

DETERMINATION OF THE MATURATION STAGE AND CHARACTERISTICS OF THE FRUITS OF TWO POPULATIONS OF *Passiflora cincinnata* Mast.¹

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ABSTRACT – *Passiflora cincinnata* Mast. (caatinga passion fruit) has acidic fruits with a peculiar flavor, green color when ripe and a low percentage of abscission making it difficult to identify the point of harvest. In order to verify the harvest period in two populations of *P. cincinnata*, flowers were marked in anthesis and after six periods the fruits were harvested. This study evaluated fruit mass, seeds and pulp mass, fruit dimensions and shape, percentage of water, color and texture of skin, volume, color and pulp yield, pH, soluble solids (SS), titratable acidity ratio, polyphenol content, flavonoids and anthocyanins. The assay was designed in a completely randomized design in a factorial arrangement (2x6), with two populations (CPEF2220 and CBAF2334) and six harvest periods (20, 40, 60, 80, 100 and 120 days after anthesis - DAA) with four repetitions. There was a reduction in thickness (43.1%) and percentage of water in the skin (9.3%), pH (40.1%), ratio, polyphenols content and pulp luminosity (brightness). There were increases in pulp mass and volume, seed mass, pulp mass yield in relation to the fruit (72%), and SS titratable acidity (44.9%) in CPEF2220 and equality between populations in fruit shape, pulp color, thickness and skin color (luminosity and °hue), pH and polyphenols. Although after 100 DAA there were higher yields, between 60 and 80 DAA it was possible to identify characteristics of SS, pH, titratable acidity, mass, volume and pulp yield related to ripe fruits, allowing harvesting after 60 DAA.

Keywords: Anthesis. Chemistry. Pulp yield. Harvest. Passion fruit.

DETERMINAÇÃO DO ESTÁDIO DE MATURAÇÃO E CARACTERÍSTICAS DOS FRUTOS DE DUAS POPULAÇÕES DE *Passiflora cincinnata* Mast.

RESUMO – *Passiflora cincinnata* Mast. (maracujá da caatinga), possui frutos ácidos com sabor peculiar, coloração verde quando maduros e baixo percentual de abscisão dificultando a identificação do ponto de colheita. Com o objetivo de verificar o período de colheita em duas populações de *P. cincinnata*, flores foram marcadas na antese e após seis períodos os frutos foram colhidos. Avaliou-se a massa dos frutos, sementes e polpa, dimensões e formato dos frutos, percentual de água, cor e textura da casca, volume, cor e rendimento de polpa, pH, sólidos solúveis (SS), acidez titulável, Ratio, teor de polifenóis, flavonoides e antocianinas. O ensaio foi esquematizado em delineamento inteiramente casualizado em arranjo fatorial (2x6), sendo duas populações (CPEF2220 e CBAF2334) e seis períodos de colheita (20, 40, 60, 80, 100 e 120 dias após a antese - DAA) com quatro repetições. Houve redução na espessura (43,1%) e porcentagem de água na casca (9,3%), pH (40,1%), Ratio, teor de polifenóis e luminosidade da polpa. Observou-se aumentos na massa e volume da polpa, massa de sementes, rendimento da massa da polpa em relação ao fruto (72%), acidez titulável e SS (44,9%) em CPEF2220 e igualdade entre as populações no formato do fruto, cor da polpa, espessura e cor da casca (luminosidade e °hue), pH e polifenóis. Apesar que após 100 DAA ocorreram maiores rendimentos, entre 60 e 80 DAA foi possível identificar características de SS, pH, acidez titulável, massa, volume e rendimento de polpa relativos a frutos maduros, permitindo a colheita após 60 DAA.

Palavras-chave: Antese. Química. Rendimento de polpa. Colheita. Maracujá.

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INTRODUCTION

The species *Passiflora cincinnata* Mast. is popularly known in Brazil as caatinga passion fruit, wild passion fruit etc (CERVI, 1997; JESUS; FALEIRO, 2016; OLIVEIRA; RUGGIERO, 2005). It has berry-like fruit, dull straw-green skin, with purplish nuances when young and yellowish green when ripe. The fruits have long durability, resistance to transport and handling, acidic and aromatic flavor very distinct from the fruits of *Passiflora edulis* Sims, sour passion fruit as it is commonly known (IMIG, 2013; OLIVEIRA; RUGGIERO, 2005).

The Caatinga passion fruit is a species native to the Northeast region, having great economic and social value, considering its food use and cultivation in arid areas subject to water stress (ARAÚJO et al., 2018). In view of this potential, in 2016 the first cultivar of the species *P. cincinnata* was launched, called BRS Sertão Forte (BRS SF) which is the result of the crossing of two populations of selected plants in the semi-arid region, CBAF2334 and CPEF2220 (EMBRAPA, 2016).

During ripening the fruits of passion fruit undergo several changes in their physicochemical composition, which is intrinsically related to the harvest point (COELHO; CENCI; RESENDE, 2010). Usually when passion fruit falls to the ground, they have already reached the physiological maturation point of the fruits. In the situation of the species *P. edulis*, in addition to abscission, maturity is accompanied by a change in the color of fruits from green to yellow (VIANNA-SILVA et al., 2008b).

In the fruits of *P. cincinnata*, fruit abscission can occur only at 230 to 371 days after anthesis, without changes in fruit color, remaining with the green skin even when ripe. This situation makes it difficult to identify the harvest point (physiological maturation), which is perceived only by pressing on the distal position of the fruit, which yields slightly to pressure when ripe (JUNGHANS; JESUS, 2015; OLIVEIRA; RUGGIERO, 2005). Initial studies conducted by Lima et al. (2017), observed fruit growth up to approximately 60 days after anthesis. After the period, the authors observed the beginning of the physiological maturation phase. At this stage of development, according to the species, it would be possible to continue the ontogeny of the fruit even after harvesting (WATADA et al., 1984).

