Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 11 August 2022
https://doi.org/10.14295/CS.v13.3857

UV-C radiation in postharvest quality of red dragon fruit

Raquel Cintra de Faria[1]*, Cristiane Maria Ascari Morgado[2], Igor Leonardo Vespucci[1], André José de Campos[2]

[1]Federal University of Goiás, Goiânia, Brazil
[2]State University of Goiás, Anápolis, Brazil
*Corresponding author, e-mail: cfsraquel@hotmail.com

Abstract

Dragon fruit cultivation in Brazil has been growing and the increase in consumption is associated with the nutritional benefits and attractiveness of the fruit. However, information on the fruit postharvest behavior relative to its conservation potential and technologies is incipient. In this context, this study aimed to evaluate the postharvest quality of red dragon fruit submitted to different doses of UV-C radiation. The fruits were obtained from a commercial orchard in the rural area of Piracanjuba-GO, Brazil. The experiment was conducted in a completely randomized design in a 4x9 factorial scheme, with four radiation doses (0, 1.81, 3.62, and 7.24 kJ m^{-2}) and nine days of analysis (0, 2, 4, 6, 8, 10, 12, 14, and 16 days). After radiation, one fruit was packed per low-density polyethylene (LDPE) package, which was refrigerated and stored in a BOD at 8±1 °C and 60±4% RH. Weight loss, postharvest conservation, soluble solids content, pH, titratable acidity, maturation index, color (°hue and chroma), betacyanins, and carotenoids were evaluated. The data were subjected to analysis of variance (P<0.05) and, when significant, to regression analysis. The dose of 1.81 kJ m^{-2} stood out for maintaining the red dragon fruit quality. The red dragon fruit, whether or not treated with UV-C radiation, packed in LDPE, can be maintained refrigerated for up to 21 days without deteriorating.

Keywords: conservation, *Hylocereus costaricensis*, physical treatment, radiation doses

Introduction

Dragon fruit is a rustic plant that belongs to the family Cactaceae and produces exotic fruits, known worldwide. There are several species of dragon fruit, with three groups of commercial value: *Hylocereus undatus*, with a red peel and white pulp; *Hylocereus costaricensis*, with red peel and pulp; and *Selenicereus megalanthus*, with a yellow peel with thorns and white pulp (Cordeiro et al., 2015; Menezes et al., 2015). However, fruits with red pulp have conquered the preference of consumers due to their sweet taste and more vivid color (Bonewati et al., 2017).

In Brazil, it is considered a promising novelty, occupying a growing niche in the exotic fruit market, and producers are interested in its cultivation, which can reach high commercial values, varying according to the time of year, region, species, and demand (Bastos et al., 2006; Lima et al., 2013; Le Bellec et al., 2006).

The dragon fruit deteriorates easily when stored under ambient conditions, with a short shelf life since it has a high water content, which favors the short postharvest period of approximately 6 to 10 days, causing acidity losses and changes in appearance and texture (Obenland et al., 2016; Hoa et al., 2006). Several techniques have been researched to maintain the quality and increase the shelf life of fruits and vegetables. These techniques, alone or in combination, are used to reduce the metabolic activity of fruits, mainly the respiratory rate and water loss (Carvalho et al., 2015).

Refrigeration is the main tool to maintain fruit quality, but it is often insufficient, making it necessary to jointly adopt another technique. Thus, the use of ultraviolet-C (UV-C) radiation has become notorious, as it is an innovative non-ionizing technique, with a wavelength between 210 and 280 ηm, and a physical method, which has been adopted in the food industry

Received: 08 November 2021
Accepted: 28 March 2022

for air disinfection, microbial decontamination of surfaces and packaging, and postharvest of fruits and vegetables (Nunes, 2015).

According to Stevens et al. (2005), UV-C radiation has a germicidal effect if used with intensity and for sufficient exposure time, as a wavelength of 254 ηm can promote resistance to pathogens in the plant tissue. This technique can induce a phenomenon known as hormesis, in which low doses of a potentially harmful agent cause a beneficial response in the treated material. The benefits of using the UV-C technique have been demonstrated for numerous types of fresh products (Campos et al., 2015; Scott et al., 2017).

Thus, the search for efficient techniques in maintaining postharvest quality and extending the shelf life of dragon fruits becomes viable due to perishability, nutritional capacity, and high market cost. In this context, this study aimed to evaluate the postharvest quality of red dragon fruits submitted to UV-C radiation doses.

