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Special Supplement: *Cerrado* **[Brazilian Savanna]**

Characterization and storage of *Eugenia klotzschiana* O. Berg fruits[1]

Alex Guimarães Sanches[2], Vanessa Maria Dantas Pedrosa[2], Maryelle Barros da Silva[2], Thiago Feliph Silva Fernandes[2], Gustavo Henrique de Almeida Teixeira[2]

ABSTRACT

Pera-do-cerrado (*Eugenia klotzschiana* O. Berg) has a good appearance and adequate post-harvest shelf life. However, little information is available regarding its maturity stages. This study aimed at characterizing *E. klotzschiana* fruits harvested at three maturity stages (immature, physiological mature and ripe), in addition to evaluating the physical and chemical changes during storage at ambient temperature (24 ± 2 ºC and 75 % ± 5 % of RH) for up to 5 days. The ripe fruits had a higher fresh mass (98.03 g), width (5.61 cm) and ratio (5.37), and lower titratable acidity (1.27 %). In contrast, immature fruits showed a greener peel (101.32 ºh) and higher vitamin C content (11.23 mg 100 g^{-1}). There was an increase in the fresh weight loss (3.05 %) and a decrease in the peel luminosity (67.09-57.12 L*) and vitamin C content (8.11-5.04 mg 100 g^{-1}). However, the soluble solids (SS) values did not change during the 5 days of storage. A reduction in the titratable acidity (TA; 1.29-1.06 %) was also observed, which resulted in a higher ratio (3.81-5.84). In conclusion, *E. klotzschiana* fruits should be harvested ripe, as they present larger dimensions, better color, higher SS/TA (flavor) and are less acidic.

KEYWORDS: Pera-do-cerrado, Myrtaceae, native fruit, Brazilian Savanna.

RESUMO

Caracterização e armazenamento de frutos de *Eugenia klotzschiana* O. Berg

A pera-do-cerrado (*Eugenia klotzschiana* O. Berg) tem boa aparência e adequada vida útil pós-colheita. No entanto, existem poucas informações sobre seus estádios de maturação. Objetivou-se caracterizar frutos de pera-do-cerrado colhidos em três estádios de maturação (imaturo, fisiológico maduro e maduro), além de avaliar as alterações físicas e químicas durante o armazenamento à temperatura ambiente (24 ± 2 ºC e 75 % ± 5 % de UR), por até 5 dias. Os frutos maduros apresentaram maior massa fresca (98,03 g), largura (5,61 cm) e proporção (5,37) e menor acidez titulável (1,27 %). Em contraste, frutas imaturas apresentaram epiderme mais verde (101,32 ºh) e maior teor de vitamina C (11,23 mg 100 g^{-1}). Houve aumento na perda de massa fresca (3,05 %), redução de luminosidade da epiderme (67,09-57,12 L*) e teor de vitamina C (8,11-5,04 mg 100 g^{-1}). No entanto, os valores de sólidos solúveis (SS) não se alteraram durante os 5 dias de armazenamento. Também foi observada redução da acidez titulável (AT; 1,29-1,06 %), o que resultou em maior proporção (3,81-5,84). Em conclusão, frutos de pera-do-cerrado devem ser colhidos maduros, por apresentarem maiores dimensões, melhor cor, maior SS/AT (sabor) e serem menos ácidos.

PALAVRAS-CHAVE: Pera-do-cerrado, Myrtaceae, fruto nativo, Cerrado.

INTRODUCTION

Cerrado (Brazilian Savanna) is a biome with a large diversity of native fruits that present unique flavors and contain high levels of sugars, minerals, fatty acids and proteins (Silva et al. 2008). Pera-do-cerrado (*Eugenia klotzschiana* O. Berg) is one of its fruits and may be consumed raw or in the form of juice, ice cream and jelly.

This fruit has a high nutritional value, particularly fiber content (6.45 g kg^{-1}) and iron (16.5 mg kg^{-1}). It is rich in carotenoids, flavonoids, phenolic compounds, ascorbic acid and has a high antioxidant activity (Carneiro et al. 2019). The physicochemical characterization of fruits during ripening is closely related to the harvest index (Silva et al. 2005).

Regarding the consumption of fresh *E. klotzschiana* fruits, understanding its maturity stages is essential to establish its post-harvest shelf life and quality. Harvesting fruits at appropriate maturity stages is crucial for their conservation in the post-harvest phase, since immature fruits do not fully ripen, thus compromising their final quality and reducing their shelf life (Chitarra & Chitarra 2005).

