and greater flavonoids. The fruits were characterized by their green color with some yellowish nuances and a low color saturation in both the progenies. The conduction system was not found to affect the physical and physicochemical characteristics as well as the anthocyanin and polyphenol contents of the studied species. The fruits of plants cultivated on vertical trellis presented with 56.73% more flavonoid content than those cultivated on horizontal trellis.

Index terms: flavonoids, coloration, polyphenols, acidity

Caracterização físico-química e química de frutos de *Passiflora cincinnata* Mast conduzidos em espaldeira e latada

Resumo - *Passiflora cincinnata* Mast., conhecida como maracujá da caatinga ocorre no Semiárido nordestino, Goiás, Minas Gerais e na Bahia. A região de cultivo e os sistemas de manejo das espécies do gênero *Passiflora* podem interferir na qualidade físico-química dos frutos. Objetivou-se avaliar características físico-química e química dos frutos de duas progênies (CPEF220 e CBAF2334) selecionadas de *P. cincinnata* conduzidas em espaldeira e latada. Frutos no estádio de maturação fisiológica foram avaliados quanto à coloração e textura da casca, pH, sólidos solúveis totais, acidez titulável, ratio, flavonoides, antocianinas e polifenóis da polpa sem sementes. Foi utilizado o delineamento inteiramente casualizado, em esquema fatorial 2 x 2 (progênies x sistemas de condução), com três repetições de quatro plantas. Foi realizada a análise de variância, e as médias foram comparadas utilizando o teste de Tukey, a 5% de probabilidade. Os frutos da seleção CBAF2334 apresentaram mais pigmentos verdes e mais flavonoides. Os frutos foram caracterizados de coloração verde com nuances amareladas, com baixa saturação de cor, nas duas populações. O sistema de condução não afetou as características físicas, físico-química e os teores de antocianinas e polifenóis das progênies de *P. cincinnata*. Os frutos das espaldeiras apresentaram 56,73% a mais de flavonoides em comparação aos obtidos na latada.

Termos para indexação: flavonoides, coloração, polifenóis, acidez.

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Received: February 27, 2019
Accepted: September 27, 2019

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Introduction

Passiflora cincinnata Mast. bears green-colored fruits (IMIG, 2013) and its fruit pulp is characterized to have acidic pH. This fruit is popularly known as the passion fruit of the bush (JESUS; FALEIRO, 2016), the passion fruit of brabo, the passion fruit of green shell, the passion fruit-shark (OLIVEIRA;RUGGIERO, 2005), and the passion fruit of the Caatinga (EMBRAPA, 2016). *P. cincinnata* is commonly found in the Caatinga and Cerrado biomes of Brazil, and it occurs abundantly in the northeastern semi-arid regions of Goiás, Minas Gerais, and Bahia (JESUS; FALEIRO, 2016).

Among the several commercially important Passifloras occurring in Brazil, *P. cincinnata* possess significant commercial potential (FALEIRO et al., 2017). For this purpose, it is deemed important to develop genetically superior cultivars of this species and optimize the production system. Presently, there is a lack of appropriate genotypes for cultivation purpose, which needs to be resolved via genetic improvement programs (MELETTI et al., 2005; VIANA; GONÇALVES, 2005). Recently, the BRS Sertão Forte (BRS SF) variety developed by Embrapa has been made available in the market; this variety is a result of the cross of 2 select plant progenies that are adapted to the semiarid region, namely, the CBAF 2334 and CPEF 2220 (EMBRAPA, 2016).

The presently available passion fruit cultivation system is based on the growth habit of this plant (BERNACCI, 2003), which needs support for conduction. Accordingly, there are 2 main types of structures: the horizontal trellis system consisting of a horizontally interwoven wire structure supported by 4 pillars (cuttings) and the vertical trellis system in which 2-3 vertically supported wires are used (LIMA et al., 2002; ZACHARIAS et al., 2016).

Komuro (2008) and Monzani (2017) did not verify the differences in the physical and chemical quality of the fruits of sour passion fruits (*P. edulis*) in different conduction systems. Based on the time of the year of the study, Carvalho et al. (2018) found differences in some of the chemical compounds in the pulp of *P. setacea* species between the two conduction systems (vertical and horizontal trellis). However, similar studies are lacking for *P. cincinnata*.

Regarding the chemical properties of *P. cincinnata*, phenolic compounds are known to be present in its leaves, stems, and fruits (from peel, pulp, and seeds) (LESSA, 2011; SIEBRA, 2013; SIEBRA et al., 2014). Phenolic compounds such as flavonoids and anthocyanins are components of the flavonoid polyphenol class - a polyphenol subtype. These compounds can act as free-radical reducing and sequestering agents (CHITARRA; CHITARRA, 2005). Owing to the beneficial effects of this fruit on the human health, this plant species has gained much interest, especially with respect to its consumption and potential for the production of functional foods (GADIOLI et al., 2018; COSTA, 2017).