In general, the fruits during the ripening process, in addition to the breathing of the fruit, it is possible to observe physical changes in the longitudinal and transverse diameter, in the color of the skin and pulp, as well as in the skin thickness and juice yield. Also, physicochemicals comprising variations in pH, titratable acidity (TA), soluble solids (SS), SS / TA ratio, sugar content, vitamin C, chlorophyll and total carotenoids can be indicative of

the point of harvest (CAMPOS, 2007; COELHO; CENCI; RESENDE, 2010).

Harvesting at the appropriate point of maturation is the main determinant of fruit flavor. Immature or harvested fruits ahead of time often fail to accumulate all the compounds responsible for their taste and aroma, besides being more susceptible to water loss and physiological disorders (CEAGESP, 2016).

This study aimed to identify the stage of fruit maturation with adequate characteristics for the harvest of two populations of *P. cincinnata*, based on physical, physicochemical and chemical characteristics of the fruits, as a subsidy to the development of fruit harvesting methods prior to abscission (early harvest) of the fruits of this species.

MATERIAL AND METHODS

The cultivation site was at the Fruit Support Unit of Embrapa Cerrados (15°36'13.02"S; 47° 43'17.34"O), located near the forest vegetation with the presence of pollinating insects, at an altitude of approximately 1050 m, in Planaltina, Federal District. The 3.5-month-old seedlings of *P. cincinnata* CBAF2334 and CPEF2220 were transplanted to the definitive site on 04/09/2015.

An analysis was performed with a completely randomized experimental design, in a 2 x 6 factorial arrangement (2 accessions x 6 fruit development ages) with 4 replications. The first factor had two levels, these being the populations of plants CPEF2220 and CBAF2334. The second factor had six levels, defined by the periods of fruit harvest after 20, 40, 60, 80, 100 and 120 days after the anthesis of the flowers.

A total of 192 fruits from flowers were evaluated in anthesis of the populations CBAF2334 and CPEF2220 of *P. cincinnata* marked on 03/18/2016, with the fruits harvested on the plant after 20 days of development. The flowers marked between 25 and 01/29/2019 had their fruits harvested after 40, 60, 80, 100 and 120 days of development in the plant. Healthy fruits were harvested and immediately taken to the Embrapa Cerrados Food Science and Technology Laboratory for evaluation without undergoing any previous treatment.

The mass of the fruit, peel and pulp (with and without seeds) determined by means of a centesimal semi-analytical balance (OhausAdventurer®) were evaluated; the volumes of the pulp with and without seeds, determined by means of a graduated cylinder of 100 ml; the longitudinal and equatorial diameters of the fruit and the skin thickness, determined by means of a digital caliper (StainlessHardened®); the firmness of the fruit pulp, obtained through three readings at points equidistant from the middle portion of the fruit, with the aid of the texturometer (Brookfield Texture Analyzer®, model CT3 4500). In

the case of firmness, the equipment was configured in "normal test" mode, with a force of 100 g, deformation of 5 mm, speed of 10 mm/s and equipped with a TA 17 tip cone 24 mm D 30°, and result expressed in Newton (N).

Pulp yield was calculated in percentage values: the mass of the pulp without seeds in relation to the pulp mass with seeds (mass/mass ratio- YPM), the volume of the pulp without seeds in relation to the volume of the pulp with seeds (volume/volume ratio - YPV), the mass/mass of the pulp without seeds in relation to the fruit (YPF) and mass/mass of the pulp with seeds in relation to the fruit (YPSF).

The skin staining performed directly on the fruit at five distinct points and on the pulp was also evaluated by reading on a transparent Petri dish containing the sample, with the aid of a portable spectrophotometer (HunterLab® MiniScan EZ model). The measurement included the determination of luminosity (L*) and values of a* and b*, used to calculate chromaticity (color intensity) and hue angle (color tone) according to McGuire (1992).

The analysis of soluble solids (SS), pH, titratable acidity (TA) and ratio were performed according to methodologies of the Adolfo Lutz Institute (2008). For the analysis of anthocyanins and flavonoids, Lees and Francis (1972) methodology was used. In the analysis of polyphenols, the methodology of Larrauri, Rupérez and Saura-Calixto (1997) was used to obtain the extracts and Obanda and Owuor (1997) to read them.

After obtaining the data, the assumptions of normality of the residues were first verified by means of the Shapiro-Wilk test (MIOT, 2017) and the homogeneity of the variance by the Levene test (LEVENE, 1960). The statistical verification of the significance of the treatments was done by Analysis

of Variance (ANOVA). Tukey's test was used to compare the averages, at a probability level of 5%.

For the joint study of the evaluated variables, the multivariate method of Principal Component Analysis (PCA) was used, which analyzes the data in a reductionist way, eliminating overlaps and choosing the best representations of data, through linear combinations of the original variables. The procedure verified the most expressive variables in the space of the main components. All analyses were performed using the statistical software R, version 3.5.0 (R CORE TEAM, 2018).

RESULTS AND DISCUSSION

There were significant differences between the evaluated periods and between plant populations in the characteristics of pulp mass with and without seeds, pulp volume with and without seeds, fresh seed mass, pulp yield, mass and equatorial diameter of the fruits, firmness, hue angle, water content, fresh and dry peel/skin mass, polyphenol content, titratable acidity, soluble solids and pulp ratio.

There was a significant effect only between the periods evaluated after anthesis on the thickness and colour of the skin, pulp chroma (luminosity, chroma and hue angle) and pH. In the luminosity of the skin, there were significant differences between the periods evaluated only in the CBAF2334 population. In the characteristics of longitudinal diameter of the fruit, content of flavonoids and anthocyanins in the pulp, there was a significant effect only among the plant populations.

