

Post-Harvest Preservation of Red Pitaya Harvested at Different Ripening Stages

ABSTRACT

Objective: 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 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 undatus*; 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 economical 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 centimeters 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 [5], 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

30 physiological processes [6]. Besides, reducing storage temperature is one of the most
31 efficient means to prolong the useful life of harvested products [7].

32 According to [8], employing refrigeration to minimize post-harvest losses is a
33 way to ensure a better fruit quality and reach markets farther from the production center.
34 As for post-harvest, pitaya is a tropical fruit that, under room temperature conditions,
35 deteriorates relatively fast and, consequently, its post-harvest useful life is short,
36 approximately 6-8 days [1,9]. According to [10], storage temperature and time influence
37 the physiological processes of pitaya, increasing its useful life, especially at a
38 temperature of 8 °C, which leads to better quality.

39 The literature reports the effect of ripening stages on chemical and physical
40 characteristics of many fruits [11, 12 and 13], but for pitaya cultivation, information
41 found diverges as to growing place and genetics. Thus, particular knowledge about
42 pitaya development in a specific region is relevant. For being considered a non-
43 climacteric fruit, it must be harvested only after coming to its physiological maturity so
44 that it reaches minimum quality for consumption as to color, taste and other
45 organoleptic characteristics. It is highly perishable, so if stored for seven days at room
46 temperature, its peel withers and its pulp softens, resulting in quality loss [14].

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

51 2. Material and Methods

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53 The fruits came from red pitaya plants (*Hylocereus undatus*) aged five years,
54 grown within a space measuring 4.0 x 3.0, with tutors perpendicular to the ground, in
55 1.80 m *aroeira* posts. The commercial orchard located in the rural area of Janaúba,
56 north of Minas Gerais, has an altitude of 544 m and is located at 15°49'48" south
57 latitude and 15°49'48" west longitude. In the midsection of each plant, healthy cladodes
58 were selected, where flower buds at visually homogeneous development stages were
59 marked. Harvest was done when fruits reached the following ripening stages: 1 – 31
60 days after anthesis (red epidermis color \leq 30%); 2 – 36 days after anthesis (red
61 epidermis color \leq 50%); 3 – 41 days after anthesis (red epidermis color 100%) FIGURE
62 1. The fruits were placed inside harvest-appropriate plastic boxes lined with cut paper to
63 prevent physical damages. Then, they were carried to the post-harvest physiology
64 laboratory of the State University of Montes Claros, Janaúba campus, Minas Gerais, and
65 washed with water containing 0.2% of detergent and immersed in a 2% sodium
66 hypochlorite solution for 15 minutes. After drying naturally, they were placed on
67 expanded polystyrene trays, which were distributed in the storage chamber with
68 temperature adjusted to 15 °C \pm 1 °C, and RH of 85 \pm 5.0%. The fruits were stored for
69 20 days, counting from the first storage day, with 5-day interval between assessments.
70 The experiment was conducted in a completely randomized design and a 3 x 5 factorial
71 scheme composed of three treatments (ripening stages) and five assessment intervals (1,
72 5, 10, 15 and 20), as well as four repeats of four fruits per experimental unit. The
73 characteristics assessed were:

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75 **Soluble Solids:** Soluble solids were determined by refractometry, using an ATAGO
76 brand bench refractometer, model N1, with reading within a range of 0-95 °Brix, after
77 juice extraction from the pulp of each fruit core. Results were expressed as °Brix.

78 **Titrateable Acidity:** Titrateable acidity was determined according to technique
79 recommended by the AOAC (1992), titrating, under agitation, the juice from the repeat

80 fruit set, after extracting, titrating and homogenizing 10 g of pulp from each fruit core in
81 90 mL of distilled water, with NaOH 0.1 N, using phenolphthalein 1% as indicator.
82 Results were expressed as eq. mg malic acid.100 mL of juice¹.

83 **pH:** pH was determined using 10 g of mashed pulp mashed homogenized with 90 mL of
84 distilled water. Reading was done using a DIGIMED brand digital pH meter, model
85 DM20.

86 **Peel Color:** Color was analyzed on Color Flex colorimeter, 45/0 (2200),
87 stdzMode:45/0, with reflectance direct reading of coordinates L* (luminance), a* (red
88 or green hue) and b* (yellow or blue hue), on Hunterlab Universal Software. With L*,
89 a* and b* values, hue angle ($^{\circ}h^*$) and chroma saturation index (C*) were calculated.
90 Each repeat used on average four measurements per fruit.

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

94 **Amide and Reducing Sugars:** Amide and reducing sugars were determined by
95 spectrophotometry using a Shimadzu brand spectrophotometer, model UV-1650PC,
96 with reading at 510 nm according to method described by Nelson (1944).