From anthesis to the maturation, fruits undergo several morphological, histochemical, and biochemical differentiations (BIALE, 1964). All these processes occur as a result of the expression of genes, especially those of the MAD-box complex, such as APETALA1 (AP1), which acts mainly in relation to the petal and sepal development, APETALA3 (AP3) and PISTILLATA (PI) for the petal and stamen, AGAMOUS (AG) for stamens and carpels, SEPALLATA 1-4 (SEP 1-4) for the floral organs, and some others that act on the reproductive development of plants (CUTRI; DORNELAS, 2011). Genes such as SHATTERPROOF 1 and 2 (SHP1 and SHP2) and FRUTIFUL (PeFUL) are also attributed for their effect on fruit development (LILJEGREN et al., 2000; SCORZA et al., 2017). Thus, the gene expression interacts with the environment and gets modulated by the area of cultivation and the cultivation system; these factors can interfere in the productivity and quality of the resultant fruits due to the differences in the climate.

The different regions in Brazil share climatic differences. For instance, the Brazilian semiarid region in the northeast is characterized by the occurrence of seasonal and periodic droughts, annual average rainfall of <800 mm, and an annual average temperature of 23-27°C (MOURA et al., 2007). In Cerrado, the average annual temperature is approximately 22-23°C and the average annual rainfall is 1200-1800 mm, concentrated mostly between October and March (COUTINHO, 2018).

In this study, we evaluated the physicochemical and chemical characteristics of the fruits of 2 *P. cincinnata* progenies in 2 different cultivation systems at the Cerrado region of the Central Plateau.

Material and Methods

Two parental progenies (CBAF 2334 and CPEF 2220) of *P. cincinnata* cv. BRS Sertão Forte were sourced from the Embrapa Semiarid germplasm bank. These progenies have their genetic origin in the northeast semi-arid regions and were grown at the Embrapa Cerrados Fruit Support Unit, 15°36’13.02”S; 47°43’17.34”O and at approximately 1050 m altitude, Planaltina-DF).

Holes with dimensions of 60 cm (diameter) and 60 cm (depth) were prepared using a drill bit. For planting, dolomitic limestone to raise V to 50%, 50 g/pit of P_2O_5 (Simple Superphosphate); 20 g/pit of N (Ammonium sulphate); 60 g of K_2O (Potassium chloride); 100 g/well of FTE BR12; and 10 L/pit of organic matter (chicken litter) were used. The first mulching was performed after 60 days of planting, followed by others at every 45 days using 100 g/plant dosage of potassium chloride and ammonium sulphate (1:2).

The crops were implemented on April 9, 2015 and transplanted to seedlings with 3.5 months in a completely randomized design using a 2 × 2 factorial scheme (2 progenies × 2 conduction systems) with 3 replications of 4 plants per plot. The plants were distributed in 2 rows, with intervals between the plants and between rows of 2.5 m × 2.5 m in the vertical trellis system and 2.5 m × 5 m in the horizontal trellis system (Figure 1).

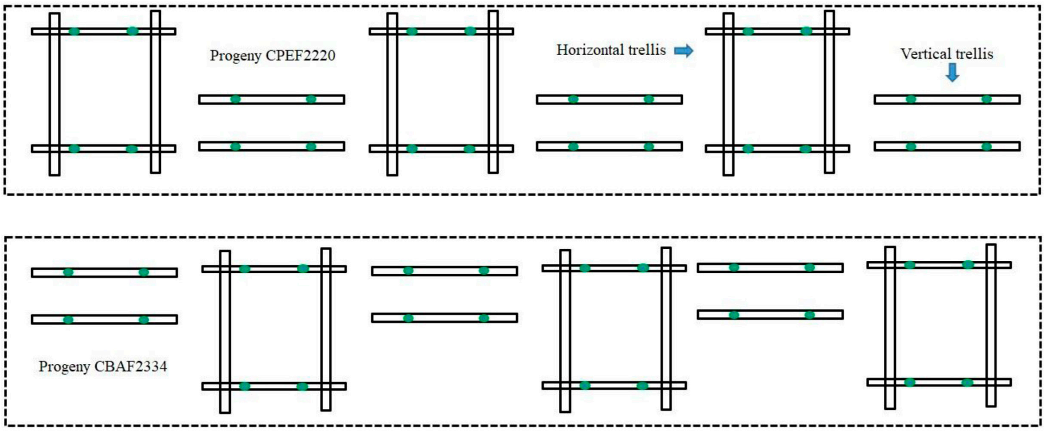

Figure 1. Representation of experimental area and plant distribution in vertical trellis and horizontal trellis.

The fruits were collected after they fell to the ground (physiological maturation point). Eight fruits from each plot were collected between May and June of the year 2016 based on the availability of fruit abscission, followed by storage at 10°C and 90% relative humidity for a maximum of 48 h until the physical, physicochemical, and chemical analysis of the collected fruits.

