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Physiological development of cagaita (*Eugenia dysenterica*)

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ABSTRACT

It was evaluated the physiological aspects of the cagaita (*Eugenia dysenterica*) development, from anthesis to ripening. The fruits have been subjected to physical and chemical analysis during the fruit life cycle. The total fruit development comprised 37 days. There was a steady increase in the total mass of the fruits and significant increase in transverse and longitudinal diameter, adjusting the double sigmoidal behavior in response to changes in the time. From the 23rd DAA, it was observed the beginning of loss of firmness, increase in total and soluble pectin content and a decrease in starch content. It occurred degradation of total chlorophyll and unmasking of carotenoids from 31st days after anthesis. A decrease in pH and, therefore, increase in acidity, low soluble solids content. The sucrose content was extremely low during the cycle. At the end of development, the respiratory and ethylene production peak was observed, suggesting climacteric behavior.

1. Introduction

Many fruit species, native from the Brazilian Cerrado region have great economic and ecological potential, as well as social importance for the native population (Correa et al., 2011). The cagaita (*Eugenia dysenterica*) belonging to the Myrtaceae family comprises 14 genera and is represented by 211 species that occur naturally in the cerrado. The Myrtaceae family has great economic potential, many of its species are used as food, how species of *Psidium guajava* L. (guava) and *Eugenia uniflora* L. (pitanga), consumed as juice, jams, jellies and ice creams (Lorenzi, Bacher, Lacerda, & Sartori, 2006), and (Myrciaria dubia (Kunth) Mc Vaugh), the "camu-camu" that has a high values of Vitamin C, according to ethnopharmacological information (Lorenzi & Matos, 2002). The cagaita fruits have a round shape, bacáceo, light yellow color, slightly acid, membranous epicarp, weighing 14–20 g, length of 3–4 cm and a diameter of 3–5 cm, with average of 3–4 lumps, it has great potential for use in agricultural systems (Naves, Borges, & Chaves, 2002). Besides fresh consumption, cagaita pulp can be used to manufacture food products (candies, juices, liquors and jellies).

The fruits of cagaita have a high potential for industrialization due to high acidity, low energy value and low content of lipids and carbohydrates (Camilo, Souza, Vera, & Naves, 2014). The vitamin C content of cagaita (18,28 mg/100 g) are higher than those found in ripe Cavendish banana and argentine apple, that are 6,4 and 5,9 mg/100 g, respectively. It has a higher content of linoleic acid, compared to those found in olive, dendê and coco, and linolenic acid content is higher than found in corn, sunflower, peanut, soybean, olive and dendê (Sano & Almeida, 1998). Despite the great importance of this specie, there are few studies about their physiological development, what has great importance in the knowledge of the flora of this biome (Carneiro & Mapeli, 2013). The knowledge of the fruits development stages is essential to help to determine the cultural practices, and can reveal critical periods in the development of the fruits that enable the production with quality, as well as the harvest in the correct period (Salomão, Siqueira, & Pereira, 2006). Given the above, it is aimed to characterize chemical and physiologically the cagaita (*Eugenia dysenterica*) from anthesis to its full maturity.

2. Materials and methods

2.1. Obtaining of fruits and experiment installation

Cagaita fruits were collected in a native area, with typical cerrado formation, located in the city of Abadia-GO, latitude −16°45′26″ and longitude −49°26′15″. There were selected, at

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random, 30 trees of the specie *Eugenia dysenterica*, and marked with woolen yarn of different colors at the time of anthesis. In intervals of four days from anthesis, about 40 fruits were collected, at random, among the 30 previously selected trees, packed in low density polyethylene bags, where were selected as to physical integrity, absence of mechanical and pathogenic damages. The samples were collected 10, 14, 18, 23, 27, 31, 34 and 37 days after anthesis, being collected 40 fruit each stage of development. The experiment was conducted in a completely randomized design (DIC), and the treatments were arranged by a single factorial composed of harvest points (10, 14, 18, 23, 27, 31, 34 and 37 days). In the days of harvest the fruits were subjected to mass analysis, transversal and longitudinal diameters, color, respiratory activities, ethylene, firmness, soluble solids, pH and titratable acidity, these analyzes were done as soon after the harvest, the samples was homogenized and the analysis were carried out three times. The remaining entire fruits were submitted to fast freezing in liquid nitrogen, then stored at −18 °C, to perform further analysis such as total chlorophyll, total carotenoids, total and soluble pectin, sugars and starch, which are analyzed from the 18th day of collection. To carry out these analyzes, the fruits were subjected to thawing and homogenization peel and pulp for each collection period.