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

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

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

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109 **Figure 1. Developing red pitaya (days after anthesis).**

110 A: 31 days after anthesis, stage 1; B: 36 days after anthesis, stage 2; C: 41 days after
111 anthesis, stage 3.



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114 3. RESULTS AND DISCUSSION

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116 There was no significant difference for fresh mass, length and diameter (Table
 117 1). The fruits mass values observed in this study are similar to those found in the
 118 literature. According to [15], red pitaya fresh mass, 31 days after anthesis, is 469.2 g,
 119 and may range from 300 to 800 g.

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

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126 **Table 1. Means observed for red pitaya physical characteristics according to**
 127 **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

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

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131 The fruits differed as to soluble solid content according to ripening stages (Table
 132 2), but there was no significant effect for storage days. The means of stages 2 and 3
 133 were higher than those of stage 1; although pitaya is a species that stores virtually no
 134 amide, small increases in soluble solid (SS) content have been observed during
 135 ripening. According to [4], sugar content usually increases as fruits ripen, through
 136 biosynthetic processes or polysaccharide degradation. Increased soluble solid content
 137 may be due to the cell wall polysaccharides converting into soluble sugars. Stages 2 and
 138 3 showed higher means compared to those of stage 1; for being a non-climacteric fruit,
 139 pitaya must be harvested close to its ripening point.

140 According to [16], non-climacteric fruits harvested unripe present sensorial
 141 quality, in addition to being susceptible to dehydration and physiological disorders.
 142 Determining the optimal harvest point is an extremely important work, as it allows for
 143 ensuring good preservation, adequate resistance to transportation, and maintenance of
 144 necessary conditions for the fruit to reach consumers with quality [17]. Soluble solids
 145 showed values within acceptable ranges. According to [4], fruits in general, when ripe,
 146 present mean soluble solid values between 8% and 14%. The literature reports similar
 147 values for pitaya – 12.51°, 11.87°, 12.23 °Brix [18].

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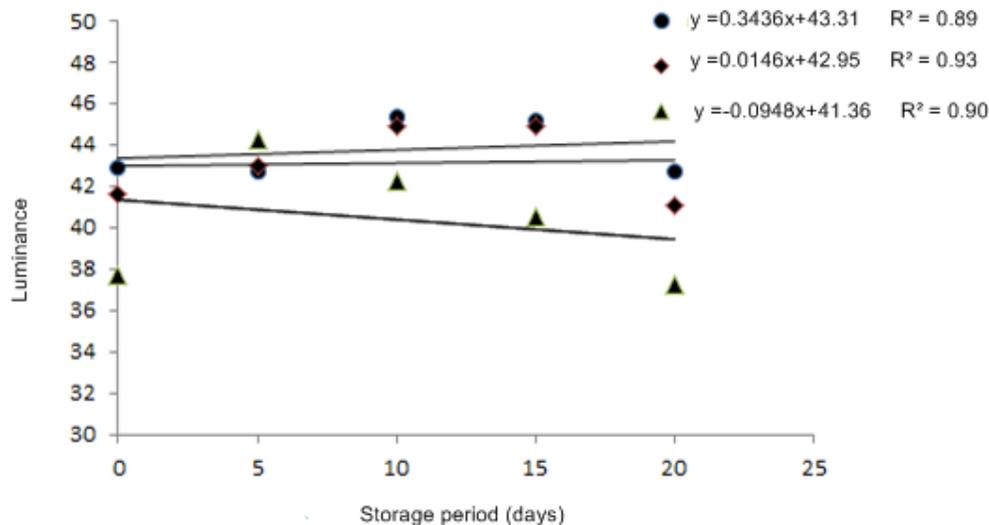
150 **Table 2. Mean soluble solid (SS) values in red pitaya according to ripening stages, at 15**
 151 **°C ± 1 °C and RU of 85 ± 5.0% (means corresponding to the whole storage period).**

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

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

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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 (Figure 1) 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 [4].



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Figure 1 – Red pitaya luminance according to ripening stages and storage days at $15\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ and RU of $85 \pm 5.0\%$.

Figure 2 shows hue angle values found in red pitaya peels at different ripening stages and after storage days at $15\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ and RU of $85 \pm 5.0\%$. For ripening stage 1, there was significant effect, with the peel still presenting a green color in 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 in 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, [15] 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 $25\text{-}30\text{ }^{\circ}\text{C}$, with scheduled irrigation and fertilization.

