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SCIENTIFIC COMMUNICATION

QUALITY INDEX AND HARVEST MATURITY OF *Eugenia cibrata* FRUITS[1]

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ABSTRACT - The aim of this study was to characterize and determine the quality index and the harvest maturity of *Eugenia cibrata* fruits. Fruits were harvested at 39, 41 and 43 days after sprouting and selected by the larger size. Fruits ripened on the plant until complete abscissions were considered standard for determining the quality index after harvest. Samples were analyzed at harvest day and at two days of storage at temperature of 26 ± 2 ° C and relative humidity of 85-90%. The following items were evaluated: firmness, number of seeds, longitudinal and transversal diameter, shape index, weight of seeds, pulp and fruit, titratable acidity (TA), soluble solids (SS), ascorbic acid, TA / SS ratio and pulp yield. The experimental design was completely randomized in a split plot scheme in time, with additional treatment. *E. cibrata* fruit is a round berry with 0.98 shape index; mass of 24.28 g, green epicarp and white endocarp. The maturity stage identified as ideal for harvest occurred from 43 days after flower opening (anthesis). Fruits selected among those with larger sizes also reached physiological maturity and quality similar to those ripened on the plant. The quality index of *E. cibrata* is pH 2.88; soluble solids of 3.7%; titratable acidity of 3.38% in citric acid; ascorbic acid of 77.05 mg $100g^{-1}$, TA / SS ratio of 1.09 and pulp yield of 72.01%.
Index terms: Post-Harvest; fruit quality; Amazonian fruits; ripening.

INDICADORES DE QUALIDADE E PONTO DE COLHEITA DE FRUTOS DE *Eugenia cibrata*

RESUMO - O objetivo deste trabalho foi caracterizar e determinar o índice de qualidade e o ponto de colheita dos frutos de *Eugenia cibrata*. Os frutos foram colhidos aos 39; 41 e 43 dias após a antese e selecionados pelo maior tamanho. Os frutos amadurecidos na planta, por ocasião da completa abscisão, foram considerados padrão para determinar o índice de qualidade após a colheita. As análises foram efetuadas no dia da colheita e aos dois dias de armazenamento sob temperatura de 26 ± 2ºC e umidade relativa de 85 - 90%. Foram determinados firmeza, número de sementes, diâmetro longitudinal e transversal, índice de formato, massa de sementes, da polpa e do fruto, acidez titulável (AT), sólidos solúveis (SS), ácido ascórbico, *ratio* (SS/AT) e rendimento de polpa. O delineamento experimental foi o inteiramente casualizado, em esquema de parcela subdividida no tempo, com tratamento adicional. O fruto da *E. cibrata* é uma baga arredondada com índice de formato de 0,98; massa de 24,28 g, cor verde no epicarpo e branca no endocarpo. O estádio de maturação fisiológica deu-se a partir de 43 dias após a abertura da flor (antese). Frutos selecionados dentre os de maiores tamanhos também atingiram estádio de maturação fisiológica e qualidade semelhante aos frutos amadurecidos na planta. O índice de qualidade da *E. cibrata*, resultado da avaliação do fruto maduro, constitui de pH em 2,88; sólidos solúveis em 3,7 ºBrix; acidez titulável em 3,38% em ácido cítrico; 77,05 mg $100g^{-1}$ de ácido ascórbico, relação sólidos solúveis/acidez titulável (*ratio*) de 1,09 e rendimento de polpa em 72,01%.
Termos para indexação: Pós-colheita; índice de qualidade; frutas amazônicas; maturação.

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Eugenia cribrata McVaugh is one of more than 1,034 species and 23 genera known in Brazil (BFG, 2015). In the Amazon region, *E. cibrata* fruits are used by the local population in the preparation of juice and blends with other fruits. It was first recorded in Venezuela, but its origin is not well understood. Popularly known as camu-camu, it differs from the true camu-camu (*Myrciaria dubia*) also found in the Amazon region, mainly by the green coloration of the epicarp, of red color in *M. dubia*. In Rio Branco, state of Acre, *E. cibrata* blooms from January to June, with peak in late January and mid February.

Data on its quality and maturity indicators such as fresh fruit mass, soluble solids, titratable acidity (TA), SS / TA ratio and vitamin C content, as well as the determination of its harvest maturity point are not yet available in literature. The physical and chemical changes that occur in fruits such as firmness, diameter, length, soluble solids, total acidity, fruit mass, vitamin content and others are observed in the development and maturation stages (MELO et al., 2013; ZILO et al. , 2013).