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[2] Universidade Estadual Paulista, Faculdade de Ciências Agrárias e Veterinárias, Departamento de Ciências da Produção Agrícola, Jaboticabal, SP, Brasil. *E-mail/ORCID*: alexsanches.eng@gmail.com/0000-0002-0755-9523; vanessapedrosa.md@gmail.com/0000-0003-2844-7747; maryellebarros@bol.com.br/0000-0001-7129-2029; thiagofeliph@hotmail.com/0000-0002-3803-0606; gustavo.teixeira@unesp.br/0000-0002-7179-080X.

Therefore, this study aimed to characterize *E. klotzschiana* fruits at different maturity stages, as well as to evaluate the physical and chemical quality parameters during the storage of mature fruits under ambient conditions.

MATERIAL AND METHODS

Eugenia klotzschiana O. Berg fruits were harvested from the collection of exotic fruits of the Universidade Estadual Paulista, in Jaboticabal, São Paulo state, Brazil (21º14′37.4″S, 48º17′54.8″W and 614 m of altitude), in May 2020. The fruits were harvested at three maturity stages, based on the peel color: 1) immature (green); 2) physiologically mature (turning); 3) ripe (yellow) (Figure 1). These fruits were used for the characterization study. The experiment was set according to a completely randomized design, with three treatments (maturity stages) and five replications of one fruit.

As the ripe fruits had better physical and chemical quality parameters, the fruits were stored at room temperature (24 ± 2 ºC and 75 % ± 5 % of RH) up to 5 days and evaluated daily. Thus, this study was set up in a completely randomized design, with six treatments (storage periods: 0, 1, 2, 3, 4 and 5 days) and five replications of one fruit.

These fruits were used to study the physical and chemical characterization, and the experiment was set according to a completely randomized design, with three treatments (maturity stages) and five replications of one fruit. The fruit quality was determined based on the following physical and chemical evaluations:

a) Length and width: the fruit dimensions were determined with a caliper (Digimatic, IP67, Brazil) and the results expressed in centimeters (cm). The length was measured from the base to the top of the fruit and the width at its equator;

b) Fresh mass: the fruits were weighed on a semi-analytical scale (Mars, model AS 2000, São Paulo, Brazil) and the results expressed in grams (g);

c) Fresh weight loss (FWL): calculated based on the change in the fruit mass under different storage periods by weighing them on a semi-analytical scale with accuracy of 0.01 g (Mars, model AS 2000, São Paulo, Brazil), with results expressed as percentage (%). The mass loss during storage was determined by weighing the fruits on an analytical scale at the beginning of the experiment (initial mass) and at each day of analysis (final mass), with results expressed as percentage (%), according to the following equation: FWL (%) = Initial WL - Final WL/Initial WL x 100;

Photo: Alex Guimarães Sanches

Immature Physiologically mature Ripe

Figure 1. *Eugenia klotzschiana* O. Berg fruits harvested at three maturity stages.

d) Color: determined with a reflectometer (Minolta, model CR-400, Osaka, Japan), expressed as luminosity (L*), chromaticity and hue angle (ºh) (McGuire 1992);

e) Soluble solids content (SSC): the pulp of peeled fruits was homogenized with a blender (Mondial, NL-26, Brazil) and the SSC determined with a digital refractometer (Atago Co., Alpha, Osaka, Japan), with results expressed as ºBrix (AOAC 2016);

f) Titratable acidity (TA): determined with 10 g of pulp by titration with 0.1 N of NaOH, using 1 % (w/v) phenolphthalein as an indicator, with results expressed as percentage (%) of citric acid (AOAC 2016);

g) SSC/TA ratio: obtained by dividing the SSC and TA values (AOAC 2016);

h) pH: determined using the potentiometric method, employing a pH meter (Thermo Scientific, model Orion 3 Star, USA) adequately calibrated with buffer solutions of pH 4.0 and 7.0 (AOAC 2016);

i) Vitamin C: the vitamin C (ascorbic acid) content was determined by titrating a 10 mL aliquot of the extract obtained by diluting 10 g of pulp in 50 mL of 5 % (w/v) oxalic acid with 2,6-dichlorophenolindophenol, with results expressed as mg 100 g^{-1} (AOAC 2016).

The data were subjected to analysis of variance (Anova) using the Agroestat software (Barbosa & Maldonado 2015), and the means were compared by the Tukey test at 0.05 % of significance.