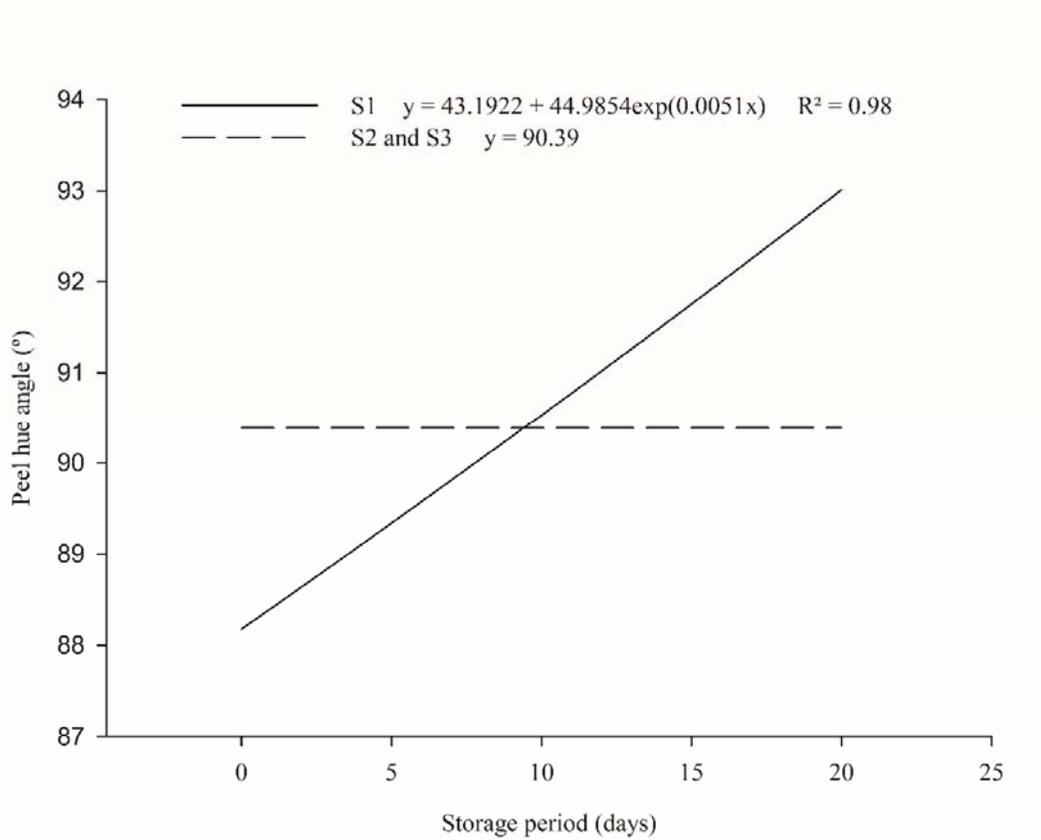
187 However, there was no significant effect for ripening stages 2 and 3, with hue
188 angle values standing at 90.39° throughout the storage period, since the peel color was
189 totally red; the small change to a brighter purple hue had no statistical influence.
190 Harvest is more appropriate at these stages because the peels have no changes in color,
191 present higher soluble solid contents and can be easily identified by producers. This
192 color change derives from the presence of pigments in pitayas, including betalains,
193 which are water-soluble N-heterocyclic compounds located mainly in the vacuoles of
194 plants. Betalains are split into two distinct groups – betacyanins and betaxanthines [21,
195 22]. Betacyanins are usually purple-red, while betaxanthines are orangish yellow, and
196 compose different colors in flowers and fruits. As for their functional properties,
197 betalains are known as a strong natural antioxidant [23, 24, 25].

198 Chromaticity values are displayed in Figure 3, where it is possible to see
199 significant effects only for ripening stage 1. As observed, there was an exponential
200 decrease for stage 1 fruits as to storage period, with values being higher on day 0 and
201 constant until 20 days of storage.