The physical features that were analyzed included the peel coloration of the fruit at 5 distinct points using a portable spectrophotometer (MiniScan EZ; HunterLab®) which measured the values of L (luminosity), 'a' (indicative of green or red), 'b' (indicative of yellow or blue) of which the average values of 'a' and 'b' were used to calculate chromaticity (color intensity) and hue angle (color tone) (McGuire, 1992); firmness of the fruits, making 3 holes at equal distance from the middle portion using a texturometer (CT3 4500; Brookfield Texture Analyzer®) configured in the normal test mode with a force of 100 g, 5-mm deformation, and the speed of 10 mm/s equipped with the TA 17-tip type 24-mm D 30°. The results were expressed in Newton (N).

The pulp was separated from the fruit using a blunt blade food mixer, followed by sieving. The physicochemical analyses of the pulp were performed according to the methodologies described by the ADOLFO LUTZ INSTITUTE (2008). For instance, soluble solids (SS) content was determined using a digital refractometer (HI 96801; Hanna®); pH with a pH meter equipped with an electrode and potentiometer (HI 221; Hanna®); titratable acidity using potentiometric volumetry by titrating the standard 0.1 N sodium hydroxide solution in 2-mL of the pulp diluted in 48 mL of distilled water using a manual dispenser (776 Dosimat ΩMetrohm®) and a pH meter (HI 2211; Hanna®); the results are expressed in per gram of citric acid and the ratio in SS/titratable acidity.

Chemical analyses of the anthocyanin and flavonoid contents (LEES; FRANCIS, 1972) were performed using 5 g of the sample (seedless pulp) homogenized in ethanol and 1.5 N (85:15 v/v) HCl solution in 50-mL volumetric flask. The samples were stored under light shelter in a refrigerated environment for 16 h. Next, the sample was filtered and subjected to absorbance measurement on a spectrophotometer (Biomate 3; ThermoFisher®) at a wavelength of 374 ηm for flavonoids and 535 ηm for anthocyanins.

The polyphenols content was determined by using the spectrophotometric method of total extractable polyphenols dosage using the Folin Ciocalteau reactive, following the procedures of obtaining the extracts by Larrauri et al. (1997) and that of reading by Obanda and Owuor (1997). The moisture in the pulp was removed by drying 5 g of the sample from each frozen experimental unit and freeze drying for 24 h; the results obtained were used to calculate the chemical compounds on dry matter basis.

Statistical verification of the significance of the treatments was performed by applying analysis of variance (ANOVA). Residual normality assumptions were verified by the Shapiro–Wilk test (MIOT, 2017) and the homogeneity of variance by the Levene test (LEVENE, 1960). Tukey's test was used to compare the means at a 5% probability level.

Associations among the physical, physicochemical, and chemical variables of the fruit were determined by the Pearson's Linear Correlation analysis. All analyzes were performed using the R statistical software (version 3.5.0) (R, 2018).

Results and discussions

The positive effects of the selected progenies CPEF 2220 and CBAF 2334 in the 2 conduction systems were evaluated, but no effect of the interaction was noted between the progenies and the adopted conduction systems. The values concerning the color and texture characteristics (firmness) of the fruits are presented in Table 1.

The fruits showed slight difference in their coloration, as the only color component that showed differences was in the values of "a", which represented color variation from red (+) to green (-). Negative 'a' values (Table 1) indicated the predominance of the green fruit color (MCGUIRE, 1992), and the differences showed that the fruits of progeny CBAF 2334 had a color that tended more toward green. The values of "b" indicate values within the yellow (+) scale of the Cielab system (MCGUIRE, 1992).

Table 1. Characteristics of color (luminosity, 'a', 'b', chroma and hue angle) and texture (firmness) of fruits of *Passiflora cincinnata* Mast. progenies CPEF 2220 and CBAF 2334 conducted in a vertical trellis and horizontal trellis, collected between May and June 2016.

Progenies	CPEF 2220	CBAF 2334	Mean	CPEF 2220	CBAF 2334	Mean	CPEF 2220	CBAF 2334	Mean
System		**Luminosity**			**'a'**			**'b'**	
Ver T*	52.01	51.40	51.70 a[1]	-4.18	-7.25	-5.72 a	24.41	26.70	25.54 a
Hor T*	53.66	50.72	52.19 a	-5.51	-6.55	-6.03 a	26.39	26.25	26.32 a
Mean	52.83 A	51.06 A	CV=6.8%	-4.84 A	-6.90 B	CV=-24.53%	25.39 A	26.47 A	CV=13.23%
		Chroma[2]			**Hue[3]**			**Firmness**	
Ver T*	24.98	27.94	26.46 a	98.66	106.48	102.57 a	12.42	9.96	11.19 a
Hor T*	26.91	27.16	27.03 a	102.52	104.34	103.43 a	13.16	8.43	10.79 a
Mean	25.94 A	27.55 A	CV=12.48%	100.59 A	105.41 A	CV=4.01%	12.79 A	9.20 A	CV=67.48%

*Vert T = Vertical trellis; Hor T = Horizontal trellis. [1]Means followed by the same lowercase letter in the column and uppercase in the row within each evaluated characteristic do not differ according to Tukey's test at 5% probability level. [2]Chroma = $(a^2+b^2)^{1/2}$ and [3]Hue = arctangent (b/a) x 57.296 for positive 'a' and 'b' values and Hue = arctangent (b/a) x 57.296 + 180 for values of negative 'a' and positive 'b'.