RESULTS AND DISCUSSION

Tables 1 and 2 show the physical and chemical characteristics of the *E. klotzschiana* fruits gathered at various ripeness stages.

Significant differences were observed for fresh mass among all maturity stages (Table 1). The ripe fruits had a higher fresh mass (98.03 ± 2.19 g) than the physiologically mature (78.10 ± 1.94 g) and immature (58.47 ± 2.05 g) fruits. Similar results were observed for fruit width, as significant differences among the maturity stages were found (Table 1). In contrast, the fruit length did not differ among the maturity stages and ranged from 7.32 to 8.14 cm (Table 1).

Ripe fruits were 30.34 % heavier and 13.18 % wider than in the other maturity stages (Table 1). These differences might be associated with the fact that ripe fruits are considered wholly developed and at the end of their development (Chitarra & Chitarra 2005). According to Hamacek et al. (2013), fruit size is an important quality attribute, mainly for fruits used by the industry, which might be the case of *E. klotzschiana*. However, there was no difference for fruit length among the maturity stages (Table 1).

Table 1. Physical characteristics of the *Eugenia klotzschiana* O. Berg fruits at three maturity stages.

Maturity stages	Fresh mass g	Width cm	Length cm	Color: Luminosity	Color: Hue angle	Color: Chromaticity
Immature	58.47 ± 2.05 c	4.63 ± 0.19 c	7.32 ± 1.65 a	57.16 ± 5.72 a	101.32 ± 2.31 a	41.19 ± 3.92 a
Physiologically mature	78.10 ± 1.94 b	5.11 ± 0.67 b	7.83 ± 2.04 a	56.81 ± 4.96 a	81.32 ± 4.90 b	43.45 ± 2.07 a
Ripe	98.03 ± 2.19 a	5.61 ± 0.43 a	8.14 ± 1.87 a	62.92 ± 3.29 a	79.56 ± 3.18 b	45.22 ± 2.85 a
F test	5.19**	6.03**	ns	ns	2.04*	ns
Standard deviation (%)	4.83	2.11	3.06	7.21	6.28	3.14

Means followed by the same letter within each column do not differ statistically from each other by the Tukey test ($p < 0.05$). * $p < 0.01$; ** $p < 0.05$; ns: non-significant.

Table 2. Chemical parameters of the *Eugenia klotzschiana* O. Berg fruits at three maturity stages.

Maturity stages	Soluble solids content (SSC) ºBrix	Titratable acidity (TA) %	SSC/TA	pH	Vitamin C mg 100 g^{-1}
Immature	6.00 ± 0.53 a	1.88 ± 0.10 a	3.19 ± 0.93 b	2.89 ± 0.71 a	11.23 ± 2.06 a
Physiologically mature	6.16 ± 0.34 a	1.86 ± 0.09 a	3.31 ± 0.31 b	2.86 ± 0.38 a	8.91 ± 3.18 ab
Ripe	6.83 ± 0.69 a	1.27 ± 0.11 b	5.37 ± 0.56 a	2.95 ± 0.47 a	7.62 ± 1.13 b
F test	ns	1.31*	2.43*	ns	2.07*
Standard deviation (%)	2.06	2.51	5.90	1.18	4.65

Means followed by the same letter within each column do not differ statistically from each other by the Tukey test ($p < 0.05$). * $p < 0.01$; ns: non-significant.

E. klotzschiana fruits are classified as pyriform (Vallilo et al. 2003). As such, the width is more developed and stands out concerning the length (Figure 1). The fruit may develop more in width at the end of the development stage, similarly to other fruits, such as rose apple (Khandaker & Boyce 2016) and pear (Wang et al. 2017).

The peel color, especially the luminosity (57.16 ± 5.72 to 62.92 ± 3.29) and chromaticity (41.19 ± 3.92 to 45.22 ± 2.85) did not vary among the maturity stages. However, the hue angle (ºh) was higher for immature fruits (101.32 ± 2.31), when compared to physiologically mature (81.32 ± 4.90) and ripe (79.56 ± 3.18) ones (Table 1).

The *E. klotzschiana* fruits showed a yellow background color with a red blush (Table 1), while the immature fruits were greener (ºh = 101.32 ± 2.31). Thus, as the luminosity and chromaticity did not differ among the maturity stages (Table 1), the hue angle was the only color parameter that allowed segregation for fruit maturity. Witherspoon & Jackson (1996) also reported that the hue angle is the most important and most used color parameter to indicate fruit maturity. In general, color is the quality attribute that attracts the consumer the most, because it is associated with maturity, freshness and flavor (Badenes et al. 1998). *E. klotzschiana* fruits with yellow and red colors would have a higher consumer preference.