2.2. Ethylene evolution and CO_2

Gas samples were collected for analysis of ethylene and CO_2 from the same bottles. For respiration rate, 22 g as of fruit on average have been put in glass containers (360 mL) and closed during 1 h with plastic cap containing a silicone septum through which aliquots of internal sample was withdrawn with help of a O_2/CO_2 gas analyzer (Illinois – LL6600). The results were expressed in mg CO^2 kg fruit^{-1} h^{-1}. The ethylene gas liberation was determined by gas chromatography as described by Fan, Blankenship, and Mattheis (1999). In order to capture this gas were used 360 mL glass bottles containing approximately 22 g of fruit. The flasks were closed over 1 h with plastic cap containing a silicone septum. After the packaging period, a multiple needle was coupled to a vacutainer tube (Vacu Tube), and the glass vessel through a septum, where was collected 9 mL of the gaseous atmosphere. The samples were injected into a gaseous chromatograph (GC), equipped with a thermal conductivity detector and column packed with Porapak-Q (60–100 mesh, 1 m of length and 3,2 mm inner diameter). Was used as carrier gas the nitrogen (N_2 – 80 kPa) with a flow of 40–45 mL min^{-1}. The results were expressed as μL g^{-1} h^{-1}.

2.3. Physical and chemical aspects of development

The fruit mass was achieved using the semi-analytical balance, expressed at grams (g) and the longitudinal and transversal diameters were obtained with the help of an analog caliper, with 12 repetitions. The results are expressed in millimeters (mm). Firmness was determined individually in the whole fruit with the peel at the equatorial region using Prob P2/N (2 mm) in texturometer (Texture Analyzer, TA-XT Plus, Surrey, England), and the results were expressed in Newton (N). The color was determined at three different points of the peel by analyzing three parameters to determine the CIE L * a * b* mode provided by colorimeter (Hunterlab, ColorQuest II).

The total soluble solids ratio was determined by means of measuring Brix degrees with digital refractometer (AR 200) at 25 °C according to the method proposed by AOAC (2010). The pH determination was performed using a digital potentiometer (TEC-3MPp). The device was calibrated with buffered solution of pH 4.0 and 7.0, and then was done the direct measurement of pH with soaking the electrode in a beaker containing the sample macerated in aqueous solution, according to the methodology proposed by the AOAC (2010). The total titratable acidity was determined by titrating with sodium hydroxide (NaOH) solution 0.01 N in triplicate according to AOAC (2010). For starch analysis after chemical extraction and hydrolysis, dosing was performed by the Somogyi method adapted by Nelson (1994), and the results expressed in percentage (%). The total and soluble pectin was extracted according to McCready and McColomb technique (1952), and determined spectrophotometrically at 520 nm according Blumenkrantz and Asboe-hansen (1973). The results were expressed as mg of galacturonic acid per 100 g of pulp. For the total chlorophyll ratio, 10 mL of 80% acetone was added to 1 g of chopped fresh peel and homogenized with the help of a tissue homogenizer. The extract was transferred to a 50 mL volumetric flask, supplementing it with acetone. After 15 h of rest in the dark was realized the filtration as described by Bruinsma (1963). The measurement of the extract absorbance was held by using Rayleigh spectrophotometer UV-1800 to 652 nm, and the results expressed as mg of total chlorophyll/100 g of sample, according to the equation adopted by Engel and Poggiani.

$$\text{Total chlorophyll} = [(A652'1000'v/1000w)/34.5]'100 \quad (1)$$

v = final volume of the chlorophyll extract; acetone; w = pell mass at g; A652 = absorbance measurement at 652 nm.

The total carotenoids were determined according to the methodology described by Higby (1962), whose extraction occurred by shaking the sample with alcohol and hexane, with three subsequent filtrations. The measurements were taken using a Rayleigh spectrophotometer UV-1800 at 450 nm, and the results were expressed in mg of carotenoids/100 g of sample.

The sucrose, glucose and fructose concentrations were determined using the methodology described by IC Application Note (2015). It was used ions chromatograph 930 Compact IC Flex (Metrohm, Herisseau, Switzerland) with attached column Metrosep Carb 1 (150/4.0) and mobile phase of sodium hydroxide (100 mmol.L^{-1}). The samples were diluted using ultra-pure and filtered water using filter with 0.45 μm pore diameter. The running conditions were: injection volume 0.25 μL, flow of 1.0 mL.min^{-1}, oven temperature 35 °C and run time of 9 min. The results were compared with a calibration curve preassembled with standard solutions, between the concentrations 1 and 1000 mg.L^{-1} (glucose and fructose) and 1–100 mg.L^{-1} (sucrose).

2.4. Statistical analysis

The experiment was conducted in a completely randomized design (DIC), and the treatments were arranged in a factorial composed of harvest points in triplicate using the Statistica program. The data were submitted to polynomial regression, where the models were selected according to the significance of the F test and the determination coefficient.

3. Results

3.1. Ethylene production and respiratory rate

The respiratory rate of cagaita was intense during the first days, with production of 2650 mg of CO_2 kg^{-1} h^{-1}, occurring decreases on 23rd DAA (314,5 mg de CO_2 kg^{-1} h^{-1}). After this period, there was an increase in the respiratory rate with a production of 1221.84 mg of CO_2 kg^{-1} h^{-1} on 34th DAA maximum peak considered during development compared to the maturation, followed by further decrease (Fig. 1a). The Ethylene production was stable between 10th and 27th DAA comprising values between 0.031 and 0.038 μL of ethylene kg^{-1} h^{-1}. It was observed an increase in the ethylene production from 31st DAA, followed by fall. However, a