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Growth and maturation of white-fleshed dragon fruit

Crescimento e maturação de frutos de pitaia de polpa branca

Crecimiento y maduración de frutos de pitaya de pulpa blanca

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Abstract
Pitaya has great potential for marketing and processing. However, the lack of knowledge about its cultivation is still a barrier that prevents its diffusion in the country. The objective of this study was to analyze the changes that occur during the growth and ripening of white-fleshed dragon fruit. Physical and physicochemical and chemical fruit characterization analyzes were conducted at several development stages (7, 14, 21, 28, 35 and 42 days after anthesis). Increases in length, fruit mass and pulp, yield and soluble solids were observed, as well as reductions in skin thickness, strength and pulp pH. Significant and important levels in mineral for the human diet were found, especially nitrogen, potassium, calcium, manganese, iron and zinc. Intense changes in seed maturation and biomass accumulation occoured during the fruit growth phase, while in the maturation stage the main changes are related to the improvement of the organoleptic characteristics such as acidity reduction and content of soluble solids, besides the reduction of the mass and thickness of the skin. The ideal harvest point, whereas organoleptic characteristics and visual aspects, is around 35 days, when fruit reached physiological maturity; however, at 42 days, the fruit pulp still had sufficient quality for consumption.
Keywords: Cactus; *Hylocereus undatus*; Physiology; Pitaya.

Resumo
A pitaia apresenta grande potencial de mercado e processamento. Porém, a falta de conhecimento sobre seu cultivo ainda é uma barreira que impede sua difusão no país. Assim, objetivou-se avaliar as alterações físico-químicas dos frutos de pitaia (*Hylocereus undatus*) colhidos em diferentes estágios de desenvolvimento bem como determinar o período ideal de colheita. Foram realizadas análises visuais e de caracterização física, físico-química e química em diferentes estádios de desenvolvimento (7, 14, 21, 28, 35 e 42 dias após a antese). As análises foram: massa do fruto, polpa e casca, rendimento, diâmetro longitudinal e transversal, índice de formato, espessura da casca, firmeza da polpa, sólidos solúveis, pH, acidez, ratio, coloração da casca e teor de minerais na polpa dos frutos. De modo geral, observa-se incrementos no comprimento, massa do fruto e polpa, rendimento e sólidos solúveis e reduções na espessura da casca, firmeza e pH da polpa. A coloração da casca muda de tons verde-amarelo em frutos imaturos para vermelho intenso ao amadurecerem. Embora ocorra redução de minerais com o desenvolvimento do fruto, são encontrados teores significativos e importantes para a dieta humana, com destaque para nitrogênio, potássio, cálcio, manganês, ferro e zinco. São observadas mudanças marcantes nas características dos frutos com o desenvolvimento. As máximas de massa do fruto, diâmetros e ratio ocorrem aos 35 dias, enquanto que a massa da polpa, rendimento e sólidos solúveis ocorrem aos 42 dias após antese. O ponto ideal de colheita, levando-se em conta características organolépticas e aspectos visuais é em torno dos 35 dias, quando alcança maturidade fisiológica, porém, aos 42 dias, a polpa do fruto ainda se encontra com qualidade para consumo.
Palavras-chave: Cactus; *Hylocereus undatus*; Fisiologia; Piataia.

Resumen
La pitaia tiene un gran potencial de mercado y procesamiento. Sin embargo, el desconocimiento sobre su cultivo sigue siendo una barrera que impide su difusión en el país. Así, el objetivo fue evaluar los cambios fisicoquímicos de los frutos de pitaia (Hylocereus undatus) recolectados en diferentes etapas de desarrollo así como determinar el período ideal de cosecha. Se realizaron análisis visuales y físicos, físico-químicos y químicos en diferentes etapas de desarrollo (7, 14, 21, 28, 35 y 42 días después de la antesis). Los análisis fueron: masa de frutos, pulpa y piel, rendimiento, diámetro longitudinal y transversal, índice de forma, espesor de piel, firmeza de la pulpa, sólidos solubles, pH, acidez, proporción, color de piel y contenido mineral en la pulpa de los frutos. En general, hay aumentos en longitud, masa de frutos y pulpa, rendimiento y sólidos solubles y reducciones en el grosor de la piel, firmeza y pH de la pulpa. El color de la piel cambia de tonos amarillo verdosos en frutos inmaduros a rojo intenso cuando maduran. Si bien existe una reducción de minerales con el desarrollo del fruto, se encuentran niveles significativos e importantes para la dieta humana, con énfasis en nitrógeno, potasio, calcio, manganeso, hierro y zinc. Se observan cambios marcados en las características de los frutos con el desarrollo. La masa, el diámetro y la proporción máximos de frutos ocurren a los 35 días, mientras que la masa, el rendimiento y los sólidos solubles de la pulpa ocurren a los 42 días después de la antesis. El punto ideal de cosecha, teniendo en cuenta características organolépticas y aspectos visuales es alrededor de los 35 días, cuando alcanza la madurez fisiológica, sin embargo, a los 42 días, la pulpa del fruto aún se encuentra con calidad para el consumo.
Palabras clave: Cactus; Hylocereus undatus; Fisiología; Pitaya.

1. Introduction

Pitaya, known worldwide as 'Dragon Fruit', belongs to the family *Cactaceae*, and is a rustic plant that easily adapts to a wide range of edaphoclimatic conditions, which makes it promising for cultivation. In addition to the pleasant taste, exotic appearance and nutritional and functional properties has aroused the interest of investors and consumers concerned about health and well-being (Rodriguez Canto, 2000; Le Bellec et al., 2006; Junqueira et al., 2010). Fruits can be consumed fresh or in the form of wine, juice, jelly, yogurt, jam, dried and other desserts (Shetty et al., 2012).