The fruits of these two progenies shared the same color shade, because there were no significant differences in the hue angle values (Table 1). The values presented indicated the yellowish-green color of the fruits, because the yellow color was indicated by 90º and the green one by 180º, which together with the saturation of these colors (MCGUIRE, 1992; MENDONÇA et al., 2003), provided the practical visualization of the fruit color tending toward green (Figure 2).

Figure 2. *Passiflora cincinnata* fruits.

Several authors have classified these fruits as green (OLIVEIRA; RUGGIEIRO, 2005; WONDRACEK, 2009; MAGALHÃES, 2010; IMIG, 2013). *P. cincinnata* fruits have also been characterized as being green in color, but with yellowish nuances of a low intensity and/or color saturation (according to the chroma values) and intermediate brightness of black and white.

The data shown in Table 2 indicate that the fruits of the 2 progenies tested, irrespective of the conduction system adopted, did not present any significant differences for the evaluated physicochemical characteristics. However, in comparison with the results reported by Lima et al. (2017), who worked with *P. cincinnata* pulp, there are values close to pH (2.91 and 2.83, respectively), but higher by 24% in the values of SST (11.84 and 9.53, respectively) and by 9.8% in pulp acidity (4.59 and 4.18, respectively), thus determining a higher value for the acidity ratio (2.56 and 2.36, respectively).

Table 2. Characteristics of pH, total titratable acidity (TTA), total soluble solids (TSS) and ratio (TSS / TTA) from the fruit pulp of *Passiflora cincinnata* Mast. progenies CPEF 2220 and CBAF 2334 conducted in a vertical trellis and horizontal trellis, collected between May and June 2016.

Progenies	CPEF 2220	CBAF 2334	Mean	CPEF 2220	CBAF 2334	Mean
System	**pH**			**Total titratable acidity (%)**1		
Ver T*	2.91	2.98	2.94 a[2]	4.94	4.60	4.77 a
Hor T*	2.89	2.87	2.88 a	4.18	4.64	4.41 a
Mean	2.90 A	2.92 A	CV= 8.82%	4.56 A	4.62 A	CV= 11.59%
	Soluble solids (ºBrix)			**Ratio**		
Ver T*	13.15	11.56	12.36 a	2.73	2.31	2.52 a
Hor T*	11.23	11.43	11.33 a	2.71	2.49	2.60 a
Mean	12.19 A	11.50 A	CV= 13.86%	2.72 A	2.40 A	CV= 11.26%

*Vert T = Vertical trellis; Hor T = Horizontal trelllis. [1]Expressed in g of citric acid / 100 g of pulp. [2]Means followed by the same lowercase letter in the column and uppercase in the row within each evaluated characteristic do not differ according to Tukey's test at 5% probability level.

These values were similar for those observed in some other progenies and cultivars of *P. edulis Sims*. For instance, according to Medeiros et al. (2009) and Abreu et al. (2009), the progeny Marília Selection of Cerrado and BRS Gigante Amarelo, cultivated in the Federal District, presented with the pH of 2.74 and 3.08, titratable acidity of 4.81 and 6.85, and brix of 13.93 and 12.68, respectively. The proximity of the values indicates the possibility to study the application of pulp in the composition of blends (NEVES et al., 2011) of *P. edulis* and *P. cincinnata*, because there was not much change in the physicochemical quality of the blend.

In previous test periods, independent of the dry or rainy season, these same authors did not find any significant differences in the flavonoid content of the fruits collected from plants in a vertical trellis versus horizontal trellis system. Thus, if the results presented in Table 3 were evaluated in the rainy season, they could present different results due to the effect of the weather.

Cohen et al. (2008) also verified the influence of the cropping system and the harvest season on yellow passion fruit cv. BRS Cerrado Sun. The authors observed higher levels of flavonoids and polyphenols in a single cultivation conducted in the conventional fertilizer system and the vertical trellis systems than when cultivated with cassava.

Thus, it is extremely important to study the effect of the conduction system for every species, because the flavonoid levels differ among species, considering that quantities of these compounds as reported for *P. tenuifila* cultivated in the DF region (SOZO et al., 2013) were higher and those for *P. setacea* (CAMPOS, 2010; CARVALHO et al., 2018) were lower than those presented by *P. cincinnata* (Table 3) on the wet weight basis.

Table 3 presents the results of the chemical analyses, wherein a significant difference was noted only for the flavonoid content.

The flavonoid contents were significantly higher in fruits sourced from plants grown on a vertical trellis and the CBAF 2334 progeny (Table 3). Carvalho et al. (2018) verified the opposite effect of the conduction system in *P. setacea*. They reported that, in the second year of the cultivation during the rainy season (February/March), lower values of flavonoid contents were recorded for fruit pulp produced in the vertical trellis system when compared to that in the horizontal trellis system, possibly due to the higher humidity and the lower sun exposure in that particular season.