Methodology

Red dragon fruits (H. *costaricensis*) were collected in a commercial orchard in the rural area of Piracanjuba, Goiás, Brazil, in Rancho do Dragão, located at 17°18'10" S and 49°01'00" W, at an average altitude of 742 m and tropical climate with a dry season.

The fruits were harvested manually when they reached the stage of physiological maturation used for commercial consumption, that is, when the peel was pink to intense red, at 32 days after pollination.

After harvesting, the fruits were transported in corrugated cardboard boxes filled with a single layer and wrapped in an expanded polyethylene (EPE) screen to the Laboratory of Drying and Storage of Vegetable Products at the Central Campus – Henrique Santillo of the State University of Goiás, located in the city of Anápolis, Goiás, Brazil, where the experiment was conducted. The fruits were selected by visual observation for size, color, and absence of physical and mechanical defects and diseases and submitted to treatments.

The experiment was completely randomized in a 4×9 factorial scheme, consisting of four radiation doses, determined by four exposure times to an irradiating source (0 kJ m^{-2} – 0 minutes, 1.81 kJ m^{-2} – 2 minutes; 3.62 kJ m^{-2} – 4 minutes; and 7.24 kJ m^{-2} – 8 minutes) and 9 days of analysis (0, 2, 4, 6, 8, 10, 12, 14, and 16 days), with four replications.

The prototype irradiator has a cylindrical plastic polymer chamber and is composed of two germicidal lamps without a filter, one at the top and another at the bottom of the irradiator, with 30 watts each and connected in parallel, with a 0.5×0.5×0.9 m geometry structure and galvanized drawn mesh, dividing the equipment into upper and lower parts.

The radiation intensity received by the fruits was measured in W m^{-2} with an HD2302.0v photo-radiometer, but the unit was expressed in kJ m-2 and the exposure times to the UV-C source. After radiation, one fruit was packed per low-density polyethylene (LDPE) package for post-harvest storage evaluation, followed by refrigeration and storage in a BOD at 8±1 °C and 60±4% RH.

Laboratory analyses were performed every 2 days, as follows:

a) Mass loss, determined by the difference, in percentage, between the initial mass and the final mass at the end of each day of analysis, using a BL 3200H precision balance with maximum and minimum loads of 3200 and 0.5 g, respectively, and precision of 0.001 g.

b) Postharvest conservation, assessment of the maximum number of days the red dragon fruits were conserved in terms of their commercial quality. This analysis was conducted by 15 untrained evaluators, who evaluated the visual quality of the fruits and informed whether or not they would buy them.

c) Pulp-to-peel ratio, estimated by the ratio between pulp and peel masses, both obtained on a precision digital electronic scale.

d) pH, determined using a Gehaka PG 1400 portable potentiometer, following the Analytical Standards of the Adolf Lutz Institute (2012).

e) Titratable acidity, performed by potentiometric titration using NaOH at 0.1 mol L^{-1} up to a pH between 8.1 and 8.2 (AOAC, 2016), with a result expressed in g malic acid per 100 g^{-1} pulp, as recommended by AOAC (2016).

f) Soluble solids, determined by refractometric reading in °Brix at 20 °C using a Quimis Abbe digital benchtop refractometer, on which 3 drops of the sample from each replication were deposited with a pipette on the prism body of the equipment, according to the methodology from AOAC (2016);

g) Maturation index (Ratio), determined by the relationship between the soluble solids content and the titratable acidity.

h) Coloring, determined by reflectance, with readings taken at two random points on the fruit peel of each replication using a Konica Minolta CR-400 portable colorimeter. The values of a*, related to the intensity of green (−a*) to red (+a*), b*, related to the intensity of blue (−b*) and yellow (+b*), °Hue, determined by Equation (1), and Chroma, determined by the Equation (2):

$$°Hue = \arctan (b^*/a^*) \qquad (1)$$

Chroma = √(a*2 + b*2) (2)

i) Betacyanins, quantified separately for the peel and pulp, according to the methodology adapted from Nilsson (1970), in which 50 mg of previously frozen pulp sample was macerated in 3000 μL of distilled water and 50 mg of dried and crushed peel was macerated in 3000 μL of 60% (v/v) methanol, used as extracting solvent. The obtained solution was placed in an Eppendorf and centrifuged using an HD MCD-2000 centrifuge at 13400 rpm for 20 minutes. The supernatant was placed in test tubes wrapped in aluminum foil and absorbance readings were taken in a spectrophotometer at 476, 538, and 600 ηm. The calculations were performed using Equations (3), (4), and (5).