There are differences in the results of mass and volume of the pulp with and without seeds and of the fresh mass of seeds of the plant populations CPEF2220 and CBAF2334 of *P. cincinnata* (Table 1).

Table 1. Pulp mass with and without seeds, pulp volume with and without seeds, fresh mass of seeds along the development of the fruits of the populations CPEF2220 and CBAF2334 of *Passiflora cincinnata* Mast.

DAA ¹	Pulp mass with seeds (g)		Pulp mass without seeds (g)			
	CPEF2220	CBAF2334	CPEF2220	CBAF2334		
20	10.4 c B ²	13.6 c A	3.4 d B		4.8 d A	
40	31.9 ab B	39.5 ab A	11.0 c B		18.7 c A	
60	37.3 ab B	47.0 ab A	16.2 abc B		24.5 abc A	
80	23.0 b B	38.9 b A	11.6 bc B		22.1 bc A	
100	33.4 ab B	42.3 ab A	19.2 ab B		26.1 ab A	
120	35.7 a B	53.1 a A	19.6 a B		29.9 a A	
CV		24.2 %			26.6 %	
	Volume of pulp with seeds (mL)		Volume of pulp without seeds (mL)		Fresh Mass of seeds (g)	
DAA	CPEF2220	CBAF2334	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	10.7 c B	13.9 c A	3.5 d B	5.0 d A	7.0 d B	8.8 d A
40	32.1 ab B	39.8 ab A	10.7 c B	18.2 c A	20.9 ab B	20.8 ab A
60	36.8 ab B	46.9 ab A	15.9 abc B	24.2 abc A	21.1 a B	22.5 a A
80	22.7 b B	39.0 b A	11.5 bc B	21.8 bc A	11.4 cd B	16.8 cd A
100	33.5 ab B	42.2 ab A	18.7 ab B	25.9 ab A	14.2 bc B	16.2 bc A
120	34.9 a B	51.9 a A	19.4 a B	29.8 a A	16.1 abc B	23.3 abc A
CV		24.2 %		26.9 %		25.7 %

¹DAA: Days after anthesis. ²Averages followed by the same lowercase letter in the column and uppercase in the row do not differ between the Tukey test at the 5% probability level.

The pulp mass and volume with and without seeds, and the fresh mass of the seeds showed similar patterns, where the values were increasing from 20 to 120 days after anthesis, and in all situations the fruits of the CPEF2220 population presented lower values of mass and volume. Franco et al. (2013) verified that the pulp of *P. edulis* began to form at 42 days after flowering and in the same way that in the present work increased throughout the development of the fruit in the plant.

Magalhães (2010), evaluating *P. cincinnata*,

found an average pulp volume with seeds of *P. cincinnata* of 47.1 mL, a value close to that seen at 120 days after anthesis (43.4 mL) in the present study. In relation to the difference existing between the populations, the fruits of CBAF2334 showed greater pulp mass and volume with and without seeds and greater fresh mass of seeds.

There are differences in the pulp yield results of plant populations CPEF2220 and CBAF2334 during the development of *P. cincinnata* fruits (Table 2).

Table 2. Pulp yields during fruit development of the CPEF2220 and CBAF2334 populations of *Passiflora cincinnata* Mast.

DAA ¹	Yield of seedless pulp mass in relation to pulp mass with seeds (YPM - %)		Yield of seedless pulp volume in relation to pulp volume with seeds (YPV - %)	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	32.9 d B ²	34.4 d A	33.2 d B	35.1 d A
40	35.3 c B	47.3 c A	33.9 d B	45.7 d A
60	44.2 b B	51.6 b A	43.8 c B	50.7 c A
80	50.2 ab B	56.7 ab A	50.2 bc B	55.6 bc A
100	57.8 a B	61.8 a A	56.9 a B	61.6 a A
120	55.0 a B	56.2 a A	55.6 ab B	57.3 ab A
CV	8.8 %		8.6 %	
DAA	Yield of seedless pulp mass in relation to fruit mass (YPF -%)		Yield of pulp mass with seeds in relation to fruit mass (YPSF -%)	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	8.8 e B	10.4 e A	27.2 e B	29.8 e A
40	14.9 d B	20.4 d A	42.4 d B	43.5 d A
60	22.0 c B	26.9 c A	50.0 c B	52.2 c A
80	26.4 b B	31.1 b A	52.6 bc B	54.9 bc A
100	32.2 a B	35.1 a A	55.7 b B	56.8 b A
120	33.0 a B	35.5 a A	60.1 a B	63.1 a A
CV	9.7 %		6.9 %	

¹DAA: Days after anthesis. ²Averages followed by the same lowercase letter in the column and uppercase in the row do not differ from each other according to Tukey's test at the 5% probability level.

Pulp yields (YPM, YPV, YPF and YPSF) increased from 20 to 120 days after anthesis (DAA) (Table 2), with the fruits of the CBAF2334 population showing higher yield in all evaluations. The increase in yield of the seedless pulp mass in relation to the fruit mass in the range of 72.01%. Among the populations of *P. cincinnata* plants evaluated, CBAF2334 showed higher pulp yield.

In *P. edulis*, Vianna-Silva et al. (2008a) found an increase in pulp yield with and without seeds in relation to the fruit as the maturation increased. The highest values were reached from 60 days after anthesis. However, in *P. cincinnata*, the highest pulp yields occurred from 80 days after anthesis, which indicates a characteristic of ripe fruits.