Table 3. Chemical characteristics of fruit pulp from *Passiflora cincinnata* Mast. progenies CPEF 2220 and CBAF 2334 conducted in a vertical trellis and horizontal trellis, collected between May and June 2016.

	Value expressed on dry basis			Equivalent value on wet basis		
Progenies	CPEF 2220	CBAF 2334	Mean	CPEF 2220	CBAF 2334	Mean
System			**Flavonoids (mg/100g)**			
Ver T*	96.05	161.33	128.69 a[1]	13.02	16.06	14.54
Hor T*	52.02	94.02	73.02 b	5.44	10.45	7.95
Mean	74.03 B	127.67 A	CV= 3.79%	9.23	13.25	-
			Anthocyanins (mg/100g)			
Ver T*	0.87	1.11	0.99 a	0.12	0.12	0.12
Hor T*	0.96	0.66	0.81 a	0.10	0.07	0.09
Mean	0.91 A	0.88 A	CV= 30.13%	0.11	0.10	-
			Polyphenols (mg/100g)			
Ver T*	467.45	537.15	502.30 a	61.07	51.16	56.11
Hor T*	380.18	413.58	396.88 a	41.54	45.68	43.61
Mean	423.81 A	475.37 A	CV= 33.85%	51.30	48.42	-
			Pulp moisture (%)			
		CPEF 2220		CBAF 2334		
Ver T*		86.34		89.64		
Hor T*		89.14		88.90		

*Vert T = Vertical trellis; Hor T = Horizontal trellis. [1]Means followed by the same lowercase letter in the column and uppercase in the row within each evaluated characteristic do not differ according to Tukey's test at 5% probability level.

Lower anthocyanins values were reported by Lessa (2011) in the pulps of *P. cincinnata*, *P. setacea,* and *P. edulis*, which did not differ from each other, with variations from 0.06 × 10^{-3} to 0.098 × 10^{-3} mg/100 pulp.

The values presented in Table 3 for polyphenols ranged from 43.61 to 56.11 mg/100 g, corresponding on a wet basis, and they were higher than that presented by Cohen et al. (2008) for the fruit pulp of *P. edulis* cv. BRS Sol do Cerrado that presented in the conventional cultivation 36.27 mg of polyphenols/100 g of pulp. Lessa (2011) used the Badiale-Furlong methodology and verified higher average values of phenolic compounds, ranging from 190.25 to 210.85 mg of gallic acid/100 g of fresh sample in *P. cincinnata, P. setacea*, and *P. edulis*. According to Lessa (2011), *P. cincinnata* showed the highest content of phenolic compounds.

Carvalho et al. (2018) used the same methodology for *P. setacea* and found that the average polyphenol content was 78.5 mg/100 g fruit pulp (wet basis). Sozo et al. (2013) reported 80.88 mg of polyphenols/100 g of pulp on wet basis in *P. tenuifila*, which was higher than that for *P. cincinnata* in this study (as presented in Table 3).

Table 4 shows the correlations between the evaluated characteristics.

Significant correlations also indicated that lower the pH, higher are the soluble solids (SS) and total titratable acidity (TTA) values, which may have occurred due to the lower concentration of free hydrogen ions in the fruit pulp, as indicated by pH (INSTITUTO ADOLFO LUTZ, 2008). Therefore, the formation of organic acids and total sugars may have interfered with the amount of free hydrogen ions in the pulp.

In addition, increases in TTA may occur with decreasing pH, depending on the concentration of organic acids in the pulp. Regarding the amount of soluble solids dissolved in the pulp, they are mainly composed of sugars and some other dissolved substances; hence, as the exact quantity is not known (CHITARRA; CHITARRA, 2005), a negative correlation was observed with polyphenols. Table 4 indicates that higher content of these compounds correlates with a lower amount of soluble solids in the fruit pulp.

A positive correlation of flavonoid contents as polyphenols can be expected (Table 4), as flavonoids are phenolic compounds (CHITARRA; CHITARRA, 2005). Other expected correlations include the chroma and 'b' values, between 'a' and angle hue values, and between soluble solids and acidity ratio.

Table 4. Estimates of Pearson's correlation coefficients between phenotypic character pairs of *Passiflora cincinnata* Mast. progenies CPEF 2220 and CBAF 2334 conducted in a vertical trellis and horizontal trellis, collected between May and June 2016.

	a	b	Chroma	hue	F	pH	TSS	TTA	Ratio	Fla	Ant	Pol
L	0.05	0.51	0.42	-0.27	-0.19	-0.37	0.28	0.06	0.33	-0.06	-0.11	-0.2
a		-0.27	-0.36	-0.93*	-0.19	0.25	0.47	0.16	0.49	-0.53	-0.12	-0.42
b			0.99*	0.02	-0.5	0.14	-0.38	-0.08	-0.43	0.34	0.37	0.01
Chroma				0.11	-0.48	0.19	-0.46	-0.1	-0.52	0.43	0.4	0.09
hue					0.33	-0.11	-0.53	-0.33	-0.41	0.47	0.07	0.53
F						-0.44	0.02	0.11	-0.07	-0.16	-0.27	0.4
pH							-0.63*	-0.6*	-0.25	0.28	0.32	0.32
TSS								0.65*	0.7*	-0.44	-0.28	-0.64*
TTA									-0.08	-0.07	-0.04	-0.38
Ratio										-0.54	-0.35	-0.47
Fla											0.25	0.65*
Ant												-0.08

L = luminosity; hue = hue angle (º); F = firmness (N); TSS = total soluble solids (%); TTA = total titratable acidity (%); Fla = flavonoids (mg/100g); Ant = anthocyanins (mg/100g); Pol = polyphenols (mg/100g). *: Significant at 5% probability.

