



Effect of Ripening Stages on Shelf Life and Quality of Pitaya Fruits during Storage

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/v37i230263

Editor(s):

(1) Dr. Rusu Teodor, Professor, Department of Technical and Soil Sciences, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.

Reviewers:

(1) Benjawan Chutichudet, Mahasarakham University, Thailand.

(2) Liamngee Kator, Benue State University, Makurdi, Nigeria.

Complete Peer review History: <http://www.sdiarticle3.com/review-history/49134>

Original Research Article

Received 05 March 2019

Accepted 20 May 2019

Published 08 June 2019

ABSTRACT

Aims: The study objective was to determine the harvest point of red pitaya produced in the north of Minas Gerais, Brazil, according to physical and chemical changes during refrigerated storage.

Study Design: The experiment was conducted through a completely randomized design in a 3 x 5 factorial scheme composed of three treatments (ripening stages) and five post-harvest assessment days (0, 5, 10, 15 and 20), with four repeats of four fruits per experimental unit.

Study Place and Duration: The experiment was conducted in a cold chamber at the State University of Montes Claros, Brazil, between July and August 2018.

Methodology: The following quality parameters were assessed: fruit fresh mass, length and diameter at harvest point, color, firmness, soluble solid content, titratable acidity, total sugars, reducing and non-reducing, pH and amide, during storage.

Results: There was no significant difference for fresh mass, length and diameter as a function of

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ripening stages. Ripening stages 2 and 3 presented higher soluble solid content means.

Conclusion: Considering the conditions of northern Minas Gerais, harvest should happen at stages 2 or 3, when fruits have a brighter red hue, that is, are more attractive and of easier identification by producers. In addition, pitayas at these stages have higher soluble solid contents and reduced pulp acidity during storage in relation to fruits harvested at S1.

Keywords: Hylocereus undatu; storage; ripening.

1. INTRODUCTION

Pitaya, known worldwide as 'dragon fruit', is a cactus belonging to the genus *Hylocereus*, from the Americas, is spread throughout several countries and presents high agricultural and economic potential due to its rusticity, good adaptability to different types of weather and soil, great and distinct taste, in addition to important nutritional properties [1,2]. *Hylocereus* species pitaya occurs spontaneously in shaded environments of tropical forests in Mexico, India, Vietnam, and South and Central America [3].

There is a variety of species, among which *Hylocereus undatus* (Haw.) Britton and Rose stands out with its red peel and white pulp and fruits with globe or semi-globe shape measuring between 10 and 20 centimetres in diameter; it can reach up to 900 grams, despite weighing on average between 350 and 450 grams, and features among the most cultivated and marketed types in the world [3].

Although its cultivation has expanded, lack of information about its ripening and quality is one of the main barriers to growing it; moreover, there is a considerable production loss due to lack of preservation techniques at post-harvest stage to prolong its marketing period while keeping its quality. There are several techniques that, associated or not, help prolong the shelf life of this fruit by reducing its metabolism [4], and among these post-harvest preservation techniques, use of refrigeration during storage can minimize the intensity of vital processes of fruits without changes in their physiological processes [5]. Besides, reducing storage temperature is one of the most efficient means to prolong the useful life of harvested products [6].

According to [7], employing refrigeration to minimize post-harvest losses is a way to ensure better fruit quality and reach markets farther from the production center. As for post-harvest, pitaya is a tropical fruit that, under room temperature conditions, deteriorates relatively fast and, consequently, its post-harvest useful life is short,

approximately 6-8 days [1,8]. According to Magaña et al. [9], storage temperature and time influence the physiological processes of pitaya, increasing its useful life, especially at a temperature of 8°C, which leads to better quality.

The literature reports the effect of ripening stages on chemical and physical characteristics of many fruits [10,11,12], but for pitaya cultivation, the information found diverges as to growing place and genetics. Thus, particular knowledge about pitaya development in a specific region is relevant. For being considered a non-climacteric fruit, it must be harvested only after coming to its physiological maturity so that it reaches minimum quality for consumption as to color, taste and other organoleptic characteristics. It is highly perishable, so if stored for seven days at room temperature, its peel withers and its pulp softens, resulting in quality loss [13].

In light of the foregoing, this study aimed to determine the harvest point of red pitaya produced in the north of Minas Gerais, Brazil, according to physical and chemical changes during refrigerated storage.

2. MATERIALS AND METHODS

2.1 Experimental Location

The fruits came from red pitaya plants (*Hylocereus undatus*) aged five years, grown within a space measuring 4.0 x 3.0, with tutors perpendicular to the ground, in 1.80 m *aroeira* posts. The commercial orchard located in the rural area of Janaúba, north of Minas Gerais, has an altitude of 544 m and is located at 15°49'48" south latitude and 15°49'48" west longitude. In the midsection of each plant, healthy cladodes were selected, where flower buds at visually homogeneous development stages were marked.