The development period of fruits from the anthesis varies with the fruit species and with the meteorological conditions among growing regions. This variable is used as a harvest indicator, important for the fresh fruit market and also for industry. Araçá boi (*E. stipitata*) has its development time in 60 days (HERNÁNDEZ et al., 2007). For pitanga, Ávila et al. (2009) identified the beginning of the maturation period at 42 days and complete maturation at 49 days; Danner et al. (2010) observed that wild cherry matures at 43 days after anthesis, uvaia at 50 days, guabiroba at 68 days, araça at 98 days and umbu-cajá (*Spondias* sp.) has its cycle completed at 157 days DANTAS et al., 2016). The harvest maturity of Amazonian camu-camu (*M. dubia*) is between 88 and 95 days after anthesis, and when the fruit presents red coloration, there is an increase in the soluble solids / titratable acidity ratio, and changes in texture by elevation in the number of soluble pectins (NEVES et al., 2015). In studies with pitanga (*E. uniflora* L.), it was verified that the ideal harvest point is between 56 and 63 days after anthesis (ÁVILA et al., 2009). Red pitanga is characterized as mature when presenting diameter of 2.24 cm; length of 1.51 cm; mass of 5.25 g; firmness of 8.16 N; solids soluble of 11.0 ° Brix; titratable acidity (% citric acid) of 1.58; pH of 3.16; soluble solids / acidity ratio of 7.46 and ascorbic acid of 51.0 mg $100g^{-1}$ (SANTOS et al., 2002). In this context, the aim of this work was to characterize and determine the quality index and the harvest maturity of *E. cibrata* fruits.

To characterize and determine the harvest maturity to determine the quality index of *E. cibrata*, physical and physicochemical analyses were performed. Twenty fruits were evaluated, and the mean and standard deviation of each variable were considered as reference values for fruit characterization, for quality indicators and determination of the harvest maturity point. Fruits were harvested during the rainy season of the region between February 2 and 22, 2013.

Fruits were collected at 39, 41 and 43 days after anthesis (Figure 1) by cutting the peduncle at the final growth stage, when they were larger, and those ripened on the plant (quality standard), were daily collected using a mesh sack placed on the plant before fruits fall to the ground (Figure 2) after abscission. Samples were analyzed at the Laboratory of Food Technology, Federal University of Acre. Fruits were evaluated two hours and two days after harvest. Storage was at ambient conditions under temperature of 26 ± 2°C and relative humidity in 85-90%. Fruits ripened on the plant were evaluated only 2 hours after harvest. For characterization, fruits were evaluated for firmness using analogue penetrometer with 8 mm diameter tip, which penetrated the fruit without removing the epicarp, number of seeds, longitudinal and transverse diameter, shape index (longitudinal diameter / transversal diameter), weight of seeds, pulp and fruit, measured in an electronic scale with precision of 0.01g. These measurements were made with fruits ripened on the plant (reference) and data were used only for the physical characterization of fruits. In order to determine the harvest maturity point, in addition to physical characterization, the following physicochemical analyses were taken into account: pH, acidity (%), soluble solids (°Brix), ascorbic acid (mg $100g^{-1}$), SS / TA ratio and pulp yield (%), performed according to the Adolfo Lutz Institute Standards (2008).

The experimental design was completely randomized with four replicates of five fruits each in a split plot scheme in time with additional treatment (4 x 2 + 1). Plot included harvest time (39, 41, 43 days after anthesis and large fruits) and subplot included days of storage (0 and 2 days). Additional treatment was composed of fruits ripened on the plant. Factorial fruits (maturity stages and storage) were compared by the Tukey's test with 5% error probability and these fruits were compared to fruits ripened on the plant (additional treatment) through the t test at 5 and 1% error probability.

E. Cibrata fruit was classified as a berry, with green epicarp, white mesocarp and andocarp, both edible, slightly elliptical round shape (Figure

2). Fruit ripened on the plant showed total weight of 24.28 ± 2.85 g, 17.51 ± 2.56 g pulp, and 6.77 ± 2.46 g of seeds per fruit, longitudinal diameter of 3.28 ± 0.16 cm and transversal diameter of 3.36 ± 0.17 cm. The shape index obtained was 0.98 ± 0.1, slightly elliptical. Fruits presented pulp yield of 72.01 ± 4.88%, ascorbic acid of 77.06 ± 10.48 mg $100g^{-1}$ of pulp, 3.7 ± 0.37 ° Brix of soluble solids, pH 2.88 ± 0.05; titratable acidity of 3.38 ± 0.23% and ratio SS / TA ratio of 1.09 ± 0.04, which characterize fruits as acid and limit fresh consumption, but potentiates industrialization, since acidic fruits have sharp pulp taste and facilitate the production of industrialized products such as jellies and jams (Torrezan, 1998).