Lessa (2011) found, in fruits of *P. cincinnata*

obtained at the Vitória da Conquista Supply Center, an average yield of seedless pulp in relation to the fruit of 31.88%. Lima et al. (2017) for the cultivar BRS Sertão Forte of the same species, found a yield of 28.70%. While in the present study, depending on the plant population, the average yield was in the range of 28 to 32%, for periods from 60 to 120 days after anthesis, values equivalent to those described by these authors.

There are differences in fruit mass and diameter, however there were no variations in the relationship between the diameters (longitudinal / equatorial) and in the longitudinal diameter between the harvest points evaluated, indicating that there were no variations in the shape of the fruits during development and between the varieties (Table 3).

Table 3. Fruit mass, longitudinal diameter, equatorial diameter and relationship between longitudinal and equatorial diameter throughout the development of the fruits of the populations CPEF2220 and CBAF2334de *Passiflora cincinnata* Mast.

DAA ¹	Fruit mass (g)		Longitudinal diameter (mm)	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	37.9 c B ²	45.2 c A	42.2 a B	45.1 a A
40	75.7 a B	90.8 a A	50.8 a B	56.7 a A
60	73.7 a B	89.5 a A	49.6 a B	55.6 a A
80	43.6 bc B	70.3 bc A	43.6 a B	53.0 a A
100	59.3 ab B	74.1 ab A	47.8 a B	53.0 a A
120	59.3 ab B	84.0 ab A	45.9 a B	54.7 a A
CV	20.3 %		9.9 %	
DAA	Equatorial diameter (mm)		Longitudinal/equatorial diameter ratio	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	43.6 c B	47.8 c A	0.97 a A	0.95 a A
40	52.9 a B	57.2 a A	0.96 a A	0.99 a A
60	52.4 a B	56.9 a A	0.95 a A	0.97 a A
80	45.3 bc B	51.8 bc A	0.96 a A	1.02 a A
100	49.7 ab B	53.3 ab A	0.96 a A	1.00 a A
120	49.6 ab B	55.5 ab A	0.93 a A	0.99 a A
CV	6.07 %		6.08 %	

¹DAA: Days after anthesis. ²Averages followed by the same lowercase letter in the column and uppercase in the row do not differ from each other according to Tukey's test at the 5% probability level.

Fruits at 20 DAA had lower fruit mass and equatorial diameter, however it occurred that in the periods of 40 and 60 days of anthesis (DAA), the evaluated fruits had higher values of mass and equatorial diameter than the others (Table 3). The result was consistent with that described by Oliveira and Ruggiero (2005) that *P. cincinnata* fruits reach 90% of their size 24 days after anthesis.

The fresh weight of the fruits and the equatorial diameter increased until the 60 days of fruit development. At 80 days, there was a decrease but at 100 days they increased and stabilized until the end of development (Table 3). Vianna-Silva et al. (2008a) also observed a similar effect in *P. edulis*, due to the morphological variability of the fruits. As

for the populations, CABF2334 fruits showed greater mass and greater longitudinal and equatorial diameter in relation to CEPF2220, indicating genetic variability between populations (Table 3).

It is observed that for all periods evaluated the fruits of the population CBAF2334 have higher mass and size, and between the periods both populations behave in a similar manner.

According to (Table 4) for the characteristics of peel thickness, fresh and dry peel mass, percentage of water in the peel and texture of the peel (firmness) significant differences were verified between populations, except in the thickness of the peel/skin.

Table 4. Peel thickness, fresh peel mass, dry peel mass, percentage of water in the peel and firmness (texture) during the fruit development of *Passiflora cincinnata* Mast populations CPEF2220 and CBAF2334.

DAA ¹	Peel/skin thickness (mm)		Fresh peel mass (g)		Dry peel mass (g)	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	6.8 a A ²	6.4 a A	26.5 b B	30.1 b A	3.3 c B	3.8 c A
40	5.5 b A	5.5 b A	40.5 a B	46.7 a A	6.1 a B	6.2 a A
60	5.0 bc A	5.1 bc A	34.1 a B	40.5 a A	5.7 a B	6.3 a A
80	4.3 cd A	4.5 cd A	18.5 b B	28.3 b A	3.6 bc B	4.9 bc A
100	3.9 de A	4.4 de A	23.9 b B	28.9 b A	4.7 ab B	5.2 ab A
120	3.5 e A	3.9 e A	21.7 b B	28.3 b A	4.5 ab B	5.8 ab A
CV	8.7 %		17.8 %		18.6 %	
DAA	Water in skin (%)		Firmness (N)			
	CPEF2220	CBAF2334	CPEF2220	CBAF2334		
20	87.5 a B	87.5 a A	27.1 b A	22.4 b B		
40	84.7 b B	86.5 b A	40.4 a A	35.0 a B		
60	83.3 c B	84.3 c A	32.4 b A	26.8 b B		
80	80.6 d B	82.8 d A	22.5 b A	23.4 b B		
100	80.2 d B	82.0 d A	24.3 b A	21.3 b B		
120	79.2 e B	79.6 e A	24.8 b A	19.7 b B		
CV	1.4 %		18.4 %			

¹DAA: Days after anthesis. ²Averages followed by the same lowercase letter in the column and uppercase in the row do not differ between the Tukey test at the 5% probability level.

During fruit development, there was a reduction in the thickness of the skin in the order of 43.14% between 20 and 120 DAA. The thickness of the peel of *P. cincinnata* varied from 3.73 to 6.56 mm, which classifies this species of passion fruit as being of thin skin (JESUS et al., 2015). The characteristic is of great importance for the industry, because thinner skin fruits have higher pulp yield.