2.2 Planting and Harvesting of the Crop

Harvest was done when fruits reached the following ripening stages: 1 – 31 days after

anthesis (red epidermis color $\leq 30\%$); 2 – 36 days after anthesis (red epidermis color $\leq 50\%$); 3 – 41 days after anthesis (red epidermis color 100%) (Fig. 1).

2.3 Disinfection and Storage of Fruits

The fruits were placed inside harvest-appropriate plastic boxes lined with cut paper to prevent physical damages. Then, they were carried to the post-harvest physiology laboratory of the State University of Montes Claros, Janaúba campus, Minas Gerais, and washed with water containing 0.2% of detergent and immersed in a 2% sodium hypochlorite solution for 15 minutes. After drying naturally, they were placed on expanded polystyrene trays, which were distributed in the storage chamber with temperature adjusted to $15\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$, and RH of $85 \pm 5.0\%$. The fruits were stored for 20 days, counting from the first storage day, with 5-day interval between assessments.

2.4 Experimental Design

The experiment was conducted in a completely randomized design and a 3 x 5 factorial scheme composed of three treatments (ripening stages) and five assessment intervals (0,5,10,15 and 20), as well as four repeats of four fruits per experimental unit. The characteristics assessed were:

Soluble Solids: Soluble solids were determined by refractometry, using an ATAGO brand bench refractometer, model N1, with reading within a range of 0-95 $^{\circ}\text{Brix}$, after juice extraction from the pulp of each fruit core. Results were expressed as $^{\circ}\text{Brix}$.

Titrateable Acidity: Titrateable acidity was determined according to technique recommended by the AOAC (1992), titrating, under agitation, the juice from the repeat fruit set, after extracting, titrating and homogenizing 10 g of pulp from each fruit core in 90 mL of distilled water, with NaOH 0.1 N, using phenolphthalein 1% as indicator. Results were expressed as eq. mg malic acid.100 mL of juice¹.

pH: pH was determined using 10 g of mashed pulp mashed homogenized with 90 mL of distilled water. Reading was done using a DIGIMED brand digital pH meter, model DM 20.

Peel Color: Color was analyzed on Color Flex colorimeter, 45/0 (2200), stdzMode:45/0, with reflectance direct reading of coordinates L* (luminance), a* (red or green hue) and b* (yellow

or blue hue), on Hunterlab Universal Software. With L*, a* and b* values, hue angle ($^{\circ}\text{h}^*$) and chroma saturation index (C*) were calculated. Each repeat used on average four measurements per fruit.

Firmness (N): It was determined by Brookfield brand texturometer, model CT3.10 KG. Firmness was measured in the fruit midsection by the penetration force, in Newton (N), necessary for the 4-mm-wide tip to penetrate 10 mm into the fruit pulp.

Amide and Reducing Sugars: Amides are usually regarded as derivatives of carboxylic acids in which the hydroxyl group has been replaced by an amine or ammonia. The lone pair of electrons on the nitrogen is delocalized into the carbonyl, thus forming a partial double bond between N and the carbonyl carbon. Amide and reducing sugars were determined by spectrophotometry using a Shimadzu brand spectrophotometer, model UV-1650PC, with reading at 510 nm according to the method described by Nelson (1944).

Total Sugars: Total sugars were determined by spectrophotometry using a Shimadzu brand spectrophotometer, model UV-1650PC, with reading at 620 nm, according to method described by Dische (1962).

Non-Reducing Sugars: Non-reducing sugars were determined by the difference between total sugars and reducing sugars, as per method described by Nelson (1944).

Statistical Analysis Description: Data were subjected to analysis of variance and, when the latter was significant, the effects of different ripening stages were compared by means of Tukey's test at 5% significance; storage period effect, in its turn, was verified by means of regression analysis. The regression models used were chosen based on the significance of coefficients, coefficient of determination (R^2) and biological behaviour, using Sigmaplot 11.0 computer program.

3. RESULTS AND DISCUSSION

There was no significant difference for fresh mass, length and diameter (Table 1). The fruits mass values observed in this study are similar to those found in the literature. According to Yah et al. [14], red pitaya fresh mass, 31 days after anthesis, is 469.2 g, and may range from 300 to 800 g.

Since there was no significant difference as to length and diameter according to ripening stages, it was possible to opt for harvest at stages 2 and 3, when the fruits had higher soluble solid contents (Table 1). In addition, pitaya is a non-climacteric fruit, that is, this parameter will not change during storage.

The fruits differed as to soluble solid content according to ripening stages (Table 2), but there was no significant effect for storage days. The means of stages 2 and 3 were higher than those of stage 1; although pitaya is a species that stores virtually no amide, small increases insoluble solid (SS) content have been observed during ripening. According to Chitarra et al. [15], sugar content usually increases as fruits ripen, through biosynthetic processes or polysaccharide degradation. Increased soluble solid content may be due to the cell wall polysaccharides converting into soluble sugars. Stages 2 and 3 showed higher means compared to those of stage 1; for being a non-climacteric fruit, pitaya must be harvested close to its ripening point.