It is little known in Brazil and, although it has already shown a great potential for commercial exploitation, there remain many doubts regarding its cultivation, mainly due to the scarcity of studies and its peculiar characteristics in relation to the other fruit trees cultivated in the country. The lack of information on this crop still contributes to an increase in the indexes of post-harvest losses. Inadequate handling accelerates senescence processes by significantly affecting quality and limiting the marketing period.

The period between anthesis and fruit ripening varies among species, usually beginning with fertilization, followed by fruit formation, growth, ripening and senescence stages (Biale and Young, 1964). The knowledge about the changes occurring in fruits during their development and the adoption of technologies that maximize production, such as management practices, fertilization, processing and others contribute to quality maintenance and increase product shelf life. According to Coombe (1976), the evaluation of the developmental pattern of a fruit from flowering helps establish maturity indices, which comprise the perceptible physical and chemical changes during development, and ensure the obtention of good quality fruits, quality at harvest season and the conservation period (Chitarra and Chitarra, 2005).

Some studies are found in the literature about the monitoring of dragon fruit development, mainly regarding the maturation stage. However, fruit growth stage is not reported at mostly of these studies, specialy for *Hylocereus undatus* species (Wanitchang et al., 2010, Chang et al., 2016, Phebe et al., 2009, Ortiz and Takahashi, 2015, Menezes et al., 2015, Magalhães et al., 2019). The knowledge about the fruit growth phase is important to assist and maximize crop management, as well as to bring basic and relevant information for further studies. Therefore, there is no report in the literature that encompass the fruit growth stage in *Hylocereus undatus* species under Brazilian conditions, justifying the development of research for this species.

Thus, the objective of this study was to monitoring and characterize the main changes that occur in dragon fruit during its growth and maturation stages.

2. Methodology

The experiment was conducted in the experimental field of the Fruit Farming Sector of the Federal University of Lavras, Lavras, Minas Gerais, Brazil. The climate of the region is Cwa - subtropical climate (21°14'S, 45°00'W and 918 m of average altitude), i.e., a subtropical climate with cold and dry winters and warm and moist summers (Köppen classification). The average environmental data for the experimental period were 24.6 ºC and 74.3% relative humidity.

The orchard used for the experiment has 180 white-fleshed dragon fruit (*Hylocereus undatus*) plants, conducted perpendicularly in 1.80-m wooden posts in an umbrella system, spaced 3 x 3 m.

On the day of flower opening, about 200 flowers, visually homogeneous, were marked in the middle part of the plant. Eight fruits from the marked flowers, were randomly collected at 7, 14, 21, 28, 35 and 42 days after anthesis, and were evaluated for their qualitative, physical, physicochemical and chemical characteristics.

The experimental design was completely randomized, represented by six collection seasons. Each collection consisted of eight replicates, and each one was represented by the average of two pitaya fruits.

Fruit analyses were performed in the Fruit and Vegetable Postharvest Laboratory, at the Food Science Department of the Federal University of Lavras. The variables evaluated were: mass of the fruit, skin and pulp, which were manually separated and weighed using a precision balance (CelTac, FA2104N model), with values expressed in grams; pulp yield (%), calculated with the results of fruit and pulp mass, by the formula: pulp mass x 100/mass of the whole fruit; longitudinal (DL) and transverse diameter (DT), measured using a digital caliper (Astro Mix 150 mm model) and expressed in centimeters, DL/DT ratio to define fruit shape; skin thickness (mm) was obtained by the mean of two measurements on opposite sides, using a digital caliper; pulp firmness (N) was determined using a semi-manual penetrometer (Magness-Taylor, FT 327 model), with an 8-mm tip, in the equatorial region of the fruits.

The pH was determined using a digital pH meter (Digimed, DM-20 model), where each sample was ground and homogenized at a ratio of 1:4 (10 g pulp and 40 mL distilled water) in a polytron, and the filtrate was used for analysis. Soluble solids were obtained using a digital refractometer (Soil Control, RTD-45 model) and the results were expressed in ºBrix. Titratable acidity was determined by titration with 0.1 N NaOH, using, 1% phenolphthalein as an indicator; 10 mL of the filtered homogenate were used for titration, after grinding the pulp in a polytron at a ratio of 1:5 (10 g pulp and 50 mL distilled water). The values were expressed as percentage of malic acid. The ratio SS/AT was obtained by the proportion total soluble solids/total titratable acidity (AOAC, 2007).

The color of the skin was determined using a Minolta colorimeter (CR-400), with illuminant D65 in the CIE L*a*b* system, and L* (luminosity), a*, b*, Chroma and Hue values were obtained.