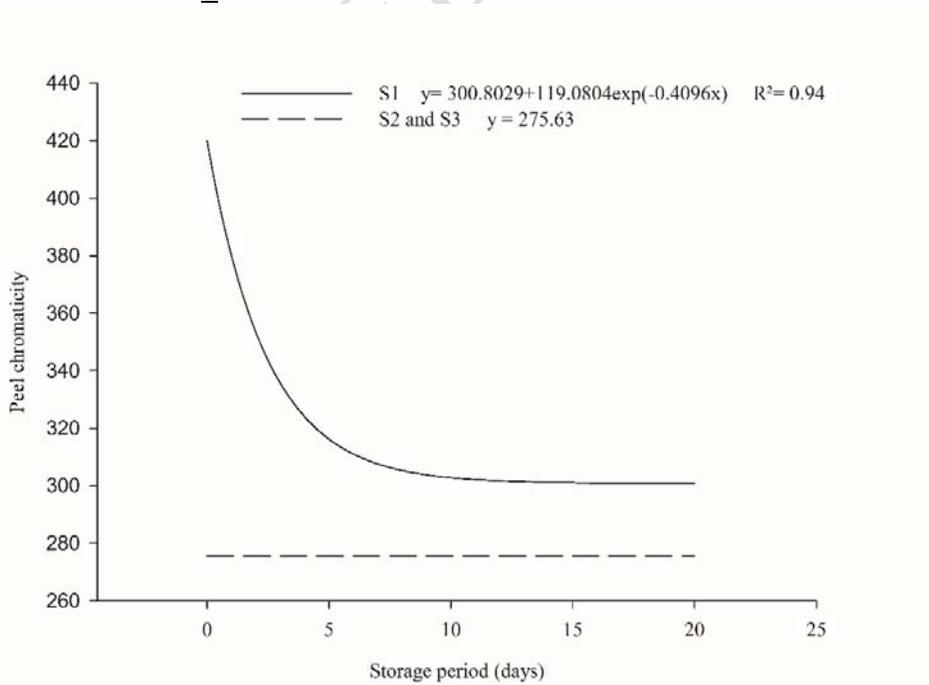
202 The optimal harvest stage for pitaya can be indicated by coordinate a^* , which
203 occurs when the peel is totally red; the present study found that, at stages 2 and 3, there
204 are higher soluble solid contents, while peel hue showed no changes, with this being
205 indicative of better harvest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

206 Figure 2 displays hue angle values found in red pitaya peels at different ripening
207 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
208 no significant effect for ripening stages 2 and 3; hue angle values stood at 90.39°
209 throughout the storage period because the peel color was totally red. For ripening stage
210 1, when the peel was still green in the beginning of storage, hue angle values rose
211 exponentially from 88° on day 0 to 93° after 20 days of storage; this change indicates a
212 peel hue evolution from green to red and to bright purple in the end of the storage
213 period. Chromaticity values are presented in Figure 3, which shows significant effects
214 only for ripening stage 1. As observed, there was a linear decrease in relation to the
215 storage period, with values being higher on day 0 and remaining constant until the last
216 storage assessment.

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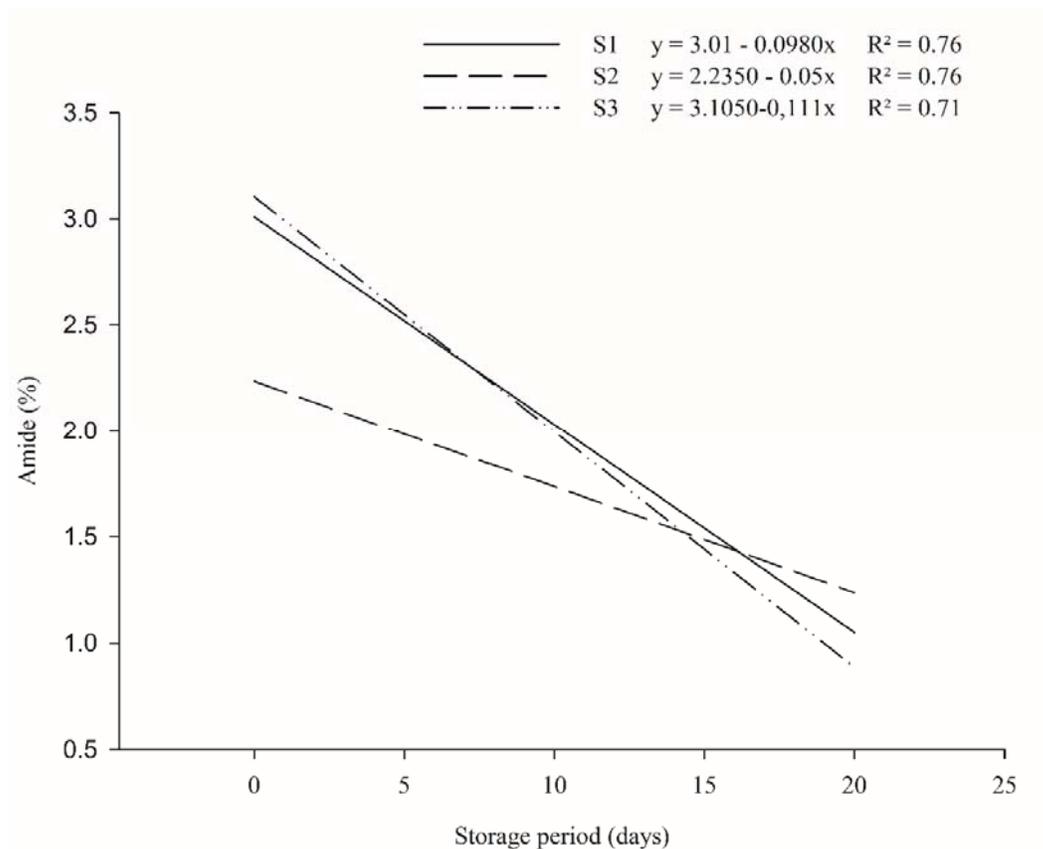


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 219 **Figure 2** – Red pitaya hue angle (°) according to ripening stages and storage days at 15
 220 °C ± 1 °C and RU of 85 ± 5.0%.