According to Wills et al. [16], non-climacteric fruits harvested unripe present sensorial quality, in addition to being susceptible to dehydration and physiological disorders. Determining the optimal harvest point is extremely important work, as it allows for ensuring good preservation, adequate resistance to transportation, and

maintenance of necessary conditions for the fruit to reach consumers with quality [17]. Soluble solids showed values within acceptable ranges. According to Chitarra et al. [15], fruits in general, when ripe, present mean soluble solid values between 8% and 14%. The literature reports similar values for pitaya—12.51°, 11.87°, 12.23°Brix [18].

Coordinate L* indicates luminance, which ranges from zero (completely black) to 100 (completely white), showing how much the sample changes its color towards darkness or lightness. In the present study, coordinate Luminance L* values at different ripening stages (Fig. 2) show that, at stage 1, the fruits had $\leq 30\%$ of their epidermis red and presented a linear increase in luminance (L*) values, with the highest value, observed ten days after storage, when the fruits were completely red. At ripening stage 2, the fruits became completely red with five days of storage, when they reached their maximum L* point. At stage 3, concerning day 0, they were less luminous, with increase after five days of storage, but after 15 days, there was a linear decrease in L* for all ripening stages due to a color change from red to bright purple. This probably resulted from the degradation of pigments such as carotenoids and chlorophylls in conjunction with the appearance of blueish and purplish pigments because of betacyanin synthesis [15].



Fig. 1. Developing red pitaya (days after anthesis)

a: 31 days after anthesis, stage 1; b: 36 days after anthesis, stage 2; c: 41 days after anthesis, stage 3

Table 1. Means observed for red pitaya physical characteristics according to ripening stage. Janaúba, MG

Days after anthesis (DAA)	Fruit fresh mass (g)	Length (cm)	Diameter (cm)
31	421.4a	9.1a	8.3a
36	440.5a	9.63a	8.5a
41	462.3a	9.09a	8.8a

Means followed by the same letter do not differ from each other by Tukey's test ($P < 0.05$)

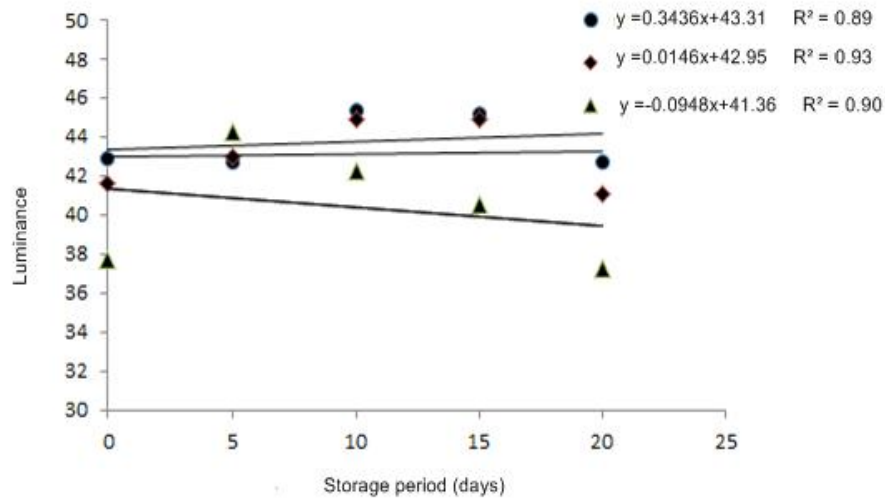


Fig. 2. Red pitaya luminance according to ripening stages and storage days at 15 °C ± 1 °C and RU of 85 ± 5.0%

Table 2. Mean soluble solid (SS) values in red pitaya according to ripening stages, at 15°C ± 1°C and RU of 85 ± 5.0% (means corresponding to the whole storage period)

Ripening Stage	SS (°Brix)
S1	11.17 b*
S2	12.16 a
S3	11.98 a

*Means followed by the same letter do not differ from each other by Tukey's test ($P < 0.05$)

Fig. 3 shows hue angle values found in red pitaya peels at different ripening stages and after storage days at 15°C ± 1°C and RU of 85 ± 5.0%. For ripening stage 1, there was a significant effect, with the peel still presenting a green color at the beginning of storage. From 88° on day 0, hue angle values rose exponentially to 93 with 20 days of storage; this change indicates peel hue evolution from green to red and to bright purple at the end of the storage period. Most likely, during this period, there was chlorophyll degradation and betacyanin synthesis.