The dry mass of the peel (Table 4) along the development followed a pattern identical to the mass of the fruits (Table 3), that is, there was a rapid gain of dry matter in the peel that remained relatively constant over time. While fresh mass was found to decrease in values from 80 DAA. The behavioral differences between the dry and fresh mass of the peel may have occurred due to the water content, in which it was possible to evidence a gradual reduction of skin moisture throughout the development of the fruits reaching 9.3% among fruits with 20 and 120 DAA.

This reduction in water content occurs because, in general, fruits during their maturation process undergo several changes that include loss of cellular turgor, changes in the permeability of cell membranes and enzyme synthesis reactions. With ripening prevails degradation that include starch hydrolysis processes that are usually converted into soluble sugars (CHITARRA; CHITARRA, 2005), a fact that may explain the increase in pulp yield presented in (Table 2).

The CBAF2334 population presented higher

fresh and dry mass, higher water content (Table 4) and higher fresh seed mass (Table 1). However, they presented similar peel thickness (Table 4), which did not prevent higher pulp yield of this population in relation to the CPEF2220 population (Table 2).

The texture at 40 DAA presented higher value in relation to the other harvest days, and the fruits of the CPEF2220 population were firmer than the fruits of the CBAF2334. According to (Table 4), it is noted that at 40 DAA in addition to greater firmness these fruits presented higher values of fresh and dry mass of the peel.

These differences may occur due to changes in texture that normally occur during fruit growth and development, which are the result of genetically programmed changes, and chemical changes to the primary components of the cell wall, cellulose, pectins and hemicellulose, and in general, firmness decreases with fruit maturity (SAMS, 1999).

The fruits at 40 DAA did not present the texture reduction expected possibly due to some maintenance in the fruit composition, because according to Chitarra and Chitarra (2005) the change in texture is due to solubilization of pectins and hydrolysis of structural polysaccharides of the cell wall.

The results of peel color with interaction results between fruit development in each plant population in terms of luminosity and hue angle characteristics are presented in Table 5.

Table 5. Luminosity, chroma and hue angle in six periods evaluated in populations CPEF2220 and CBAF2334 of *Passiflora cincinnata* Mast.

DAA ¹	Luminosity		Chroma		Hue angle (°)	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	55.2 a A ²	29.1 a A	29.1 a A	32.1 a A	108.2 ab A	106.9 cd A
40	51.3 a A	27.9 a A	27.9 a A	30.1 a A	109.3 a B	111.7 b A
60	49.6 a A	23.9 c A	23.9 c A	22.6 c A	109.8 a B	115.2 a A
80	54.1 a A	25.7 bc A	25.7 bc A	24.9 bc A	107.7 ab B	109.9 bc A
100	53.1 a A	25.9 ab A	25.9 ab A	28.4 ab A	106.5 b A	104.8 d A
120	54.0 a A	24.6 bc A	24.6 bc A	26.0 bc A	106.3 b A	106.5 d A
CV	5.8 %		8.9 %		1.1%	

¹DAA: Days after anthesis. ²Means followed by the same lowercase letter in the column and uppercase in the row do not differ according to the Tukey test at the 5% probability level.

In the fruits of the CPEF2220 population, the fruit's luminosity remained constant at the evaluated points. In the CBAF2334 population, differences in luminosity were observed throughout the development of the fruits, and at 60 DAA the evaluated fruits had less luminosity.

Chroma, which indicates color intensity and saturation, showed lower values at 60 and 120 DAA. The highest values were verified at 20 DAA and 40 DAA which did not differ significantly from the 100 DAA, thus presenting more intense colors (with lower gray tint) in the peel.

The hue angle that defines the tonality presented the lowest value at 100 and 120 DAA with

a value of 106°. The highest value was at 60 DAA (115.19°) in the CBAF2334 population. In this angulation range there is a yellowish green tint. Thus, from 40 to 80 DAA, the fruits of the CBAF2334 population presented a tint tending more to green than the CPEF2220 population. Within the CPEF2220 population, it is verified that after 120 DAA the color tone tends to be less green. In the CBAF2334 population, in addition to the 100 and 120 DAA, at 20 DAA the fruits also showed a lower shade of green. Despite slight variations in hue and the contribution of yellow and green pigments, the visual perception was of green colored fruits.

The situation observed is different from that with the fruits of the sour passion fruit *P. edulis*, whose change of color from green to yellow begins around 64 DAA, reaching the complete yellow

coloration around 100 DAA (SILVA et al., 2005).

As shown in Table 6, there were variations in pulp color throughout ripening, with a decrease in fruit luminosity.

Table 6. Luminosity, chroma and hue angle of the pulp during the development of fruits of populations CPEF2220 and CBAF2334 of *Passiflora cincinnata* Mast.

DAA ¹	Luminosity		Chroma		Hue angle (°)	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	68.8 a A ²	64.3 a A	18.0 b A	18.5 b A	98.8 ab A	102.1 ab A
40	63.3 b A	60.8 b A	19.1 ab A	20.5 ab A	101.8 a A	100.6 a A
60	55.5 c A	59.2 c A	21.4 ab A	18.4 ab A	98.8 ab A	99.0 ab A
80	51.5 c A	54.9 c A	24.1 a A	22.9 a A	97.2 b A	95.8 b A
100	52.2 c A	54.5 c A	25.7 a A	21.7 a A	95.9 ab A	98.9 ab A
120	46.4 d A	49.1 d A	22.8 ab A	23.0 ab A	97.3 ab A	97.7 ab A
CV	4.5 %		16.0 %		2.9 %	

¹DAA: Days after anthesis. ²Means followed by the same lowercase letter in the column and uppercase in the row do not differ between Tukey's test at the 5% probability level.

The luminosity of the fruit pulp decreased during the fruit development. The results indicate that the pulp tends to darken during development, with a lighter color at 20 DAA and darker at 120 DAA.