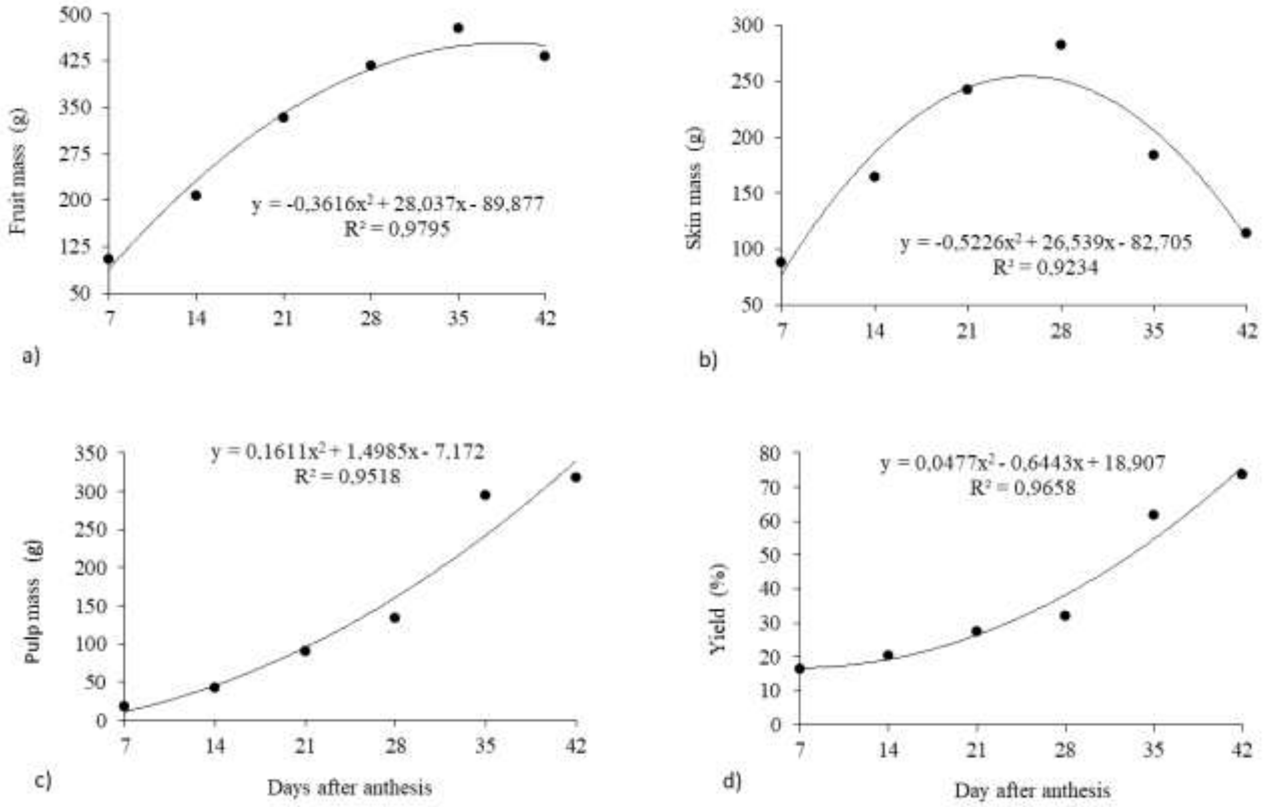
The contents of nutrients in dragon fruit were obtained by the nitric-perchloric extract. P levels were determined by colorimetry; Ca, Mg, Cu, Fe, Mn and Zn, by atomic absorption spectrophotometry, and K by flame photometry. The total N contents were determined by the Kjeldahl semi-micro method. After dry digestion, B was determined by colorimetry (curcumin method) (Malavolta et al., 1997).

Data were submitted to analysis of variance, using the Sisvar® software (Ferreira, 2011). The means of the evaluation periods were submitted to polynomial evaluation, and the models were selected according to the significance of the F test and the coefficient of determination.

3. Results and Discussion

Fresh fruit mass showed a quadratic behavior throughout its development (Figure 1a), reaching maximum growth at 35 days (477.69g), decreasing at 42 days after anthesis (431.74g). Rodríguez (2010), who obtained similar results for native dragon fruit, points out that the maximum fresh mass value was found when the fruit became completely red, with mass loss occurring shortly thereafter. In another study, it was evaluated the maturation phase of dragon fruits from 28 to 42 days after anthesis and no difference on fresh fruit mass was found, probably fruits had already reached the maximum biomass accumulation on this period (Magalhães et al., 2019). The current research shows that the fruit mass increases mainly during the fruit growth stage, previous the maturation phase.

Figure 1. a) Fruit mass (g); b) skin mass (g); c) pulp mass (g) and d) yield (%) of white-fleshed dragon fruit throughout its development.



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The phase in which the fruit reaches the maximum fresh mass can be an indicative of physiological maturation, because mass loss indicates the beginning of degradation processes that occur in the senescence phase, such as water loss, which can be easily visualized by dehydration and wilting of bracts or scales (Figure 1b), indicating loss of quality. Lima et al. (2014), evaluating six dragon fruit genotypes of the same species, found fresh mass variations between 343.5 and 752.5g in mature fruits.