$$X = 1.095\ (a - c) \quad (3)$$

$$Y = (b - Z - X)/3.1 \quad (4)$$

$$Z = a - X \quad (5)$$

where X is the betacyanin absorption, Y is the betaxanthin absorption, Z is the impurity absorption, a is the sample reading at 538 ηm, b is the sample reading at 476 ηm, and c is the sample reading at 600 ηm.

j) Total carotenoids, performed using the methodology of Lichtenthaler (1987) and Arnon (1949), with adaptations, using a fraction of approximately 50 mg of crushed red dragon fruit peel sample per replication, being macerated and stored with 1.5 mL of acetone in a refrigerator at a temperature of 2 °C for 1 hour to extract the pigments. After this period, the Eppendorf flasks were centrifuged in an HD MCD-2000 centrifuge for 15 minutes at 13400 rpm and the supernatant was read in an Instrutherm UV-2000A spectrophotometer at wavelengths of 470, 648, and 664 ηm, using Equations (6), (7), (8) and (9):

$$C_a=(13.36.A_{664}-5.19.A_{648}).8.1/D_w \quad (6)$$

$$C_b=(27.43.A_{664}-8.12.A_{648}).8.1/D_w \quad (7)$$

$$C_T=C_a+C_b \quad (8)$$

$$C_{x+c}=(4.785.A_{470}+3.657.A_{664}-12.76.A_{648}).8.1/D_w \quad (9)$$

wherein C_a is the chlorophyll a, C_b is the chlorophyll b, C_T is the total chlorophyll, C_{x+c} is the carotenoids, A_{648} is the absorbance at 648 ηm, A_{664} is the absorbance at 664 ηm, A_{470} is the absorbance at 470 ηm, and D_W is the extracted plant tissue dry mass.

The data were subjected to analysis of variance (P<0.05) and, when significant, to regression analysis. The SISVAR 5.7 software was used for the statistical analysis.

Results and Discussion

According to mass loss and postharvest conservation, a gradual increase was observed for all treatments throughout the storage period (Figure 1). Accumulated losses reached up to 0.395% (7.24 kJ m^{-2}) in radiated red dragon fruits (*H. costaricensis*). However, the maximum final difference in the mass loss was 0.064% between treatments, evidencing that UV-C radiation did not negatively affect this parameter. Noboa et al. (2016) evaluated the effect of gamma radiation on yellow dragon fruit (*Selenicereus megalanthus*) and observed losses of 8.59 to 10.20% at 14 days of storage. Fernandes et al. (2010) found losses of up to 12.12% in dragon fruit *H. undatus* treated with gamma radiation and stored for 10 days. Thus, both authors found losses higher than those observed in this study.

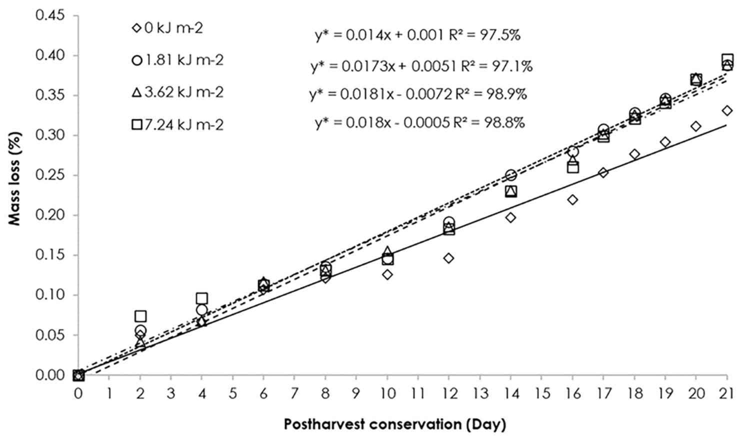

Figure 1. Fresh mass loss (%) and postharvest conservation (days) of red dragon fruits (*H. costaricensis*) stored at 8±1 °C and subjected to different ultraviolet-C radiation doses for 21 days. UEG/CCET, Anápolis, 2021. *Significant at a 5% probability. [ns]Not significant.