High chroma values indicate that the color of the pulp is more intense, as occurred in the fruits evaluated at 80 and 100 DAA. The lower values indicate that the pulp tends to be more grayish as observed in the fruits at 20 DAA.

Silva et al. (2005) verified that there was no pattern of evolution during the development of the pulp color of *P. edulis* after anthesis, through the characteristics of luminosity, and the pigments green

(a*) and yellow (b*).

As for the hue angle, the color shade/ tone ranged from 95 to 102°, indicating yellowish green color, tending to yellow. There was no pattern of evolution in pulp color throughout development, where colors tending to greenish were concentrated in the early stages of development.

Thus, the color of the pulp showed a greenish yellow hue, being more greenish at the beginning of development, tending to be more intense after 80 DAA and darker in the final stages of development (Table 6).

The results of titratable acidity, pH, total soluble solids and pH are presented in Table 7.

Table 7. Titratable acidity, pH, soluble solids and the pulp ratio over the development of the fruits of the populations CPEF2220 and CBAF2334 of *Passiflora cincinnata* Mast.

DAA ²	Total titratable acidity ¹		pH	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	0.6 d A ³	0.6 d A	4.4 a A	4.5 a A
40	2.7 c A	2.8 c A	3.2 b A	3.1 b A
60	4.0 b B	4.5 b A	2.7 cd A	2.7 cd A
80	4.4 ab A	4.7 b A	2.8 c A	2.8 c A
100	4.7 a B	5.3 a A	2.7 cd A	2.7 cd A
120	4.5 a B	5.3 a A	2.6 d A	2.6 d A
CV	6.5 %		3.1 %	
DAA	Soluble solids (°Brix)		Ratio	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	6.7 d A	6.7 d B	14.0 a A	12.0 a B
40	10.0 c A	8.3 c B	3.6 b A	3.0 b B
60	10.9 b A	10.5 b B	2.7 c A	2.3 c B
80	12.6 a A	11.0 a B	2.8 c A	2.3 c B
100	12.9 a A	11.5 a B	2.7 c A	2.2 c B
120	12.5 a A	11.8 a B	2.7 c A	2.2 c B
CV	6.1 %		6.1 %	

¹Expressed in g of citric acid / 100 g of pulp. ²DAA: Days after anthesis. ³Means followed by the same lowercase letter in the column and uppercase in the row do not differ between the Tukey test at the 5% probability level.

The acidity of the fruits of the CPEF2220 population was lower at 60, 100 and 120 DAA when compared to the fruits of the CBAF2334 population. From 60 DAA on, there was a higher titratable acidity value compared to the 20 and 40 DAA points in both plant populations, reaching maximum values after 80 DAA in the CPEF2220 population and 100 DAA in the *P. cincinnata* population CBAF2334.

At 20 and 40 DAA, the highest pH values were verified compared to the other points evaluated. In yellow passion fruit Silva et al. (2005) verified a reduction in pH from 52 to 70 DAA followed by an increase until 100 DAA.

The fruits of the CPEF2220 population had a higher content of soluble solids, however in both populations there was an increase in soluble solids throughout the development of the fruits and a reduction in pH by 40.09% from 20 to 120 DAA. The increase in the soluble solids content was progressive until 80 DAA, remaining constant until 120 DAA. Silva et al. (2005) evaluating yellow passion fruit (from 52 to 100 DAA), observed that in this species the increase in soluble solids ranged from 52 to 76 DAA and remained constant after this period (up to 100 DAA), indicating similar patterns

of soluble solids in these two species (Table 7).

The ratio, in fruits of the CBAF2334 population, presented lower values, and in both populations this variable decreased until 60 DAA. The reduction in the ratio was caused by the increase in titratable acidity. In yellow passion fruit (*P. edulis*) Silva et al. (2005) found the opposite, an increase in titratable acidity up to 60 DAA and after this period, a decrease to 100 DAA and an increase in the ratio from 60 to 76 DAA.

The most common during the ripening of the fruits is that there is a consumption of organic acids, however some species may not exhibit this behavior (CHITARRA; CHITARRA, 2005). In the case of two populations of *P. cincinnata* studied, there was an accumulation of citric acid after 60 DAA, which was corroborated by the results of pH reduction. As a consequence, lower values were found in the ratio, showing the sensory characteristic of acid fruits of this species when mature.

There are differences in the results of the levels of flavonoids, polyphenols and anthocyanins found in the pulp of *P. cincinnata* throughout the development of the fruits (Table 8).

Table 8. Flavonoid, anthocyanin and polyphenol content of the pulp during the development of *Passiflora cincinnata* Mast fruits.

Flavonoids (mg/100g)				
DAA ¹	Value expressed on dry basis		Equivalent value on wet basis	
	CPEF2220	CBAF2334	CPEF2220	CBAF2334
20	70.4 a B ²	196.2 a A	8.9	24.9
40	79.7 a B	126.8 a A	9.5	14.5
60	57.7 a B	135.3 a A	7.4	16.9
80	61.4 a B	120.5 a A	8.4	15.3
100	47.6 a B	97.8 a A	6.4	11.8
120	41.1 a B	125.3 a A	5.4	15.9
CV	21.5 %		-	
Anthocyanins (mg/100g)				
DAA	Value expressed on dry basis		Equivalent value on wet basis	
	CPEF2220	CBAF2334	CBAF2334	CPEF2220
20	0.58 a A	0.54 a B	0.07	0.07
40	0.50 a A	0.41 a B	0.06	0.05
60	0.46 a A	0.44 a B	0.06	0.05
80	0.43 a A	0.36 a B	0.06	0.05
100	0.60 a A	0.42 a B	0.08	0.05
120	0.40 a A	0.43 a B	0.05	0.05
CV	31.62 %		-	
Polyphenols (mg/100g)				
DAA	Value expressed on dry basis		Equivalent value on wet basis	
	CPEF2220	CBAF2334	CBAF2334	CPEF2220
20	806.0 a A	957.9 a A	102.3	121.6
40	466.5 b A	511.3 b A	55.9	58.7
60	575.8 b A	536.3 b A	73.8	67.5
80	628.0 b A	633.2 b A	87.0	80.8
100	574.9 b A	594.7 b A	77.6	72.1
120	452.0 b A	546.8 b A	58.9	69.6
CV	18.4 %		-	

¹DAA: Days after anthesis. ²Means followed by the same lowercase letter in the column do not differ according to the Tukey test at the 5% probability level.