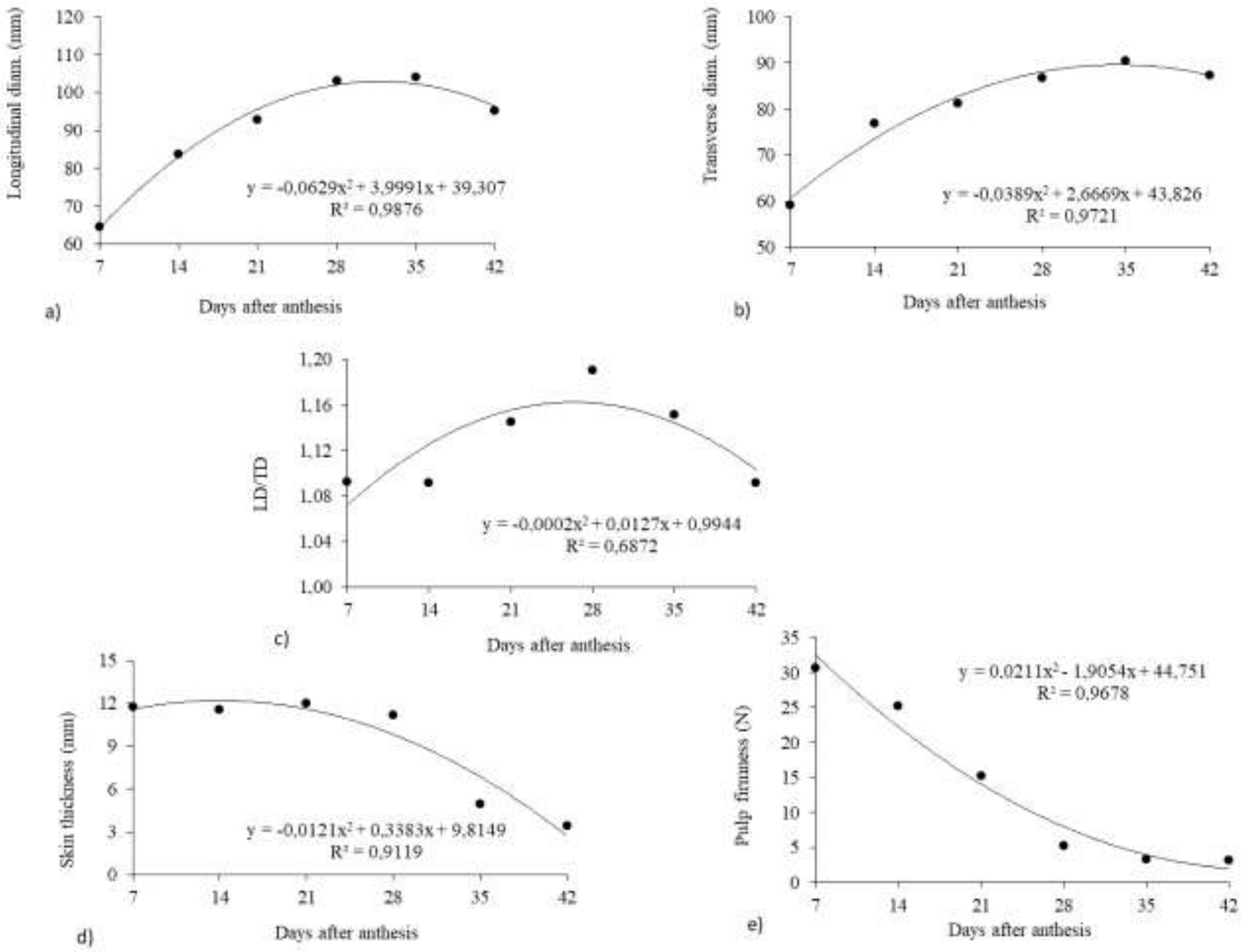
Increases in fresh skin mass (Figure 1c) were observed up to 28 days after anthesis with subsequent losses, showing that fresh skin mass increased predominantly during the growth period. Magalhães et al (2019) and Ortiz and Takahashi (2015) also observed a decrease on fresh skin mass, but the period evaluated by theses authors was only related to the maturation stage.

Fresh pulp mass showed growth with maturation (Figure 1d). Accordingly, Ortiz and Takahashi (2015), who evaluated the development of dragon fruit from 22 to 32 days, obtained maximum values at 26 days of anthesis. Likewise, Centurión et al. (2008), when evaluating fruits from 5 to 35 days after flowering, obtained maximum values at 20 days. The authors also found increasing pulp mass values during fruit development. According to Chitarra and Chitarra (2005), the mass, mainly of the pulp, has cell number, volume and density as determinants; the latter is increased due to the accumulation of water and solutes with its development.

Pulp yield (Figure 1d) followed the fruit mass behavior, reaching its peak at 42 days (73.63%). Ortiz and Takahashi (2015) found maximum yield values of 66% at 32 days after anthesis, while Lima et al. (2014) reported variations from 65.20 to 78.20%, when evaluating fruits of different accessions. According to Cordeiro et al. (2015), dragon fruit has a lot of pulp, when compared to other cacti, and it is an interesting qualitative index for the processing industry.

The measurements of longitudinal and transverse diameter (Figures 2a and 2b), were consistent with the mass gain of the fruits, increasing with fruit maturation up to 35 days, with a slight subsequent decline.

Figure 2. a) Longitudinal diameter (mm); b) transverse diameter (mm); c) longitudinal/transverse diameter ratio; d) skin thickness (mm); e) mean pulp firmness (N) of white-fleshed dragon fruit throughout its development.



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The maximum values of longitudinal and transverse diameter were observed at 35 days of anthesis, corresponding to 104.01 mm and 90.50 mm, respectively. Longitudinal and transverse diameters are important for fruit characterization; however, the DL/DT ratio complements these data, because it indicates fruit shape. The closer to 1.0, indicates a tend to the rounded shape. The DL/DT ratio (Figure 2c) of the evaluated fruits ranged from 1.09 to 1.19, indicating a subglobous shape. The size and shape of fruits are important attributes for commercialization because the variation among the individual units can affect consumer choice of this product; in addition, it directly influences visual attractiveness.

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In relation to skin thickness (Figure 2d), it is possible to observe a reduction as the fruit develops, with means of 11.14 to 11.98 mm while the skins showed green color in a period of 7 to 28 days, decreasing to 4.92 and 3.44 mm, at 35 and 42 days, respectively, when the skins already had a pink color. Fruit skin has an important factor from a post-harvest point of view, as it protects against water loss and mechanical, chemical and biological damage. Thus, thinner skins may result in fruits more susceptible to damage. On the other hand, thicker skins tend to reduce pulp yield, since it is a ratio variable.