According to [19], betacyanins are the predominant pigments in most cactus peels and responsible for their red color while fruits develop. Forty-one days after anthesis, [14] found in studies conducted in Mexico a bright red hue all over red pitaya peels. [20] registered the first color change 24-25 after anthesis, and 4-5 days later the fruits were fully colored, under cultivation conditions of 25-30 °C, with scheduled irrigation and fertilization.

However, there was no significant effect for ripening stages 2 and 3, with hue angle values standing at 90.39 throughout the storage period, since the peel color was totally red; the small change to a brighter purple hue had no statistical influence. Harvest is more appropriate at these stages because the peels have no changes in color, present higher soluble solid contents and can be easily identified by producers. This color change derives from the presence of pigments in pitayas, including betalains, which are water-soluble N-heterocyclic compounds located mainly in the vacuoles of plants. Betalains are split into two distinct groups – betacyanins and

betaxanthines [21,22]. Betacyanins are usually purple-red, while betaxanthines are orangish yellow, and compose different colors in flowers and fruits. As for their functional properties, betalains are known as a strong natural antioxidant [23,24,25].

Chromaticity values are displayed in Fig. 4, where it is possible to see significant effects only for ripening stage 1. As observed, there was an exponential decrease for stage 1 fruits as to storage period, with values being higher on day 0 and constant until 20 days of storage.

The optimal harvest stage for pitaya can be indicated by coordinate a^* , which occurs when the peel is totally red; the present study found that at stages 2 and 3, there are higher soluble solid contents, while peel hue showed no changes, with this being indicative of better harvest points.

Fig. 3 displays hue angle values found in red pitaya peels at different ripening stages and with different storage days at $15^\circ\text{C} \pm 1^\circ\text{C}$ and RU of $85 \pm 5.0\%$. There was no significant effect for ripening stages 2 and 3; hue angle values stood at 90.39° throughout the storage period because the peel color was totally red. For ripening stage 1, when the peel was still green in the beginning of storage, hue angle values rose exponentially from 88° on day 0 to 93° after 20 days of storage; this change indicates a peel hue evolution from green to red and to bright purple in the end of the storage period. Chromaticity values are presented in Fig. 4, which shows significant effects only for ripening stage 1. As observed, there was a linear decrease in relation to the storage period, with values being higher on day 0 and remaining constant until the last storage assessment.

Amid content reduced during storage at all ripening stages (Fig. 5); however, stage 2 presented lower amide percentage on day 0. Amide degradation is one of the most remarkable characteristics in fruit ripening; as amide is hydrolyzed, there is an increase in total soluble sugar levels. Fig. 6 shows that, for all ripening stages, there was a decrease in total sugar contents, from 5% to 3% on average, during storage. Nevertheless, stage 1 fruits presented higher total sugar levels after zero and 20 days of storage.

Fig. 6 shows that, for all ripening stages, there was a decrease in total sugar levels, from 5% to 3% on average, during storage. However, stage

2 fruits presented lower total sugar content after zero and 20 days of storage. According to [26], ripening reduces amide content at the same it increases levels of total sugars, non-reducing sugars and soluble solids, with the increasing conversion of amide into simple sugar. This, however, was not observed for the ripening stages of pitaya as it is a non-climacteric fruit. For reducing sugars, there was no significant effect. As for non-reducing ones (Fig. 7), there was the significant effect only for ripening stages 1 and 3; on storage day 0, there was a higher percentage of non-reducing sugars, with values at 3.9% and 4.5%, respectively.

Concerning firmness, there was no significant effect between ripening stages, but values decreased throughout the storage period (Fig. 8), ranging from 24 N on harvest day to 14 N after 20 days of storage, indicating pulp softening. A similar value (6.3 N) was reported by Centurión et al. [27] and [14] 31 days after anthesis. According to Enciso et al. [28], pitaya firmness reduces considerably when total ripeness is reached. This pulp softening in pitaya, according to Centurión et al. [27], results from the actions of pectinases present in the cell wall, pectin methylesterase (PME) and polygalacturonase (PG), which degrade cell walls, causing chemical and structural changes [14].

For pitaya pulp titratable acidity, there was a significant difference as to all ripening stages (Fig. 9). At stage 3, because the fruits were completely ripe already, on storage day 0 they had a higher titratable acidity value, 0.27 mg of malic acid 100 mL^{-1} of juice, and there was an increase at stages 2 and 3 during the first 15 days of storage, followed by a decrease. This reduction in acidity values occurred simultaneously with the color change in the fruit peel; this is a consequence of the alternative routes that this fruit takes, which leads to changes in peel color and to acid production. Organic acid accumulation was found as well by Silva et al. [29] in passion fruit juice, followed by a decline until the fruits were done ripening. According to [30], during fruit ripening, organic acids represent one of the main substrates for respiratory processes and, in general, tend to decrease during this phase. Titratable acidity reduction throughout red pitaya ripening was verified by Wilberth et al. [14] 20 to 31 days after flowering, observing 1.4 g to 0.4 g of malic acid. Enciso et al. [28] also found an 80% reduction in pitaya acidity during storage.