Firmness obtained for fruits harvested at 39 DAA (days after anthesis) was 16.39 N, higher than in fruits harvested at 41.43 DAA and fully developed fruits (large fruits), which did not differ among themselves (Table 1). After ripening, firmness decreased in almost all maturity stages, except for fruits harvested at 43 DAA (Table 1). According to Melo et al., 2013; Zilo et al., 2013, firmness is reduced during fruit maturation development, which is attributed to changes in pectin molecules (Canteri et al, (2012), catalyzed by enzymes pectinmetylesterase and polygalacturonase (PINHEIRO, 2008).

Based on fruit firmness, harvesting fruits from 41 DAA with firmness of 12.8 N allows pulp softening after ripening. Similar to *E. cibrata*, camu-camu fruits (*M. dubia*) suffered rapid loss of firmness during storage due to the activity of enzymes pectinamethylesterase and polygalacturonase (PINTO et al., 2013). The firmness values observed are close to those found for Guava (*P. guajava*), since in the maturation stage considered suitable for harvest, Campos et al. (2011) found firmness of 15.5 N, while *E. cibrata* presented firmness of 12.18 N. The comparison of maturation stages with fruits ripened on the plant was not carried out, since they did not allow more readings and were extremely softened at two days of storage. Cavalini et al. (2015) found that guava cv 'Paluma' harvested on the last maturation stage only remained preserved for one day, similar to what occurred to the fruit under study. This rapid loss of firmness was also observed in cagaita fruits (*Eugenia dysenterica*) stored at ambient conditions of 25°C, with shelf life limited to 5 days (CARNEIRO et al., 2015).

The average fruit mass increased with advancement in the maturation stage, reaching 19.06 g at 43 DAA. The largest fruits weighed 36.46 g (large fruits), which differed from the others (Table 1). Canteri et al. (2012) reported that during expansion, the cell wall has its surface increased, and during growth, there is increase of the intercellular spaces and weight, giving a rounded shape to the fruit (PINHEIRO, 2008). Chitarra and Chitarra (2005) reported that the cell expansion and consequent weight gain may continue until fruit maturation, when they acquire harvest indexes.

Longitudinal and transversal diameters increased proportionally with fruit ripening. Fruits with larger longitudinal and transversal diameters were those ripened on the plant, followed by those with 43 DAA. This trend was the same after maturation (Table 1). Umbu-cajá fruits (*Spondia* sp.) had measures similar to those of *E. cibrata*, with transversal diameter of 2.34 cm and longitudinal diameter of 2.99 cm (Dantas et al., 2016). For araçá (*Psidium guineense*), Melo et al. (2013) found transversal diameter values close to those of the present work, between 2.05 and 2.62 cm. Carneiro et al. (2015) verified mean longitudinal and transversal diameter of 2.46 and 2.99 cm in cagaita fruits (*E. dysenterica*), respectively. Maximum growth was observed at 43 DAA (Table 1), when Chitarra and Chitarra (2005) and Pinheiro (2008) described maximum increase in the surface of the cell walls, consequently the largest diameters, which may also coincide with physiological maturation. Borges et al. (2010) reported that the growth of pitanga do cerrado (*E. calycina*) was stopped at the final maturation stage, similar to *E. cibrata*.

The shape index verified for *E. cibrata* measured 0.98 and this relation gives a slightly elliptic rounded aspect, differing from other myrtaceae such as umbu-cajá, which presents ovoid shaped (DANTAS et al., 2016). Chitarra and Chitarra (2006) reported that the rounded shape of fruits is an important feature for industries. Fruits harvested at 43 DAA presented the same longitudinal and transversal diameter of those ripened on the plant, indicating that they can be harvested from this stage (Table 1), using longitudinal diameters from 2.99 to 3.81 cm (larger fruits) or transversal diameters from 3.05 to 4.34cm (larger fruits) (Table 1), since Gonçalves et al. (2013) reported that the size of fruits is an important indicator in their selection for fresh consumption, and also indicate greater amount of pulp.

The pH of fruits did not differ on the day of harvest among the different maturation stages; however, fruits differed from those harvested at 39 DAA with ripe fruits. The pH decreased from 3.0 at the beginning of maturation to 2.88 in fruits ripened on the plant (Table 1). The little pH variation observed corresponds to the little variation in acidity, which in this case seems to indicate the presence of few buffering substances (mineral salts and pectin), differing from most fruits, which maintain pH stable with increasing acidity (ALVARENGA Et al., 2014). In studies with uvaia fruits (*E. uvalha*), little variation in pH was observed (2.73 to 2.78) in fruit development stages (Alvarenga et al., 2014).