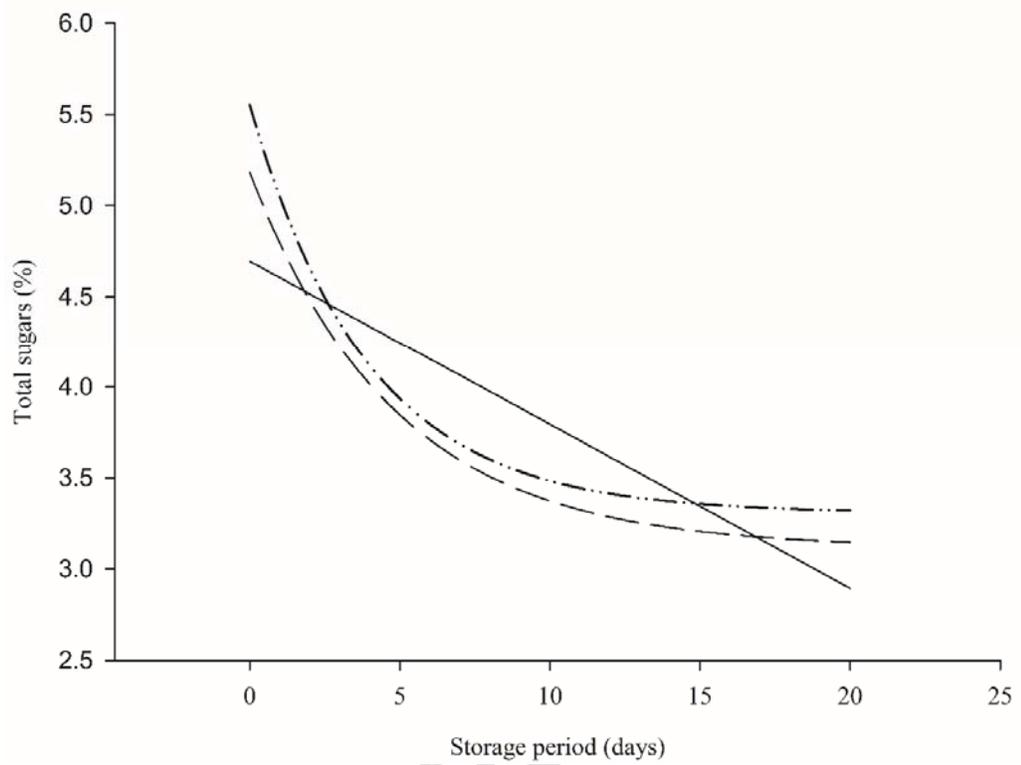
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 222 **Figure 3** – Red pitaya chromaticity according to ripening stages and storage days at 15
 223 °C ± 1 °C and RU of 85 ± 5.0%.
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225 Amid content reduced during storage at all ripening stages (Figure 4); however,
 226 stage 2 presented lower amide percentage on day 0. Amide degradation is one of the
 227 most remarkable characteristics in fruit ripening; as amide is hydrolyzed, there is an
 228 increase in total soluble sugar levels. Figure 5 shows that, for all ripening stages, there
 229 was decrease in total sugar contents, from 5% to 3% on average, during storage.
 230 Nevertheless, stage 1 fruits presented higher total sugar levels after zero and 20 days of
 231 storage.
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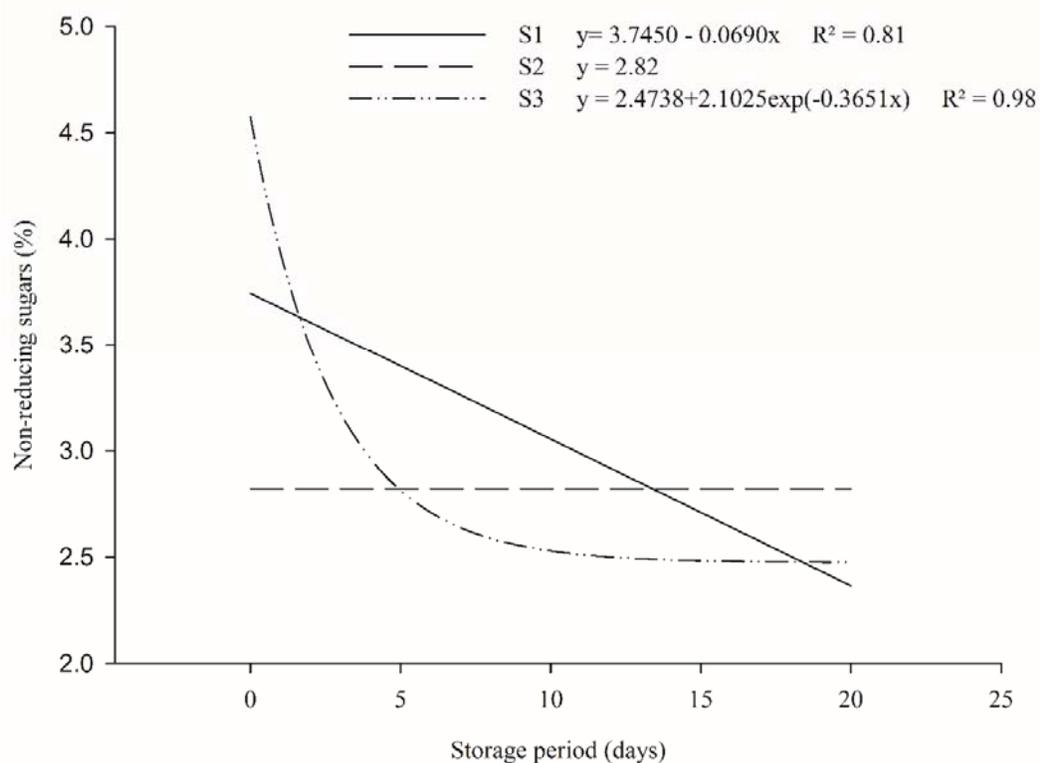
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 235 **Figure 4** – Amide content (%) of red pitaya fruits according to ripening stages and
 236 storage days at $15\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ and RU of $85 \pm 5.0\%$.
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238 Figure 5 shows that, for all ripening stages, there was a decrease in total sugar
 239 levels, from 5% to 3% on average, during storage. However, stage 2 fruits presented
 240 lower total sugar content after zero and 20 days of storage. According to [26], ripening
 241 reduces amide content at the same it increases levels of total sugars, non-reducing
 242 sugars and soluble solids, with an increasing conversion of amide into simple sugar.
 243 This, however, was not observed for the ripening stages of pitaya as it is a non-
 244 climacteric fruit. For reducing sugars, there was no significant effect. As for non-
 245 reducing ones (Figure 6), there was significant effect only for ripening stages 1 and 3;
 246 on storage day 0, there was a higher percentage of non-reducing sugars, with values at
 247 3.9% and 4.5%, respectively.