The chemical parameters, SSC (6.0-6.83 ºBrix) and pH (2.89-2.85) did not show significant differences among the maturity stages (Table 2). In contrast, ripe fruits had a lower TA (1.27 % ± 0.11 %) content and, consequently, a higher ratio (SSC/TA = 5.37 ± 0.56), when compared to physiologically mature (TA = 1.86 % ± 0.09 % and ratio = 3.31 ± 0.31) and immature (1.88 % ± 0.10 % and 3.19 ± 0.93) fruits, respectively. The vitamin C content was higher in immature fruits (11.23 ± 2.06 mg 100 g^{-1}), when compared to physiologically mature (8.91 ± 3.18 mg 100 g^{-1}) and ripe (7.62 ± 1.13 mg 100 g^{-1}) fruits (Table 2).

E. klotzschiana fruits may be considered very acidic, since the TA content varied between 1.27 and 1.88 % of citric acid. Even ripe fruits have substantial TA levels (1.27 % of citric acid), being consistent with the findings of Carneiro et al. (2019). Similarly, the pH values were very low due to the high organic acid content. The SSC was low (6.0-6.83 ºBrix) and the TA was high, even though the ripe fruits showed a low SSC/TA ratio (Table 2). The vitamin C content was 32.14 % higher in immature fruits than in ripe ones, possibly due to the role of this vitamin in the growth and development of fruits during ripening (Akram et al. 2017).

The color of the ripe *E. klotzschiana* fruits was better, since they were larger and heavier (Table 1). This maturation stage was deemed the best for fruit storage because of its superior chemical characteristics, notably lower acidity and more outstanding SSC/TA ratio (Table 2). An increase in the fresh weight loss was observed during the storage of ripe fruits, which reached 3.05 % ± 0.28 % on the last day of storage (Table 3).

Regarding fruit color, the luminosity reduced during storage (Table 3); however, the hue angle (ºh) and chromaticity did not change during this period (Table 3).

There were no observed significant differences ($p > 0.05$) in the chemical parameters for the SSC during storage, with values ranging from 5.10 ± 0.68 to 6.86 ± 0.52 ºBrix (Table 4). Similarly, the pH

Table 3. Physical characteristics of the ripe *Eugenia klotzschiana* O. Berg fruits under storage at ambient conditions (23 ± 2.0 ºC) for up to 5 days.

Storage period	Fresh weight loss (%)	Color		
		Luminosity	Hue angle	Chromaticity
0	0.00 ± 0.00 e	67.09 ± 3.62 a	97.09 ± 1.01 a	46.34 ± 2.16 a
1	0.21 ± 0.08 d	66.63 ± 1.18 a	95.20 ± 3.87 a	47.03 ± 1.18 a
2	0.89 ± 0.05 d	64.81 ± 3.27 a	94.41 ± 2.96 a	46.35 ± 0.98 a
3	1.82 ± 0.12 c	63.73 ± 2.51 a	94.47 ± 2.19 a	47.18 ± 2.03 a
4	2.12 ± 0.09 b	56.28 ± 1.03 b	92.65 ± 3.62 a	47.40 ± 1.84 a
5	3.05 ± 0.28 a	57.12 ± 2.04 b	89.09 ± 2.13 a	48.63 ± 1.35 a
F test	2.98*	3.04**	ns	ns
Standard deviation (%)	0.87	3.19	2.96	2.12

Means followed by the same letter within each column do not differ statistically from each other by the Tukey test ($p < 0.05$). * $p < 0.01$; ** $p < 0.05$; ns: non-significant.

Table 4. Chemical characteristics of the ripe *Eugenia klotzschiana* O. Berg fruits during storage under ambient conditions (23 ± 2.0 ºC) for up to 5 days.