In relation to pulp firmness (Figure 2e), there was an abrupt decrease up to 28 days, after that a tendency of stabilization was observed. Values ranged from 30.57 to 3.09 N. These results indicated a high pulp tissue softening with ripening, which is confirmed by Chitarra and Chitarra (2005), who affirm that this softening is one of the first signs and one of the main transformations in fleshy fruits, having a marked influence on quality and shelf life, and a direct relationship with the chemical components of cell walls. Still according to these authors, pectin solubilization is the main responsible for tissue softening. In addition, the decomposition of other cell wall components (celluloses and hemicelluloses), as well as starch hydrolysis and the hydration degree of the tissues (cell turgor) help in this process.

For total titratable acidity, represented by the percentage of malic acid, a quadratic behavior is observed, ranging from 0.27 to 1.36%, increasing in early development stages, with a significant increase at 28 days, before the pigmentation stage of the fruit skin (Figure 3a). Subsequently, there is a decrease in the contents of malic acid in the fruit pulp. According to Arévalo-Galarza and Ortíz Hernández (2004), the increase in acidity before color change shows the beginning of maturation processes. Menezes et al. (2015) reported a similar trend, and an acidity showing a marked increase before color change, whereas for Ortiz and Takahashi (2015) found that acidity increased until the 27th day, when it reached maximum values of 1.4% malic acid, followed by a decrease up to 32 days, reaching a minimum value of 0.27% malic acid. In contrast, Centurión et al. (2008) observed an increasing reduction in acidity from 21 to 31 days of flowering, when it reached 0.4% malic acid. In general, organic acids tend to decrease with maturation due to their use as a substrate in respiration or their conversion into sugars (Chitarra and Chitarra, 2005).

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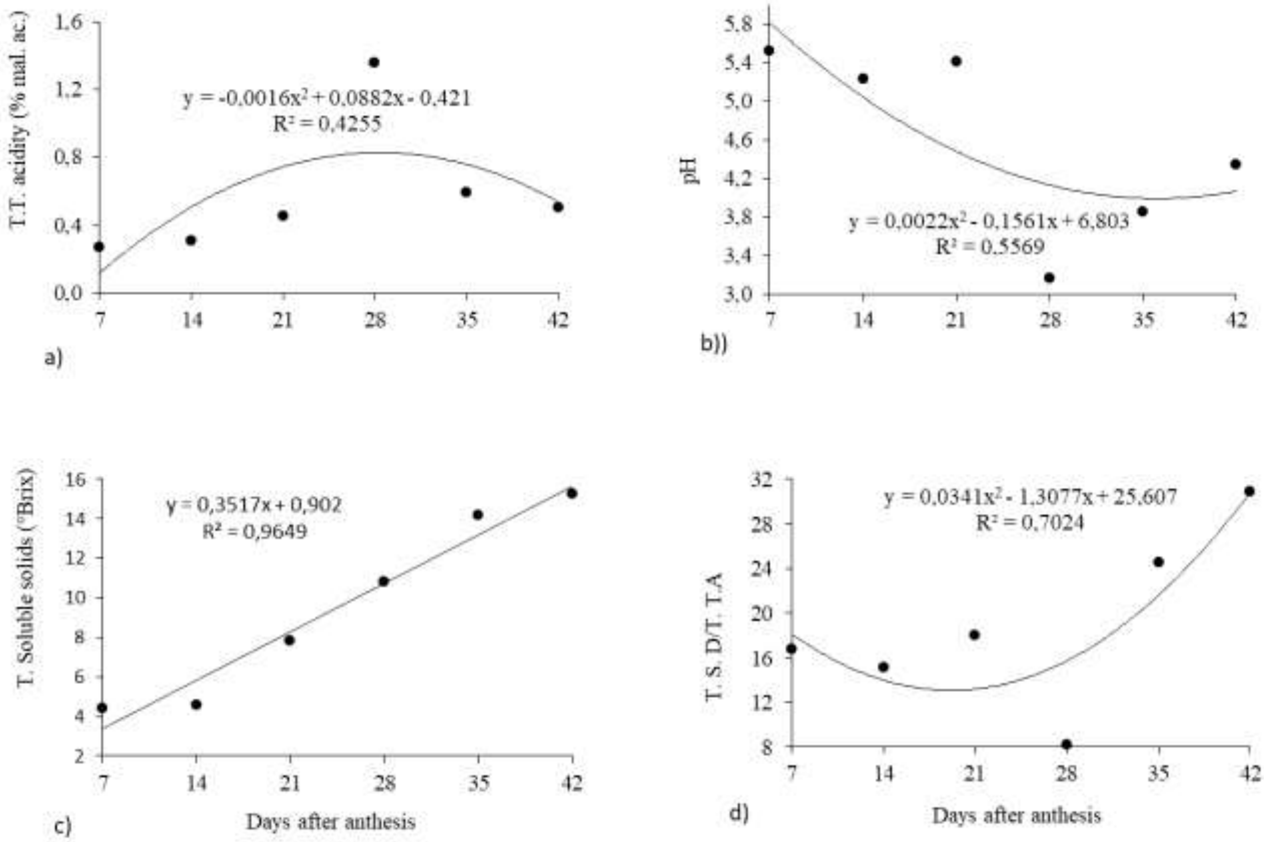
Figure 3. a) Mean total titratable acidity (% malic acid); b) pH; c) total soluble solids and d) total soluble solids/total titratable acidity ratio in the pulp of white-fleshed dragon fruit throughout its development.



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The results found for pH corroborate the acidity data (Figure 3b). The variations were from 3.16 to 5.52, with a sharp decrease between days 21 and 28, and increase in the subsequent days. The reduction in pH with maturation occurs due to the accumulation of organic acids, and its increase is due to the consumption of these organic acids in respiration (Silva et al., 2005).