Conclusions

The fruits of *P. cincinnata* were characterized by their green color with yellowish nuances and low intensity and/or color saturation and intermediate brightness to black and white. Of all, the fruits of progeny CBAF 23334 have greater intensity of the green color and greater flavonoid content in the pulp when compared to that in the fruits of progeny CPEF2220.

The type of conduction system did not affect the physical and physicochemical characteristics and the anthocyanins and polyphenols content of the fruits, although the system in the vertical trellis provided the production of fruits of *P. cincinnata* with higher flavonoid content.

References

ABREU, S. de P.M.; PEIXOTO, J.R.; JUNQUEIRA, N.T.V.; SOUSA, M.A. de F. Características físico-químicas de cinco genótipos de maracujazeiro-azedo cultivados no Distrito Federal. **Revista Brasileira de Fruticultura**, Jaboticabal, v.31, n.2, p.487-491, 2009.

BERNACCI, L. C. (coord.). *Passifloraceae*. *In*: WANDERLEY, M.G.L. et al (ed.). **Flora fanerogâmica do Estado de São Paulo**. São Paulo: Instituto de Botânica, 2003. v.3, p.247-274.

BIALE, J.B. Growth, maturation, and senescence in fruits. **Science**, New York, v.146, n.3646, p.880-888, 1964.

CAMPOS, A. V. S. **Características físico-químicas e composição nutricional da polpa de *Passiflora setacea***. 2010. Dissertação (Mestrado) -Universidade de Brasília, Brasília, DF, 2010.

CARVALHO, M.V.O. de; OLIVEIRA, L. de L. de; COSTA A.M. Effect of training system and climate conditions on phytochemicals of *Passiflora setacea*, a wild Passiflora from Brazilian savannah. **Food Chemistry**, London, v.266, p. 350–358, 2018.

CHITARRA, M. I. F.; CHITARRA, A. B. **Pós-colheita de frutos e hortaliças**: fisiologia e manuseio. 2.ed. Lavras: FAEPE, 2005.

COHEN, K.de O.; COSTA, A.M.; TUPINAMBÁ, D.D.; JUNQUEIRA, N.T.V.; FALEIRO, F.G.; BAIOCCHI, M.do V.; SOUSA, H.N. **Compostos funcionais na polpa dos frutos do híbrido de maracujazeiro-azedo BRS Sol do Cerrado**. Planaltina, DF: Embrapa Cerrados, 2008. (Comunicado Técnico, 157).

COSTA, A.M. Propriedades das passifloras como medicamento e alimento funcional. *In*: JUNGHANS, T.G.; JESUS, O.N. (org.). **Maracujá do cultivo à comercialização**. Brasília, DF: Embrapa, 2017. p.299-308.

COUTINHO, L. M. Aspectos do cerrado: clima. *In*: ASPECTO do cerrado: clima. 2018. Disponível em: http://eco.ib.usp.br/cerrado/aspectos_clima.htm. Acesso em: 29 out. 2018.

CUTRI, L.; DORNELAS, M. C. PASSIOMA: Exploring expressed sequence tags during flower development in *Passiflora* spp. **Comparative and Functional Genomics**, Chichester, v.2012, p.1-11, 2012.

EMBRAPA. **Cultivar de maracujazeiro silvestre (*Passiflora cincinnata* Mast.) para a Caatinga e para o Cerrado BRS Sertão Forte**. 2016. (Folder técnico). Disponível em: http://www.cpac.embrapa.br/publico/usuarios/uploads/ lancamentosertaoforte/foldercultivarbrssertaoforte.pdf. Acesso em: 05 out. 2016.

FALEIRO, F.G.; JUNQUEIRA, N.T.V.; JESUS, O.N.; COSTA, A.M.; MACHADO, C.F.; JUNQUEIRA, K.P.; ARAÚJO, F.P.; JUNGHANS, T.G. Espécies de maracujazeiro no mercado internacional. *In*: JUNGHANS, T.G.; JESUS, O.N. (ed.). **Maracujá**: do cultivo à comercialização. Brasília, DF: Embrapa, 2017. p.15-37.

GADIOLI, I.L.; CUNHA, M.S.B.; CARVALHO, M.V.O; COSTA, A.M.; PINELI, L.L.O. Systematic review on phenolic compounds in Passiflora plants: Exploring biodiversity for food, nutrition, and popular medicine. **Critical Reviews in Food Science and Nutrition**, Boca Raton, v.21, n.5, p.785–807, 2018.