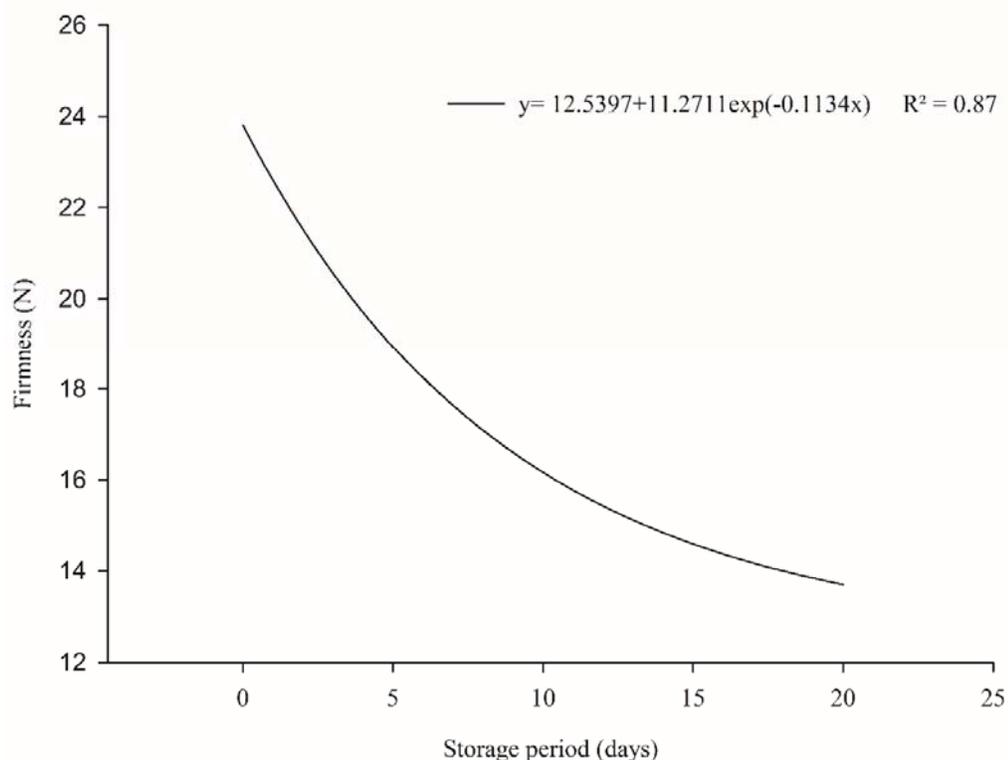
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 249 **Figure 5** – Total sugars (%) of red pitaya fruits according to ripening stages and storage
 250 days at 15 °C ± 1 °C and RH of 85 ± 5.0%.
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UNDER PEER REVIEW