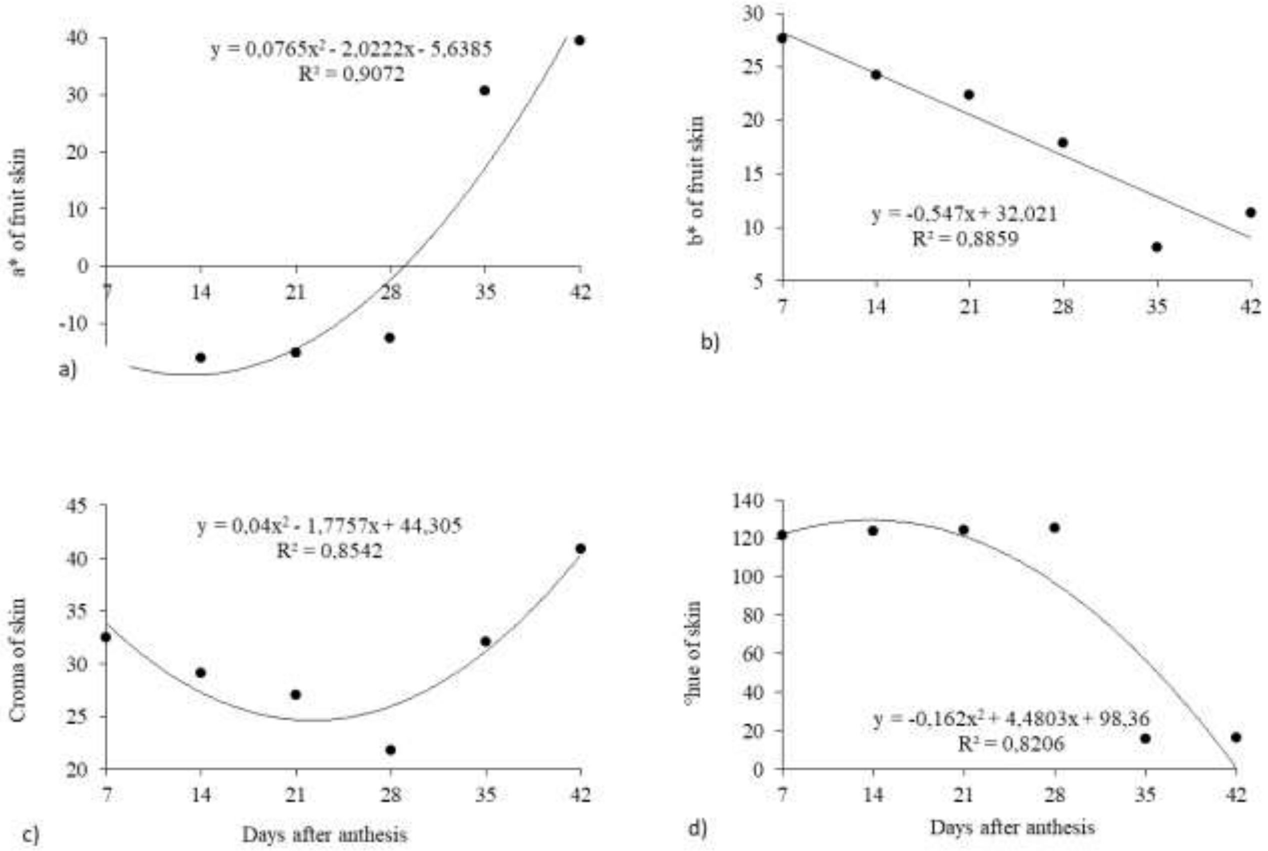
In relation to soluble solids (Figure 3c), values between 4.40 and 7.84 °Brix between days 7 and 21 after anthesis were observed, with a significant increase at 28 days (10.80 °Brix), with a gradual increase in subsequent evaluations, reaching maximum values of 13.24 °Brix at 42 days. Ortiz and Takahashi (2015) obtained maximum soluble solid values at 31 days (12.2 °Brix) of anthesis. For Centurión et al. (2008), the maximum soluble solid content was revealed at 27 days (12.8 °Brix) of flowering, while Menezes et al. (2015), at 42 and 46 days of anthesis, reported values of 19.58 °Brix. Lima et al. (2014), studying the quality of ripe fruits of 6 dragon fruit accessions, found soluble solid values in the median part of the fruit between 11.2 and 14.9 °Brix, consistent with those reported in this study. The content of soluble solids is an indirect measure of the sugar content, since it increases as these contents accumulate in the fruit, which occurs with ripening due to the degradation of polysaccharides, and it is a good indicator of the degree of maturation and taste of the fruits.

The ratio values (SS/AT) showed a quadratic behavior with fruit development (Figure 3d). The maximum value was found at 42 days (30.83), and the minimum at 28 days after anthesis (8.18). Consistent results were reported by Centurión et al. (2008), who found SS/AT ratio of 3.4 to 33.5 from 20 to 31 days of flowering. Acidity and sugars are the main attributes responsible for fruit taste, representing the balance between sweet and sour taste. Thus, the soluble solids/titratable acidity ratio represents a variable of perception of taste intensity, by taste and smell, and is extremely important for the sensory acceptance of the product, for a high sugar content, and low acid content, result in a pleasant flavor (Grierson and Kader, 1986; Chitarra and Chitarra, 2005).