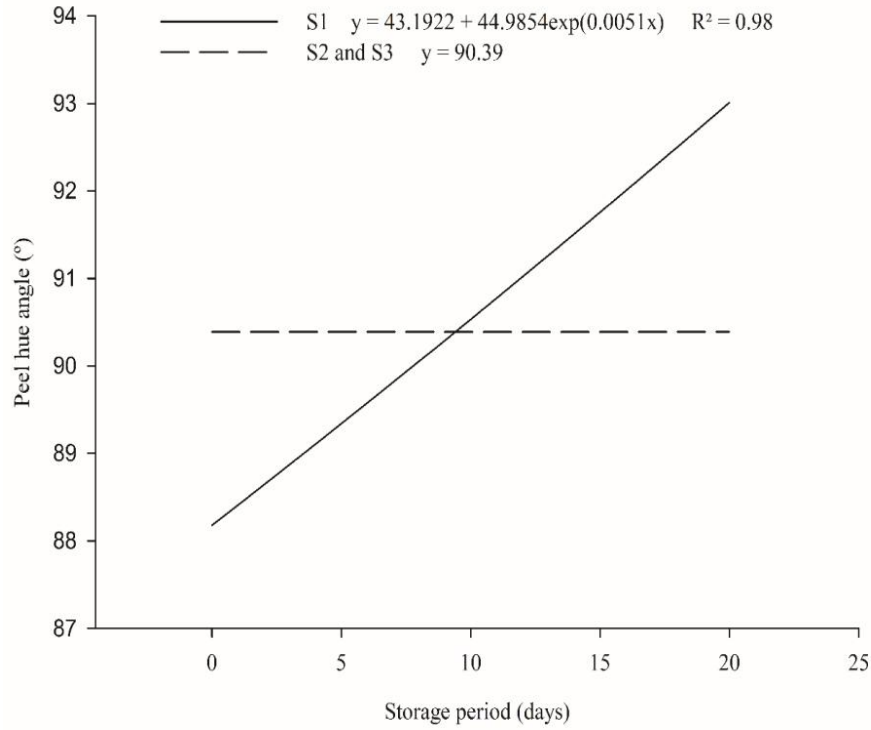


Fig. 3. Red pitaya hue angle (°) according to ripening stages and storage days at 15 °C ± 1 °C and RU of 85 ± 5.0%

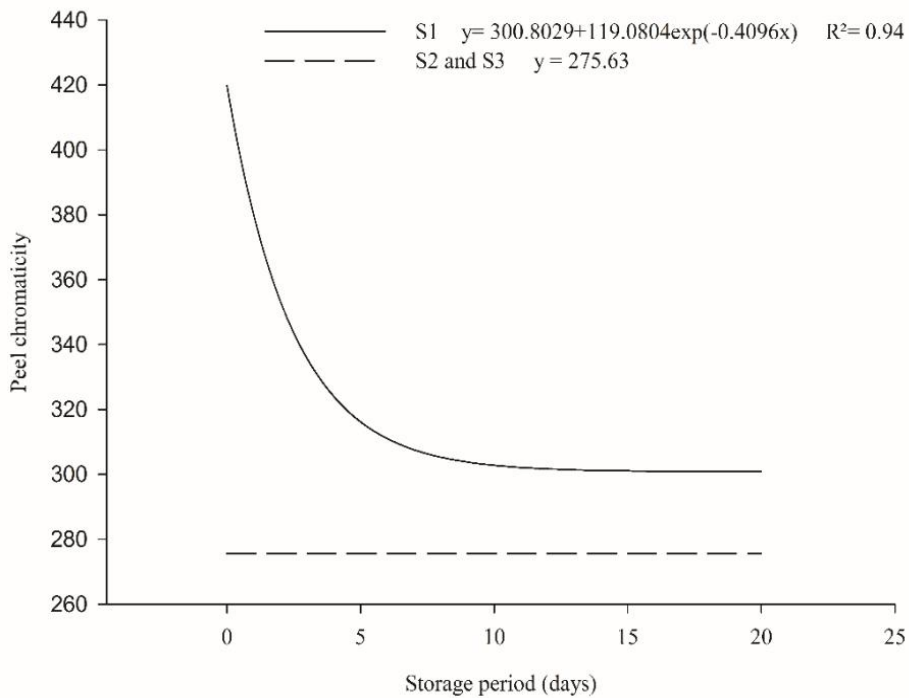


Fig. 4. Red pitaya chromaticity according to ripening stages and storage days at 15°C ± 1°C and RU of 85 ± 5.0%