The fruits of the CPEF2220 population had a higher anthocyanin content and a lower flavonoid content in relation to the fruits of the CBAF2334 population, but did not differ in polyphenol content.

In the polyphenols content in both populations, only at 20 DAA was there a higher value, which may be related to the maturation process of this species. According to Zielinski et al. (2015) blackberry fruits also had a higher polyphenol content in green fruits. According to Bevilaqua (1995), some grape varieties also had a high content of total polyphenols at the beginning of maturation.

The levels of flavonoids and anthocyanins remained constant (Table 8), but other non-evaluated compounds, such as phenolic acids and tannins, can be studied in the future in order to verify if these compounds are correlated to the higher content of

polyphenols at the beginning of *P. cincinnata* fruit development.

Flavonoids and anthocyanins are included in the class of polyphenols flavonoids, a subtype of polyphenol. These compounds can act as reducing and sequestering agents of free radicals (CHITARRA; CHITARRA, 2005), and due to the fact that they have a beneficial effect on human health, there is currently interest in the consumption and study of plants with potential for the so-called functional foods (GADIOLI et al., 2018; COSTA, 2017).

According to the results of the Principal Components Analysis (PCA), two components explained 67.9% of the total variability, with the components Dim1 (45.5%) and Dim2 (22.4%) (Figure 1).

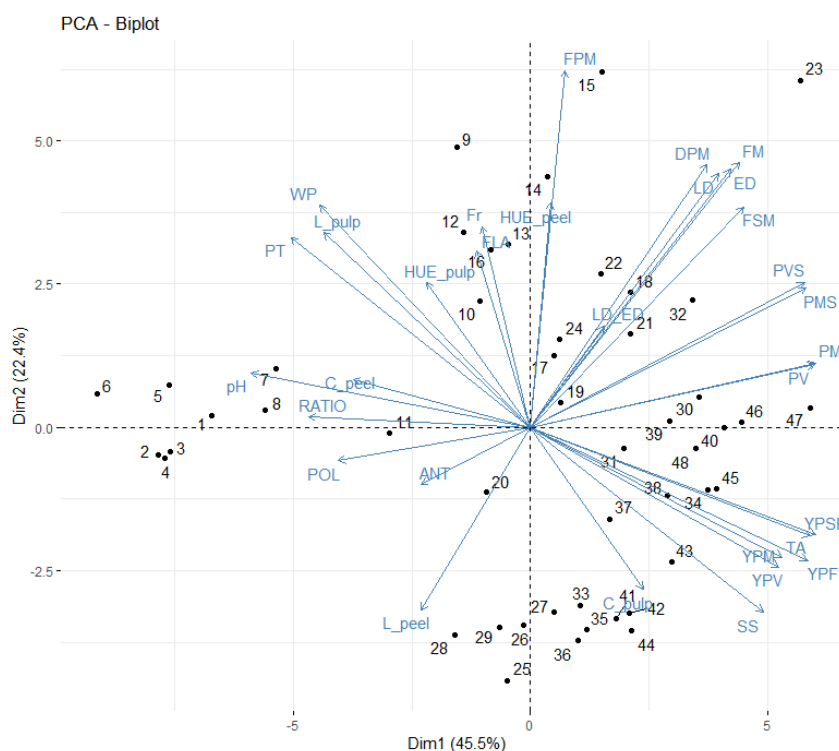


Figure 1. Analysis of main components related to the evaluated characters of two populations of *Passiflora cincinnata* Mast. with fruits developed from 20 to 120 days after anthesis. Legends: HUE: Hue angle; FPM: Fresh peel mass; DPM: Dry peel mass; FM: Fruit mass; LD: Longitudinal diameter; ED: Equatorial diameter; LD_ED: LD / ED ratio; FSM: Fresh seed mass ; PVS: Pulp volume with seeds; PMS: Pulp mass with seeds; PM: Pulp mass without seeds; PV: Pulp volume without seeds; TA: Titratable acidity; Yields: YPSF-of pulp mass with seeds in relation the mass of the fruit, YPF-of the mass of the pulp without seeds in relation to the mass of the fruit, YPM-of the mass of the pulp without seeds in relation to the mass of the pulp with seeds, YPV- of the volume of the pulp without seeds in relation to the volume of the pulp with seeds; SS: soluble solids; C: Chroma; L: luminosity/Brightness; ANT: Anthocyanins; POL: Polyphenols; PT: peel/skin thickness; WP:% of water in the peel; FLA: Flavonoids; Fr: Texture (firmness). Numbered points: 20 days after anthesis (DAA) points 1 to 8 (1 to 4 = CPEF2220 and 5 to 8 = CBAF2334); 40 DAA points 9 to 16 (9 to 12 = CPEF2220 and 13 to 16 = CBAF2334); 60 DAA points 17 to 24 (17 to 20 = CPEF2220 and 21 to 24 = CBAF2334); 80 DAA points 25 to 32 (25 to 28 = CPEF2220 and 29 to 32 = CBAF2334); 100 DAA points 33 to 40 (33 to 36 = CPEF2220 and 37 to 40 = CBAF2334); 120 DAA points 41 to 48 (41 to 44 = CPEF2220 and 45 to 48 = CBAF2334).