Storage period	Soluble solids content (SSC) ºBrix	Titratable acidity (TA) %	SSC/AT	pH	Vitamin C g 100 g^{-1}
0	5.10 ± 0.68 a	1.29 ± 0.11 a	3.81 ± 0.42 b	2.90 ± 0.62 a	8.11 ± 0.29 a
1	5.96 ± 0.52 a	1.51 ± 0.10 a	4.45 ± 0.11 b	2.87 ± 0.28 a	8.08 ± 0.36 a
2	6.10 ± 0.62 a	1.42 ± 0.08 a	4.68 ± 0.36 b	2.89 ± 0.33 a	7.56 ± 0.46 a
3	6.23 ± 0.17 a	1.26 ± 0.07 a	4.97 ± 0.17 b	2.95 ± 0.26 a	7.61 ± 0.74 a
4	6.86 ± 0.52 a	1.02 ± 0.06 b	5.84 ± 0.39 a	2.91 ± 0.18 a	6.52 ± 0.19 b
5	5.72 ± 0.31 a	1.06 ± 0.07 b	4.66 ± 0.14 b	3.00 ± 0.58 a	5.04 ± 0.11 c
F test	ns	7.97**	2.91*	ns	4.18**
Standard deviation (%)	4.19	3.74	5.88	0.89	1.60

Means followed by the same letter within each column do not differ statistically from each other by the Tukey test ($p < 0.05$). * $p < 0.01$; ** $p < 0.05$; ns: non-significant.

values did not vary during storage, and an average value of 2.92 was observed (Table 4). During the storage period, a reduction in the TA levels was observed from the fourth day of storage, leading to an increase in the ratio (3.81-5.84) (Table 4). The vitamin C content showed significant reductions from the fourth day of storage and reached its lowest value on the fifth day (5.04 ± 0.11 mg 100 g^{-1}) (Table 4).

Although the fresh weight loss increased during the storage period and reached 3.05 ± 0.28 % on the fifth day (Table 3), it was below the 5 % threshold value that is the limit for conserving fruits and vegetables (Kader 2003). Therefore, *E. klotzschiana* can be considered a fruit with low water loss, because higher fresh weight losses were reported at ambient storage. Morgado et al. (2010) reported fresh weight losses of 8.5 % in guava, and values of 8.0 % were found for avocado (Vieites et al. 2012) and 7.0 % for mango (Cordeiro et al. 2014). This characteristic may have led Carneiro et al. (2019) to report that *E. klotzschiana* fruits have an excellent post-harvest shelf life, as the losses caused by the evaporation may compromise the fruit visual appearance, texture and juiciness (Ribeiro & Freitas 2020). The trichomes existing on the peel of the fruit may have acted to prevent these losses.

During storage, the fruit showed few changes in color, with only a small reduction in luminosity related to the peel brightness (Zhao et al. 2020, Zhao et al. 2021). It is possible that, as the fruit was harvested ripe, reactions of carotenoid compounds synthesis and chlorophyll degradation had already occurred (Chitarra & Chitarra 2005). In this way, the yellowish-reddish color was maintained during storage. The reduction in luminosity could be associated with the fresh weight loss and the process of synthesis of the red flush, which is darker (Figure 2).

Similarly to color, the fruit did not show significant changes for SSC and pH, with only a small reduction in the TA content and, consequently, an increase in the SSC/TA ratio (Table 4). The absence of significant changes in the physical and chemical parameters is an indication that the fruit had already stored carbohydrates and organic acids in their vacuoles, because this organelle accumulates a large

Photos: Alex Guimarães Sanches

Figure 2. Appearance of the ripe *Eugenia klotzchiana* O. Berg fruits during storage at ambient conditions (24 ± 2 ºC and 75 ± 5 % of RH) for up to 5 days.

number of organic compounds at the end of fruit ripening (Shiratake & Martinoia 2007). In addition, it can be inferred that, during storage, there was no starch degradation, as this would lead to an increase in SSC (Chitarra & Chitarra 2005). However, reductions in the TA content were observed after 4 days of storage (Table 4). This behavior was reported for other Myrtaceas, for example, yellow strawberry guava (Sanches et al. 2017a), red strawberry guava (Muniz et al. 2017) and Brazil cherry (Sanches et al. 2017b).

Finally, the 37.85 % reduction in the vitamin C content showed that this antioxidant compound was used to maintain the oxidative homeostasis during the fruit storage. Vitamin C is an essential antioxidant in several biological reactions (Mditshwa et al. 2017). However, this compound is easily degraded, especially during storage, as senescence leads to catabolic reactions (Severo et al. 2009).

CONCLUSIONS

1. *Eugenia klotzschiana* O. Berg fruits should be harvested ripe, as they present larger dimensions, better color, are less acidic and have a higher soluble solids content (SSC)/titratable acidity (TA) ratio (flavor).
2. During the storage of ripe *E. klotzschiana* at room temperature, the fruit presents a reduced fresh weight loss and does not show significant color changes. Similarly, the physical and chemical parameters remain unchanged, with small reductions in the TA, a consequent increase in the SSC/TA ratio, and a reduction in the vitamin C content.

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