IMIG, D.C. **Estudo taxonômico da família Passifloraceae Juss. no Distrito Federal, Brasil**. 2013. Dissertação (Mestrado em Botânica) - Universidade Federal do Paraná, Curitiba, 2013.

INSTITUTO ADOLFO LUTZ. **Métodos físico-químicos para análise de alimentos**. São Paulo, 2008. 1020 p.

JESUS, O.N.; FALEIRO, F.G. Classificação botânica e biodiversidade. *In*: FALEIRO, F.G.; JUNQUEIRA, N.T.V. (ed.). **Maracujá**: o produtor pergunta, a Embrapa responde. Brasília: Embrapa, 2016. p.24-39. (Coleção 500 perguntas, 500 respostas).

KOMURO, L.K. **Efeitos de sistemas de condução sobre o crescimento, produção, qualidade dos frutos e custos de instalação de maracujazeiro amarelo (*Passiflora edulis Sims*. f. *flavicarpa* Deg)**. 2008. Dissertação (Mestrado em Agronomia) - Universidade Estadual Paulista, Ilha Solteira, 2008.

LARRAURI, J.A.; RUPÉREZ, P.; SAURA-CALIXTO, F. Effect of drying temperature on the stabilitity of polyphenols and antioxidant activity of red grape pomace peels. **Journal of Agricultural Food Chemistry**, Easton, v.45, p.1390-1393, 1997.

LEES, D.H., FRANCIS, F J. Standardization of pigment analyses in cranberries. **HortScience**, Alexandria, v.7, n.1, p.83-84, 1972.

LESSA, A.O. **Determinação do teor de compostos fitoquímicos e estudo do potencial para processamento da polpa de frutos de maracujá das espécies silvestres (*Passiflora setacea* DC, *Passiflora cincinnata* MAST).** 2011. Dissertação (Mestrado em Engenharia de Alimentos) - Universidade Estadual do Sudoeste da Bahia, Itapetinga, 2011.

LEVENE, H. Robust tests for equality of variances. *In*: OLKIN, I. (ed.). **Contribution to probability and statistics**. Stanford: Stanford University Press, 1960. p.278-292.

LILJEGREN, S.J., DITTA, G.S., ESHED, Y., SAVIDGE, B., BOWMAN, J.L.; YANOFSKY, M.F. Shatterproof MADS-box genes control seed dispersal in Arabidopsis. **Nature**, London, v. 404, p.766-770, 2000.

LIMA, A. A; JUNQUEIRA, N.T.V. VERAS, M.C.M.; CUNHA, M.A.P. Tratos culturais. *In*: LIMA, A.A. (ed.). **Maracujá produção**: aspectos técnicos. Brasília: Embrapa Informação Tecnológica, 2002. 104p. (Frutas do Brasil, 15).

LIMA, H. C.; COSTA, A. M.; RINALDI, M. M.; ADAIR, S. T. Cultivo, aspectos produtivos, rendimento e caracteristicas dos frutos do maracujazeiro da caatinga, 'cultivar BRS Sertão Forte' no Cerrado do Brasil central. *In*.: CONGRESSO BRASILEIRO DE FRUTICULTURA, 25., 2017, Porto Seguro. **Anais** [...]

MAGALHÃES, A.C.B. **Caracterização de frutos e sementes e germinação de *Passiflora edulis* Sims f. *flavicarpa* Degener e *Passiflora cincinnata* Mast.** 2010. Dissertação (Mestrado em Recursos Genéticos Vegetais) - Universidade Estadual de Feira de Santana, Feira de Santana, 2010.

MCGUIRE, R. G. Reporting of objective colour measurements. **HortScience**, Alexandria, v.27, p.1254-1255, 1992.

MEDEIROS, S.A.F. DE; YAMANISHI, O.K.; PEIXOTO, J.R.; PIRES, M.C.; JUNQUEIRA, N.T.V.; RIBEIRO, J.G.B.L. Caracterização físico-química de progênies de maracujá-roxo e maracujá-azedo cultivados no Distrito Federal. **Revista Brasileira de Fruticultura**, Jaboticabal, v.31, n.2, p.492-499, 2009.

MELETTI, L.M.M.; SOARES-SCOTT, M.D.; BERNACCI, L.C.; PASSOS, I.R.S.Melhoramento genético do maracujá: passado e futuro. *In*: FALEIRO, F.G.; JUNQUEIRA, N.T.V.; BRAGA, M.F. **Maracujá**: germoplasma e melhoramento genético. Planaltina: Embrapa Cerrados, 2005. p.55-78.

MENDONÇA, K.; JACOMINO, A.P.; MELHEN, T.X.; KLUGE, R.A. Concentração de etileno e tempo de exposição para desverdecimento de limão "Siciliano". **Brazilian Journal of Food Technology**, Campinas, v.6, n.2, p.179-183, 2003.

MIOT, H.A. Avaliação da normalidade dos dados em estudos clínicos e experimentais. **Jornal Vascular Brasileiro**, São Paulo, v.16, n.2, p. 88-91. 2017.