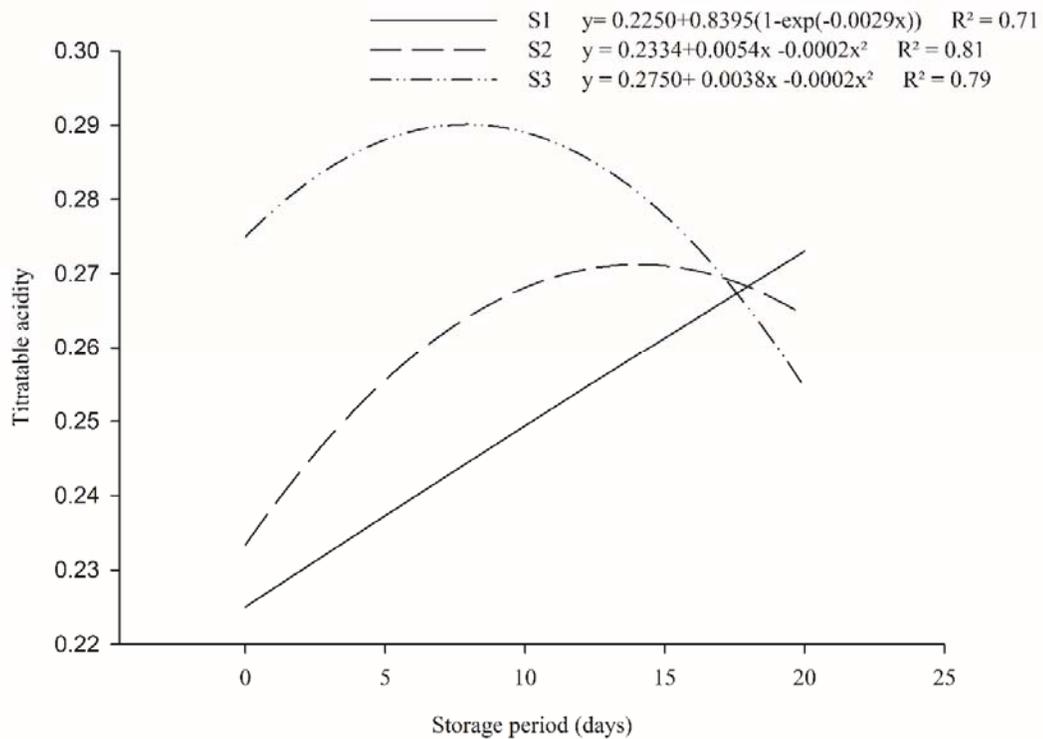
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 253 **Figure 6** – Non-reducing sugars (%) of red pitaya fruits according to ripening stages
 254 and storage days at $15\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ and RU of $85 \pm 5.0\%$.
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256 Concerning firmness, there was no significant effect between ripening stages,
 257 but values decreased throughout the storage period (Figure 7), ranging from 24 N on
 258 harvest day to 14 N after 20 days of storage, indicating pulp softening. A similar value
 259 (6.3 N) was reported by [27] and [15] 31 days after anthesis. According to [28], pitaya
 260 firmness reduces considerably when total ripeness is reached. This pulp softening in
 261 pitaya, according to [27], results from the actions of pectinases present in the cell wall,
 262 pectin methylesterase (PME) and polygalacturonase (PG), which degrade cell walls,
 263 causing chemical and structural changes [15].
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 266 **Figure 7** - Firmness (N) of red pitaya fruits according to ripening stages and storage
 267 days at $15\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$ and RU of $85 \pm 5.0\%$.
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269 For pitaya pulp titratable acidity, there was significant difference as to all
 270 ripening stages (Figure 8). At stage 3, because the fruits were completely ripe
 271 already, on storage day 0 they had a higher titratable acidity value, 0.27 mg of malic
 272 acid 100 mL^{-1} of juice, and there was an increase at stages 2 and 3 during the first 15
 273 days of storage, followed by a decrease. This reduction in acidity values occurred
 274 simultaneously with the color change in the fruit peel; this is a consequence of the
 275 alternative routes that this fruit takes, which leads to changes in peel color and to
 276 acid production. Organic acid accumulation was found as well by [29] in passion