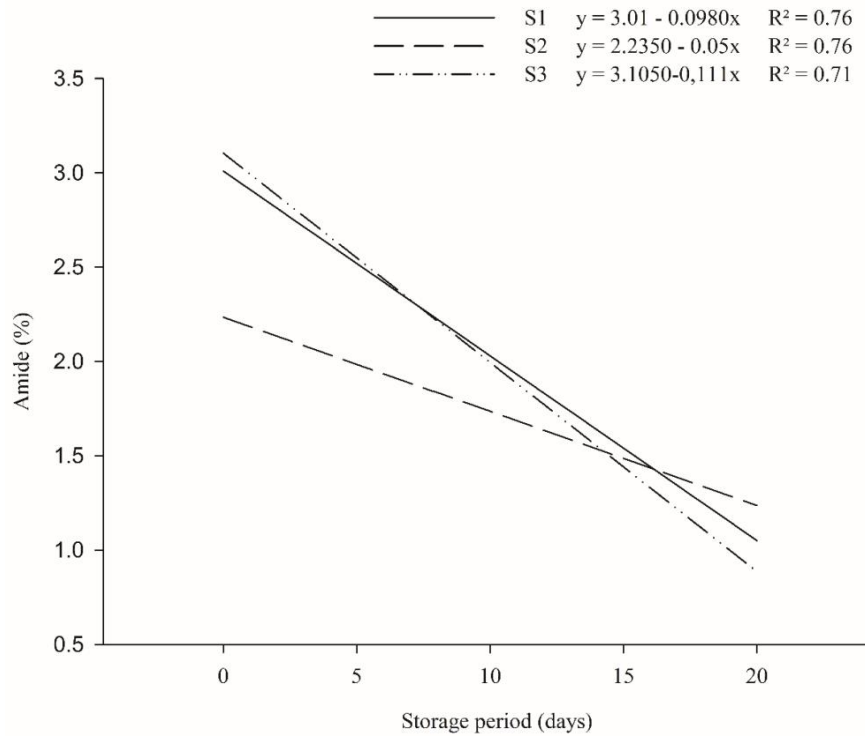


Fig. 5. Amide content (%) of red pitaya fruits according to ripening stages and storage days at 15°C ± 1°C and RH of 85 ± 5.0%

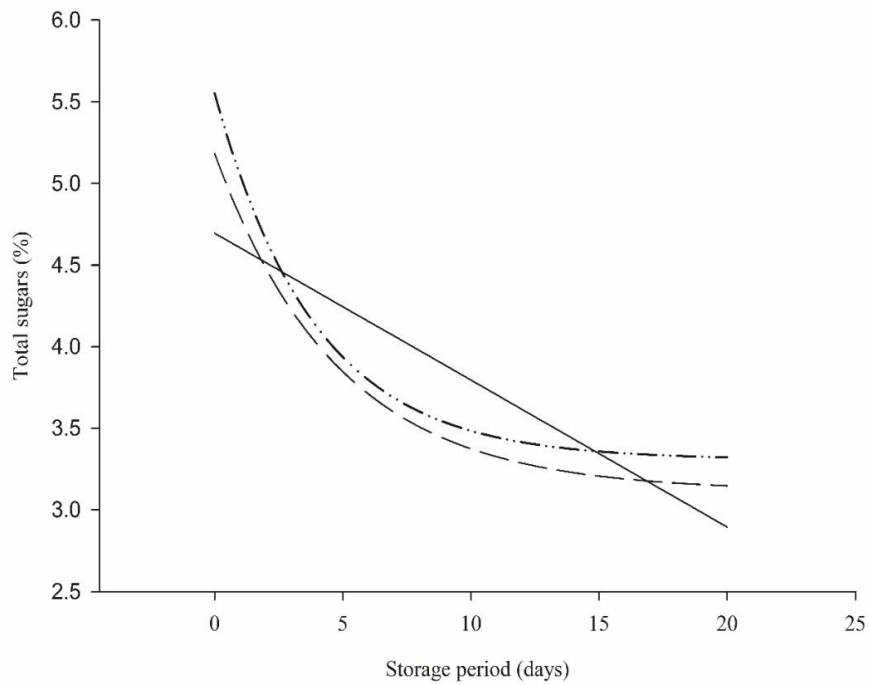


Fig. 6. Total sugars (%) of red pitaya fruits according to ripening stages and storage days at 15°C ± 1°C and RH of 85 ± 5.0%