The soluble solids contents did not differ on the day of harvest among the different maturation stages, but after maturation, SS contents were higher in fruits harvested at 41 and 43 DAA, which did not differ from the SS content of fruits ripened on the plant (Table 1), characterizing that from this development stage (41 and 43 DAA), fruits already accumulated reserves of polysaccharides, as in cajá fruits - *Spondias cytherea* Soon (SILVA et al., 2009) and *Physalis peruviana* (RODRIGUES et al. , 2005), because when approaching maturation, fruits may only increase the soluble solids content by the degradation of polysaccharides from the cell wall or due to loss of water (CHITARRA and CHITARRA, 2005).

Acidity differed among maturation stages at harvest, reaching the highest amount of organic acids (3.90% citric acid) at 41 DAA (Table 1). After maturation, there was no difference among maturation stages, which presented TA values similar to fruits ripened on the plant (Table 1). Studying Guavira (*Campomanesia* sp.), Campos et al. (2012) found that the organic acids content did not decrease with maturation. In most fruits, the content of these acids decreases as in red pitanga (0.83 to 1.58%) (SANTOS et al., 2002) and in guava cv. Paluma and cv. Kumagai (0.71%) than in those harvested later (0.57%) (CAVALINI et al., 2015), but there are exceptions, and it is possible to characterize *E. cibrata* in this group. Similarly to the maturation of *E. cibrata, M. dubia* acidity had changed only in the first maturation phase, ranging from 2.87 to 2.65% citric acid at the end of maturation (Pinto et al., 2013).

E. cibrata fruits at 39 DAA have 99.34 mg $100g^{-1}$ ascorbic acid, the largest amount among ripening stages. The content of this vitamin reduced with fruit ripening after harvest (Table 1). Cohen et al. (2010) reported that the ascorbic acid content did not differ among the first maturation stages and increased with maturation in *M. dubia* fruits. The amount of this vitamin in ripe fruits under study is relevant (77 mg $100g^{-1}$), and was higher than at 43 DAA, because the longer the fruit remain on the plant, the less it needs to consume organic acids in breathing (CHITARRA; CHITARRA, 2005). The value of 77.05 mg $100g^{-1}$ in mature fruits is similar to values found in white guava, with 76.80 mg $100g^{-1}$ (Pereira et al., 2006) and red guava, with 80.60 mg $100g^{-1}$ (TACO, 2011), and lower for cv 'Paluma', which was approximately 110mg / 100g (CAVALINI, 2015).

The ascorbic acid content found in *E. cibrata* is higher than that found in ripe pitanga (*E. uniflora*), which for the purple variety is 55 mg $100g^{-1}$ and for red variety is 51 mg $100g^{-1}$ in physiological maturity. Araçá-pera has 44.00 mg 100^{-1} of ascorbic acid for red variety and 28 mg for yellow variety (Giacobbo et al., 2008), but these values are lower than those of other Myrtaceae such as *M. dubia* (Camu Camu), which presents 1.071 mg $100g^{-1}$ on the day of harvest in purple maturation stage (PINTO et al., 2013).

The SS / TA ratio did not differ among maturation stages on the day of harvest, but it was different from fruits ripened in the plant only after 41 days (Table 1). These results show that the species has low amount of sugar, and the most representative soluble solid value is of organic acids not of sugar, altering only slightly the SS / TA ratio, which is not a good indicator of quality or ripeness for *E. cibrata*. Another myrtaceae, araçá-boi (*E. stiptata*) also presents low SS / TA ratio 2.33; but its importance in the composition of nectars with low-acidity fruits is highlighted (SACRAMENTO et al., 2008).

The yield found for fruit pulp at stages 41, 43 DAA and selected fruits was the same of fruits ripened on the plant, but the maturity stage of 39 DAA presented higher yield (Table 1). The post-ripening yield remained the same compared to the day of harvest, but decreased with advancing maturity stages, reaching 73.02% in selected fruits, which is statistically similar to the yield of fruits ripened on the plant. Similar results were found by Araújo et al. (2013) when studying the potential use of *E. floribunda* fruits and verified that the average pulp yield was 72.13% among genotypes.

E. cibrata fruit ripened on the plant is a rounded berry with shape index of 0.98 ± 01, weight of 24.28 ± 2.85 g, epicarp of green color and white mesocarp and endocarp. It has 17.51 ± 2.56 g of pulp; 6.77 ± 2.46 g of seeds; with 2.17 seeds per fruit, longitudinal diameter of 3.28 ± 0.16 cm and transversal diameter of 3.36 ± 0.17 cm.