Besides being an important quality requirement in the acceptance of the product by the consumer, color can be used in the determination of maturity indices to indicate the ideal harvest point of the fruits. In the CIE L*a*b* system, colors are three-dimensionally represented. The L* coordinate indicates luminosity, ranging from zero (completely black) to 100 (completely white). The a* coordinate expresses the green-red variation degree and the b* coordinate expresses blue-yellow variations. Chromaticity (C*) indicates the degree of color saturation, while the hue is indicated by the Hue angle.

Regarding dragon fruit skin color, the luminosity index did not show statistical differences ($p<0.05$), with mean values of 51.77. Centurion et al. (2008) did not find differences when evaluating developing pitaya fruits. As for the a* coordinate, its values fit a quadratic curve with increasing values, from 35 positive days (Figure 4a). These results indicate that the red color prevailed after 35 days, evidencing the transformation of green fruits into mature fruits, in agreement with the moment in which the main evolutions in the flavor characteristics such as pH, acidity, soluble solids, ratio and firmness were observed, which is a good indicator in determining fruit maturity.

Figure 4. Fruit skin color: a) a* of fruit skin b) b* of fruit skin c) Chroma of fruit skin and d) Hue of white-fleshed dragon fruit throughout its development.



Source: Authors.

For the b* coordinate (Figure 4b), there was a linear decrease with fruit development, which is in agreement with a study by Ortiz and Takahashi (2015), who found decreasing values ranging from 30.6 to 7.6, from 21 to 32 days of evaluation. It is possible that this decrease is related to the degradation of skin pigments that occur throughout maturation, such as chlorophylls and carotenoids. The chroma (Figure 4c) showed quadratic behavior, with a reduction up to 28 days, and increase up to 42 days. These results indicate a reduction in green color saturation, and may be indicative of the differentiation process of the colors involved in dragon fruit maturation, such as degradation and synthesis of skin pigments, and later rising as the fruits became pigmented, indicating saturation with the accumulation of reddish pigments, as betalain. The Hue angle (Figure 4d) had values close to 130 up to 28 days, when the fruits were completely green, indicating a green color; subsequently, with fruit ripening, it sharply decreases to values around 20, indicating a more intense reddish-pink color. These results indicate the variation in the fruit hue from yellow to green when immature, and then strongly reddish. To et al. (2002) suggested that hue values are below 30 for fruit harvest; therefore, at 35 days, these are already suitable for harvesting.

Regarding the mineral composition in the fruit pulp (Table 1), there was a reduction in the concentrations of all minerals with fruit development, with the exception of sulfur, which was detected only in the first evaluation at 7 days after anthesis. Regarding macronutrients, fruits had a higher concentration of N, K and Ca in their composition, with averages ranging from 31.0 to 15.0; 26.7 to 12.5 and 7.2 to 4.4 g kg^{-1}, respectively, from 7 to 42 days. Cordeiro et al. (2015) evaluated ripe red-fleshed dragon fruit and found larger amounts of these macronutrients, with averages of 11.3; 12.6 and 8.0 g kg^{-1} of N, K and Ca, respectively. As for micronutrients, Mn, Zn and Fe were found at higher amounts. These results demonstrate that white-fleshed dragon fruit ha significant levels of important minerals in the human diet. Besides, the higher content of minerals, together with their antioxidant and nutritional properties, can guide further studies aiming to evaluate the potential of immature fruits on nutritious flour processing or other nutraceuticals products.

Table 1. Macro- and micronutrient contents in the pulp of white-fleshed dragon fruit throughout its development.

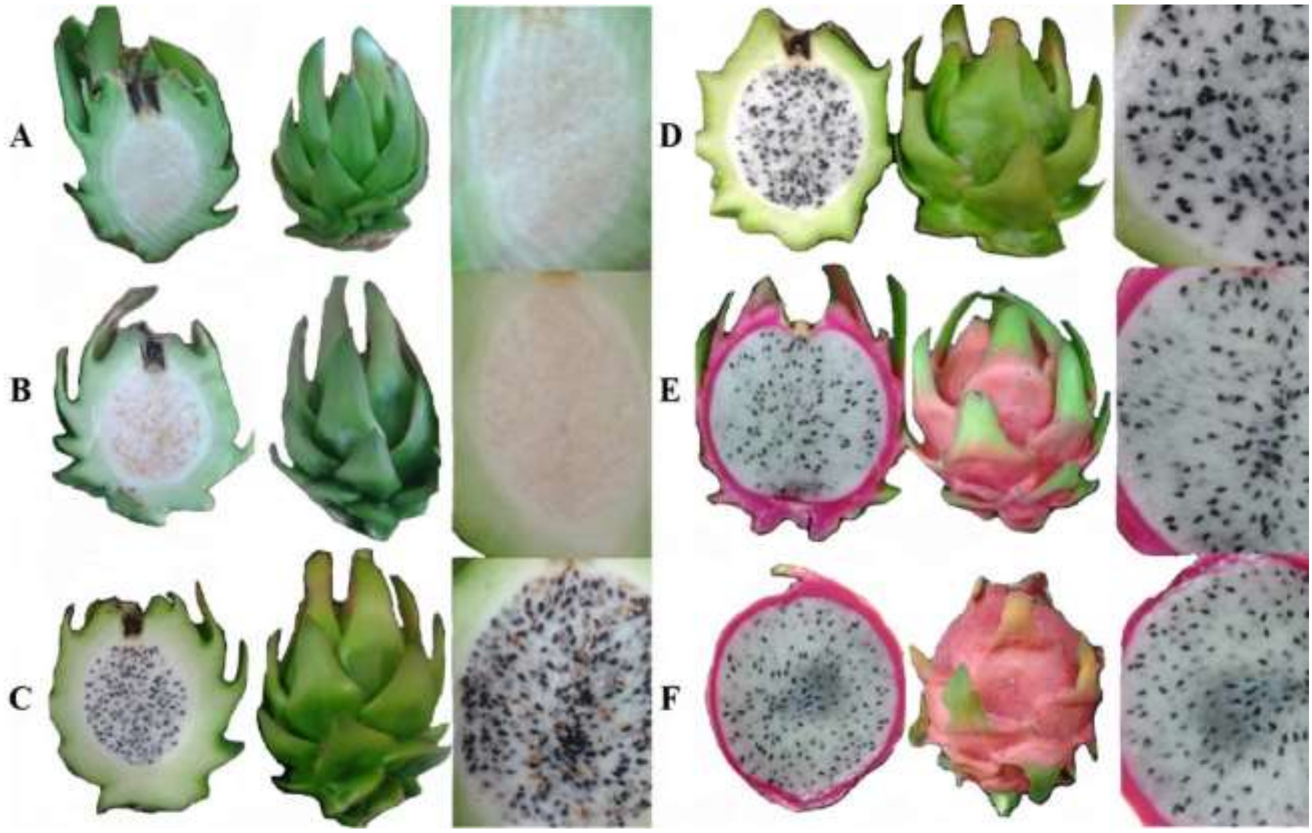
Days	g kg^{-1}						mg kg^{-1}				
	N	P	K	Ca	Mg	S	B	Cu	Mn	Zn	Fe
7	31.0	5.8	26.7	7.2	3.0	2.1	19.6	11.1	66.4	47.1	51.8
14	21.6	4.0	23.4	6.6	2.8	nd	8.8	4.6	68.1	30,2	42.9
21	19.7	2.9	22.8	5.5	2.9	nd	8.2	3.4	43.8	28.9	46.4
28	19	2.6	19.5	4.7	2.7	nd	9.0	3.3	24.1	23.9	64.2
35	11.8	1.8	14.8	4.1	1.5	nd	6.9	0.1	6.0	11.0	33.3
42	15.0	1.9	12.5	4.4	1.4	nd	2.9	0.9	6.0	14.2	27.8