According to Figure 1, there is a negative correlation between pH, titratable acidity and soluble solids, that is, the lower the pH value the higher these values are. This fact possibly occurs due to the fact that the pH indicates concentration of hydrogen ions free in the pulp (INSTITUTO ADOLFO LUTZ, 2008). Thus, the formation of organic acids and total sugars can reduce the amount of free hydrogen ions.

Another relevant correlation is related to the flavonoid content in the fruit pulp in direct correlation to the chroma value, indicating that a greater synthesis of this compound could be related to the color of the pulp, collaborating to reduce the intensity of the pulp color.

The contents of polyphenols and

anthocyanins are related to fruits in early development (20 and 40 DAA) and negatively correlated with the highest mass and volume of pulp, seeds and fruit (Figure 1).

Polyphenols are composed with a structure containing an aromatic ring and at least one hydroxyl, which contribute to fruit color, acidity and flavor (CHITARRA; CHITARRA, 2005), so its highest values at 20 and 40 DAA may be related to a higher concentration of these in tissues that are still developing.

The discrimination of three groups of *P. cincinnata* populations (CPEF2220 and CBAF2334) according to the points of harvest is presented in Figure 2.

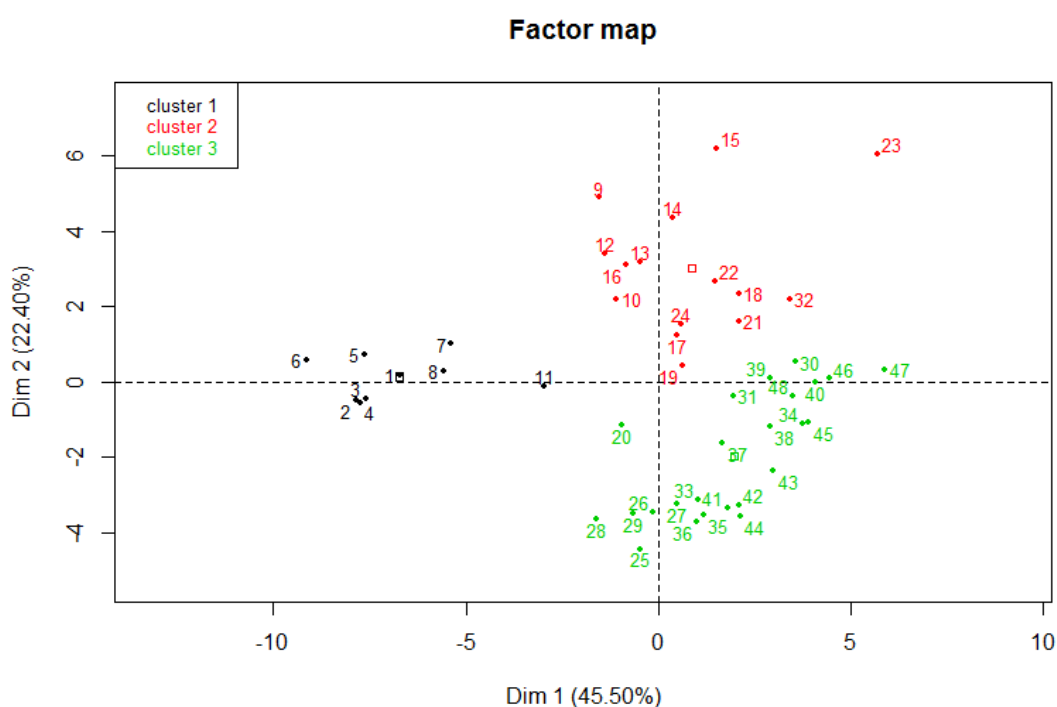


Figure 2. Cluster analysis of *Passiflora cincinnata* Mast populations at different harvest points. Legend: 20 days after anthesis (DAA) points 1 to 8 (1 to 4 = CPEF2220 and 5 to 8 = CBAF2334); 40 DAA points 9 to 16 (9 to 12 = CPEF2220 and 13 to 16 = CBAF2334); 60 DAA points 17 to 24 (17 to 20 = CPEF2220 and 21 to 24 = CBAF2334); 80 DAA points 25 to 32 (25 to 28 = CPEF2220 and 29 to 32 = CBAF2334); 100 DAA points 33 to 40 (33 to 36 = CPEF2220 and 37 to 40 = CBAF2334); 120 DAA points 41 to 48 (41 to 44 = CPEF2220 and 45 to 48 = CBAF2334).

There is a fruit cluster with a higher frequency of fruit 20 days after anthesis, another with 40 and 60 DAA, and a third larger group that includes fruits harvested at 80, 100 and 120 DAA (Figure 2).

Also when verifying Figures 1 and 2, it was observed that the fruits of the third group are associated with the characteristics of titratable acidity, soluble solids, pulp yields, pulp mass and volume, seeds and fruits, which can be indicators of

maturity of the fruits at these stages of harvest.

CONCLUSION

Between 60 and 80 days after anthesis, the fruits of the populations CPEF2220 and CBAF2334 present characteristics of soluble solids, pH, titratable acidity, mass, volume and pulp yields relative to ripe fruits, however, higher pulp yields

were identified after 100 days of anthesis of the *P. cincinnata* flower.

The point of harvest of the fruits of this passion fruit species, under the conditions evaluated in this work, can be started after 60 days of anthesis and fertilization of the flower. The improvement of techniques for use of soluble solids as a parameter for harvesting is a viable option.

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