Mass loss influences fruit appearance, which can cause consumer rejection due to the wilting condition (Schiavon et al., 2021), a fact that was not observed in this study, which presented very low losses (below 0.5%), demonstrating that all treatments were efficient in conserving this parameter.

Red dragon fruits submitted to different UV-C radiation doses were evaluated after the 16th day regarding postharvest conservation at 1-day intervals and fruits from all treatments remained stable and with conditions of commercialization and consumption for up to 21 days based on their external visual appearance. The fruits showed a dark coloring of the peel from the 22nd day of storage, with the appearance of apparent signs of deterioration, such as fermentation of the peel's tissues, although the pulp was internally intact. Istianingsih & Efendi (2013) preserved dragon fruits (*Hylocereus costaricensis*) for 14 days stored at 15 °C and found a shorter shelf life than that verified in this study. However, Purwanto (2011) kept dragon fruits (*H. costaricensis*) stored for up to 25 days refrigerated at 10 °C, using the passive modified atmosphere technique for a longer time than that observed here.

Regarding pH (Figure 2), a significant interaction was observed for the factor days of storage and all treatments showed a linear trend, with a progressive increase over the days of analysis, with higher values for the dose of 3.62 kJ m^{-2}. The 0 kJ m^{-2} treatment presented the lowest pH increase, but it presented the lowest coefficient of determination (R^2) (48.55%) due to variation over the evaluated period. The pH behavior reported for red dragon fruits agrees with those observed by Campos et al. (2015) in 'Pitenza' tomato fruits and data from Bal & Kok (2009) in an evaluation of refrigerated kiwifruits treated with UV-C. A significant increase in pH throughout the evaluation days was observed in both studies.

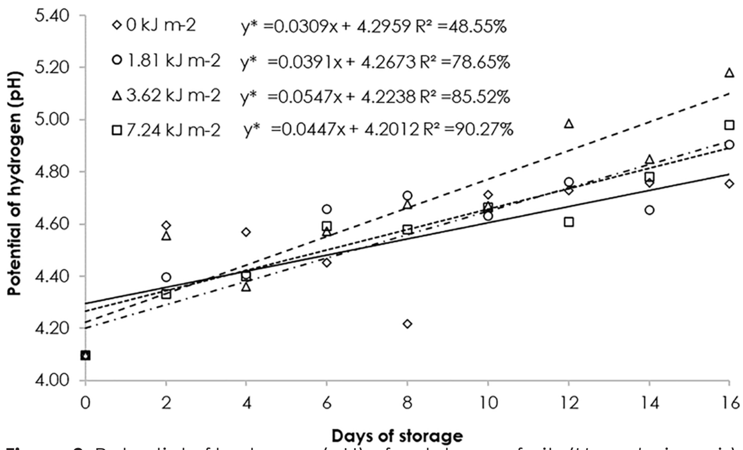

Figure 2. Potential of hydrogen (pH) of red dragon fruits (*H. costaricensis*) stored at 8±1 °C and subjected to different ultraviolet-C radiation doses for 16 days. UEG/CCET, Anápolis, 2021. *Significant at a 5% probability. [ns]Not significant.

Mean values ranged from 4.10 on the first day of analysis to 5.18 on the 16th day. Fernandes et al. (2010) observed similar values in dragon fruits (*H. undatus*) submitted to different gamma irradiation doses, in which no change was observed in this variable over 20 days of storage, unlike what was observed in this experiment.

All treatments decreased titratable acidity levels linearly during storage (Figure 3). Thus, the behavior is consistent with the increase in pH since the consumption of organic acids in oxidative reactions during maturation results in a reduction in acidity (Neves et al., 2008). The lowest decrease was observed in the 0 kJ m^{-2} treatment, followed by the 1.81 kJ m^{-2} dose, but the 0 kJ m^{-2} dose showed a low coefficient of determination (R^2) in the evaluation period. Therefore, no significant difference was observed at the end of the experiment between the different evaluated doses, suggesting that this variable was not influenced by UV-C radiation.

The mean titratable acidity data agree with those verified by Noboa et al. (2016) and Fernandes et al. (2010) for yellow and *H. undatus* dragon fruits, respectively, treated with gamma radiation, with no statistical differences between doses throughout the evaluation period.

The observed mean values of titratable acidity reduced from 0.37 g malic acid 100 g^{-1} on day 0 to 0.09 g malic acid 100 g^{-1} on the 16th day of evaluation. The initial acidity values are attributed to the fruit maturation stage, as greener fruits have a higher acidity (Duarte et al., 2017), whose organic acid content tends to decrease during the storage process of refrigerated products due to their use in the course of reactions, such as respiration (Rinaldi et al., 2015).