nd = not detect. Source: Authors.

In addition to the nutritional aspect, as a mineral source in the human diet, mineral elements are important in the development of fruit properties because they have significant influence on color, aroma, shape, size, appearance, resistance to mechanical damage, disease incidence, physiological disorders, physicochemical characteristics and post-harvest life (Aular and Natale, 2013). In addition, the knowledge about the accumulation of the minerals in the different phenological phases, such as fruiting, is essential to estimate the crop nutritional needs, as well as to identify the most appropriate moments for fertilizer application (Ramirez et al., 2002), which is very important in the case of dragon fruit, where studies are lacking, such as the recommendation for crop fertilization. Nutrient management has been one of the main operations to ensure higher fruit yield and quality (Kishore, 2016).

As for the visual aspects, it is possible to clearly observe the changes suffered during fruit development, with marked characteristics in each phase (Figure 5). The formation and growth of white-fleshed dragon fruit began with flower pollination and fertilization, followed by a rapid growth of the ovary walls, resulting in the initial formation of the fruit in the first days after flower opening, and the mesocarp (pulp) was visualized at 7 days of anthesis (Figure 5a). At this stage, therefore, the pulp forms a white and homogeneous mass, compact and with a low yield.

Figure 5. Development phases of white-fleshed dragon fruit. A: 7 days after anthesis; B: 14 days after anthesis; C: 21 days after anthesis; D: 28 days after anthesis; E: 35 days after anthesis; F: 42 days after anthesis.



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A slight color in the seeds is observed only at 14 days after anthesis (Figure 5b), and the progress of its development is clear since then when, at 21 days (Figure 5c), it is possible to observe a transition phase in seed maturation, in which seeds occur from light brown to completely black.

The seeds are completely formed at 28 days (Figure 5d), when the first signs of skin color also appear, although they still occur only in the inner part of the fruit. At this stage, there is also an increase in pulp proportion. It is likely because at this stage, seeds have reached physiological maturity, while the fruit begins its maturation.

At 35 days, there is a great evolution as to the external color of the skin (Figure 5e), which acquires an intense pink color throughout the skin, except the ends of bracts that remain green and turgid. In addition, there is a considerable increase in the edible portion of the fruit, accompanied by a reduction in skin thickness. This stage represents the ideal harvest point, once it is visually more attractive with intense pink color in the skin and, in its majority, it has internal qualities suitable for consumption, evidencing that the fruit reached its physiological maturity.

At 42 days, the first signs indicating the beginning of senescence appear (Figure 5f), when the bracts begin to wilt and depigmentate, acquiring a yellowish coloration. Although the edible part of the fruits still has good organoleptic quality, its visual quality begins to be compromised, which directly affects commercialization, since the visual aspect is one of the criteria used by consumers in the choice and selection of the product.

4. Conclusion

Important changes occurred in dragon fruit during the growth and maturation stages, notably regarding alterations on color, physical and physical-chemical characteristics. Significant changes in seed maturation and biomass accumulation occurred during the fruit growth phase, while in the maturation stage the main changes are related to the improvement of the organoleptic characteristics, such as acidity reduction and increase of soluble solids, besides the reduction of the mass and skin thickness.

Fruit mass, diameters and ratios reached their maximum values at 35 days after anthesis. The maximum pulp mass, yield and soluble solids occurred at 42 days after anthesis. The ideal harvest point was around 35 days, when fruit reached its physiological maturity, parameter that can be associated to the intense pink color of the skin. At 42 days, the pulp still had sufficient quality for consumption.

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