MONZANI, R. M. **Intensidade de doenças, produção e qualidade de frutos de maracujazeiro-azedo sob dois sistemas de condução e cultivo anual**. 2017. 92 f. Tese (Doutorado em Ciências Agrárias)- Universidade Federal do Paraná, Curitiba, 2017.

MOURA, M.S.B.; GALVINCIO, J.D.; BRITO, L.T.L.; SOUZA, L. S. B.; SÁ, I.I.S.; SILVA, T.G.F. Clima e água de chuva no Semi-Árido. *In*: BRITO, L.T.L.; MOURA, M.S.B.; GAMA, G.F.B. (ed.). **Potencialidades da água de chuva no Semi-Árido brasileiro**. Petrolina: Embrapa Semi-Árido, 2007. 181 p.

NEVES, L.C.; BENEDETTE, R.M.; TOSIN, J.M.; CHAGAS, E.A.; SILVA, V.X. DA; PRILL, M.A. DE S.; ROBERTO, S.R. Produção de blends a partir de frutos tropicais e nativos da Amazônia. **Revista Brasileira de Fruticultura**, Jaboticabal, v.33, n.1, p.187-197, 2011.

OBANDA, M.; OWUOR, P.O. Flavanol Composition and Caffeine Content of Green Leaf as Quality Potential Indicators of Kenyan Black Teas. **Journal of the Science of Food and Agriculture**, New York, v.74, p. 209-215, 1997.

OLIVEIRA, J.C.; RUGGIERO, C. Espécies de maracujá com potencial agronômico. *In*: FALEIRO, F.G.; JUNQUEIRA, N.T.V.; BRAGA, M.F. **Maracujá**: germoplasma e melhoramento genético. Planaltina: Embrapa Cerrados, 2005. p.143-158.

R Core Team. **R:** a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing, 2018. Disponível em: https://www.R-project.org. **(4)**

SCORZA, L.C.T.; HERNANDES LOPES, J.; MELO DE PINNA, G.F.A.; DORNELAS, M.C. Expression patterns of *Passiflora edulis* Apetala1/Fruitfull homologues shed light onto tendril and corona identities. **EvoDevo**, London, v.8, n.3, p. 2-15, 2017.

SIEBRA, A.L.A. **Avaliação do perfil químico, toxicológico e farmacológico in vivo e in vitro de *Passiflora cincinnata* Mast. (Maracujá-do-Mato)**. 2013. Dissertação (Mestrado em Bioprospecção Molecular) - Universidade Regional do Cariri, Crato, 2013.

SIEBRA, A.L.A.; LEMOS, I.C.S.; DELMONDES, G.A.; MARTINS, A.O.P.B.; SIEBRA, D.C.; COUTINHO, H.D.M.; ALBUQUERQUE, R.S.,; LEITE, N.F.; COSTA, J.G.M.; MENEZES, I.R.A.; KERNTOPF, M.R.; OLIVEIRA, L.R. Atividade antimicrobiana e caracterização fitoquímica dos extratos hidroalcoólicos de *Passiflora cincinnata* Mast. (maracujá-do-mato). **Revista Cubana de Plantas Medicinales**, La Habana, v.19, n.1, p.319-328, 2014.

SOZO, J.S.; COSTA, A.M.; CELESTINO, S.M.C; MADALENA, J.O.M.; CARDOSO, E.R.; CAMPOS, G.A.; FIGUEIRA, G.M.; SILVA, J.R.; R.CASSIA A.P.; VIANA, A.M. Teores de polifenóis e flavonóides em amostras de *P. tenuifila* cultivadas em diferentes regiões brasileiras. *In*: LATIN AMERICAN SYMPOSIUM OF FOOD SCIENCE, 10., 2013. Campinas. **Anais** [...]. Disponível em: https://www.embrapa.br/busca-de-publicacoes/-/publicacao/977645/teores-de-polifenois-e-flavonoides-em-amostras-de-p-tenuifila-cultivadas-em-diferentes-regioes-brasileiras.

VIANA, A.P.; GONÇALVES, G.M. Genética quantitativa aplicada ao melhoramento genético do maracujazeiro. *In*: FALEIRO, F.G.; JUNQUEIRA, N.T.V.; BRAGA, M.F. **Maracujá**: germoplasma e melhoramento genético. Planaltina: Embrapa Cerrados, 2005. p.243-275.

WONDRACEK, D.C. **Caracterização e diversidade genética de acessos de maracujá do cerrado com base no perfil de carotenóides**. 2009. Dissertação (Mestrado) – Faculdade de Agronomia e Medicina Veterinária,Universidade de Brasília, Brasília, DF, 2009.

ZACHARIAS, A.O., JUNQUEIRA, N.T.V.; JUNQUEIRA, K.P., FALEIRO, F.G., JUNQUEIRA, L.P. Sistemas de condução e podas. *In*: FALEIRO, F.G.; JUNQUEIRA, N.T.V. (ed.). **Maracujá**: o produtor pergunta, a Embrapa responde. Brasília, DF: Embrapa, 2016. p.119-125. (Coleção 500 perguntas, 500 respostas).