 277 fruit juice, followed by a decline until the fruits were done ripening. According to
 278 Tucker (1993), during fruit ripening, organic acids represent one of the main
 279 substrates for respiratory processes and, in general, tend to decrease during this
 280 phase. Titratable acidity reduction throughout red pitaya ripening was verified by
 281 [15] 20 to 31 days after flowering, observing 1.4 g to 0.4 g of malic acid. [28] also
 282 found an 80% reduction in pitaya acidity during storage.
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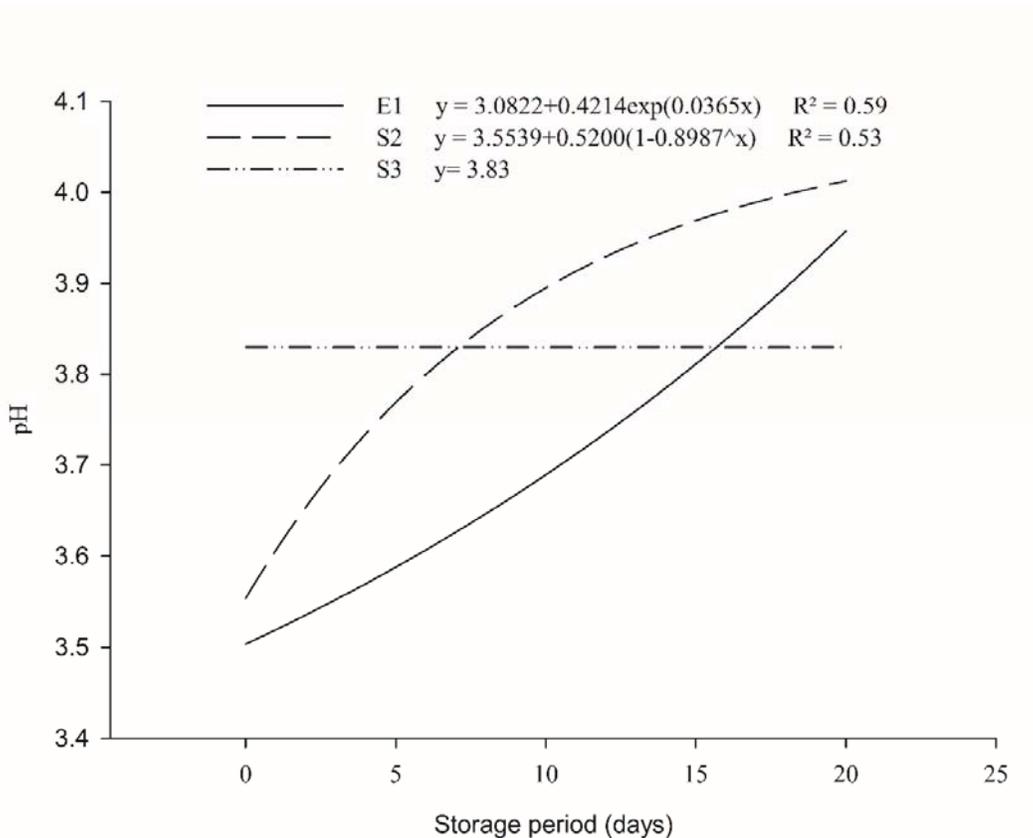
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285 **Figure 8** – Titratable acidity (mg of malic acid 100 mL⁻¹ of juice) of red pitaya
 286 according to ripening stages and storage days at 15 °C ± 1 °C and RU of 85 ± 5.0%.

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288 pH showed an inverse behavior compared to acidity (Figure 9); there was
 289 significant effect only for ripening stages 1 and 2, with reduction as the fruits
 290 ripened. Perhaps, the concentration of 330 metabolizable organic acids at S3 is not
 291 enough to change pH. This behavior was also observed by [29] in passion fruit juice.
 292 According to the authors, pH reduction may be due to accumulation of organic acids,
 293 and pH increase to consumption of organic acids during fruit ripening, as they are
 294 used as substrate in respiration or converted into sugars [4]. Similar results were
 295 found by [2] with pitaya fruits; when their peels became red, values ranged from 3.47
 296 to 4.75.

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299 **Figure 9** – pH of red pitaya fruits according to ripening stages and storage days at 15 °C
 300 ± 1 °C and RU of $85 \pm 5.0\%$.

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302 4. CONCLUSIONS

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

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