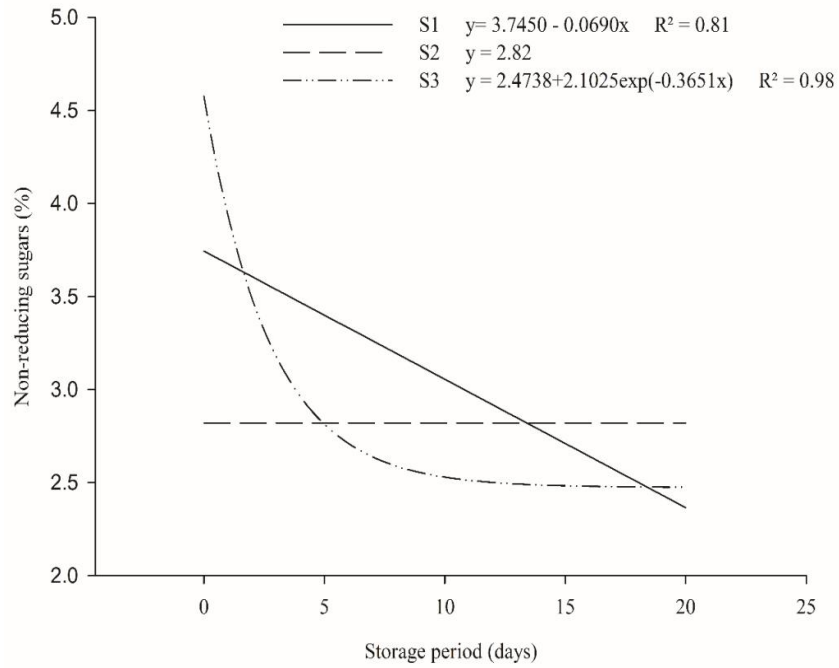


Fig. 7. Non-reducing sugars (%) of red pitaya fruits according to ripening stages and storage days at 15°C ± 1°C and RU of 85 ± 5.0%

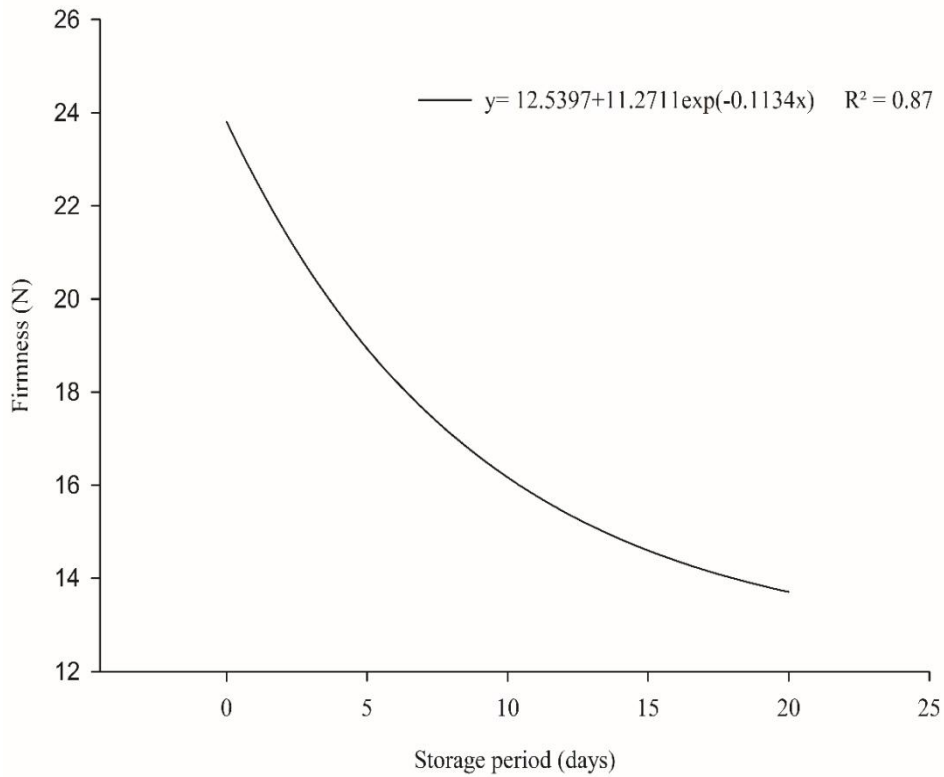


Fig. 8. Firmness (N) of red pitaya fruits according to ripening stages and storage days at 15°C ± 1°C and RU of 85 ± 5.0%