The quality index of *E.cibrata* consisted of pH 2.88 ± 0.05, solids soluble of 3.70 ± 0.37 °Brix, titratable acidity of 3.38 ± 0.23% in citric acid, 77.05 ± 10.48 mg $100g^{-1}$ of ascorbic acid, SS / TA ratio of 1.09 ± 0.04 and pulp yield of 72.01 ± 4.88%.

Fruits harvested at 43 days after flower opening and those selected among those of larger sizes are considered at physiological maturation stage and can be harvested at the moment they present the following harvest indicators: longitudinal diameter of 2.99 cm, transversal diameter of 3.05 cm, weight of 19.06 g, firmness of 5.48 N, soluble solids of 3.43 °Brix, TA of 3.20% in citric acid, ascorbic acid of 55.04 mg $100g^{-1}$, SS / TA ratio of 1.07 and pulp yield of 77.50%.

TABLE 1 - Results of the evaluations of *E. cibrata* fruits harvested at different ripening stages and ripened at temperature of 26 ± 2^{o}C. UFAC, Rio Branco, AC, 2013.

Age (days after anthesis)	Firmness (N)		Average Fruit Weight (g)	
	Days after harvest			
	0	2	0	2
39	16.39aA	8.91aB	11.79cA**	10.15cA**
41	12.18bA	4.25bB	14.10cA**	11.82bcA**
43	5.48cA	5.07bA	19.06bA^{ns}	14.50bB**
Large fruits	6.00cA	3.58bB	36.46aA**	33.33aB**
Fruit ripened on the plant	-	-	24.28	-
	Longitudinal diameter (cm)		Transversal diameter (cm)	
39	2.59cA**	2.49cA**	2.63cA**	2.53cA**
41	2.71cA**	2.63cbA**	2.76cA**	2.68bcA**
43	2.99bA^{ns}	2.74bB**	3.05bA^{ns}	2.79bB**
Large fruits	3.81aA**	3.78aA**	4.34aA**	4.11aB**
Fruit ripened on the plant	3.28	-	3.36	-
	pH		SS (^{O}BRIX)	
39	2.96aA^{ns}	3.00aA^{ns}	3.70aA^{ns}	2.98bB**
41	3.01aA*	2.88bB^{ns}	3.60aA^{ns}	3.73aA^{ns}
43	2.91aA^{ns}	2.91abA^{ns}	3.43aA^{ns}	3.73aA^{ns}
Large fruits	2.89aA^{ns}	2.95abA^{ns}	3.40aA^{ns}	2.96bB**
Fruit ripened on the plant	2.88	-	3.70	-
	TA (%citric acid)		AA (mg 100g^{-1})	
39	3.47abA^{ns}	3.67aA^{ns}	99.34aA**	89.16aA^{ns}
41	3.90aA*	3.42aB^{ns}	92.46aA^{ns}	83.67aB^{ns}
43	3.20bA^{ns}	3.47aA^{ns}	55.04bA**	59.44bA**
Large fruits	3.37bA^{ns}	3.36aA^{ns}	56.13bA*	60.52bA*
Fruit ripened on the plant	3.38	-	77.05	-
Age (days)	SS / TA ratio		Pulp yield (%)	
39	1.07aA^{ns}	0.81bB**	81.81aA*	86.72aA**
41	0.92aB**	1.09aA^{ns}	78.24aA^{ns}	84.47aA*
43	1.07aA^{ns}	1.08aA^{ns}	77.50aA^{ns}	83.86abA*
Large fruits	1.03aA^{ns}	0.89bB*	75.36aA^{ns}	73.02bA^{ns}
Fruit ripened on the plant	1.09	-	72.01	-

[1] Means followed by the same lowercase letter in the column and upper case in the row do not differ by the Tukey test at 5% probability.
[2] Means followed by * differ at 1%, followed by ** differ at 5%, and ^{ns} do not differ significantly by the t-test.
[3] Soluble solids (SS), titratable acidity (TA), ascorbic acid (AA), SS / TA ratio.

FIGURE 1 - Development of * *E. Cibrata* * from the appearance of the floral bud up to physiological maturity (maximum growth). (Photo: Sebastião Elviro de Araújo Neto).

FIGURE 2 - Ripe * *E. Cibrata* * fruit. (Photo: Guiomar Sousa Diniz).

FIGURE 3 - Developing * *E. Cibrata* * fruit. (Photo: Sebastião Elviro de Araújo Neto).

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