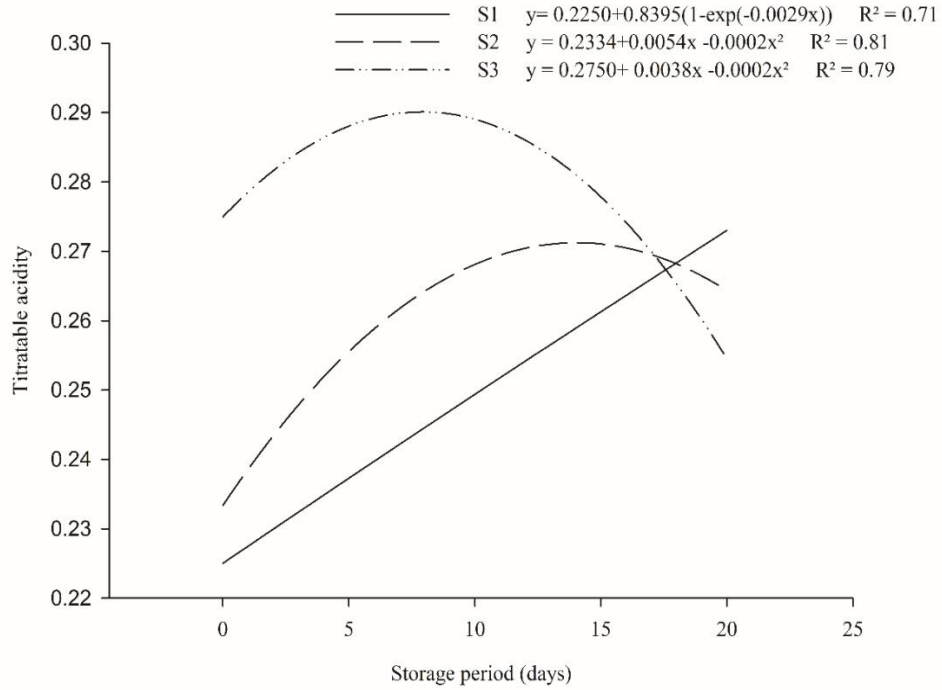


Fig. 9. Titratable acidity (mg of malic acid 100 mL⁻¹ of juice) of red pitaya according to ripening stages and storage days at 15°C ± 1°C and RU of 85 ± 5.0%

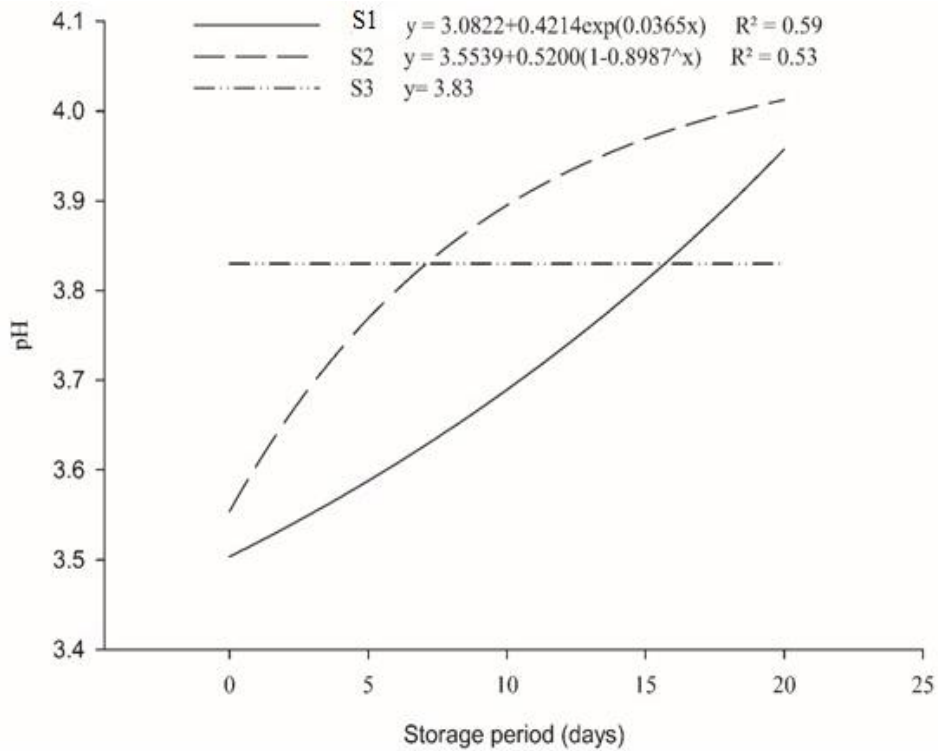


Fig. 10. Ph of red pitaya fruits according to ripening stages and storage days at 15°C ± 1°C and RU of 85 ± 5.0%

pH showed an inverse behaviour compared to acidity (Fig. 10); there was a significant effect only for ripening stages 1 and 2, with reduction as the fruits ripened. Perhaps, the concentration of 330 metabolizable organic acids at S3 is not enough to change pH. This behaviour was also observed by Silva et al. [29] in passion fruit juice. According to the authors, pH reduction may be due to the accumulation of organic acids, and pH increase to the consumption of organic acids during fruit ripening, as they are used as a substrate in respiration or converted into sugars [15]. Similar results were found by [2] with pitaya fruits; when their peels became red, values ranged from 3.47 to 4.75.

4. CONCLUSION

Considering the conditions in the north of Minas Gerais, harvest should happen at stages 2 or 3, when fruits present peels with a brighter red hue, that is, are more attractive and easier to be identified by producers. In addition, at these stages, pitayas have higher soluble solid contents and faster pulp acidity reduction during storage compared to fruits harvested at S1.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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