The maturation index of red dragon fruits submitted to different UV-C radiation doses (Figure 4) showed a significant interaction over the days of storage since all treatments increased linearly, being more expressive from the 10th day of storage, with a significant difference between doses only on the last analysis, in which the doses of 3.62 and 7.24 kJ m^{-2} were higher than the others. According to Pinto et al. (2003), the increased index usually indicates a good flavor, and this relationship can also be used as an indicator of ripeness.

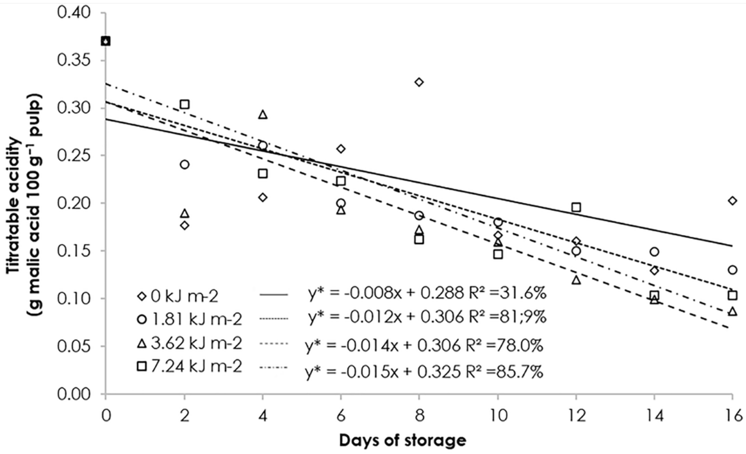

Figure 3. Titratable acidity (g malic acid 100 g^{-1} pulp) of red dragon fruits (*H. costaricensis*) stored at 8±1 °C and subjected to different ultraviolet-C radiation doses for 16 days. UEG/CCET, Anápolis, 2021. *Significant at a 5% probability. ^{ns}Not significant.

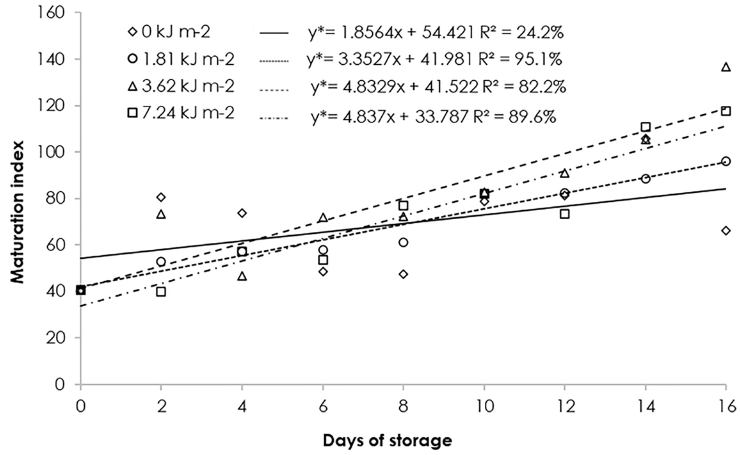

Figure 4. Maturation index of red dragon fruits (*H. costaricensis*) stored at 8±1 °C and subjected to different ultraviolet-C radiation doses for 16 days. UEG/CCET, Anápolis, 2021. *Significant at a 5% probability. ^{ns}Not significant.

Duarte et al. (2017) also observed a trend towards an increase in the maturation index in investigations on the effect of organic fertilization associated with refrigeration on the quality of dragon fruits (*H. undatus*). On the contrary, Fernandes et al. (2010) found that gamma radiation doses did not significantly affect this index in dragon fruits (*H. undatus*) after 20 days of cold storage.

Furthermore, the 1.81 kJ m^{-2} treatment showed an increase, but at a lower proportion than the other evaluated doses, indicating a lower ripening rate in these fruits. According to Menezes et al. (2015), the sharp increase in the maturation index may be an indication of fruit senescence, a fact not observed in this study, in which the red dragon fruit showed signs of deterioration only after the 22nd day of storage.

The mean values of the maturation index ranged from 40.74 on day 0 to 104.20 on the 16th day of storage, with an overall mean of 72.68. Chang et al. (2016) observed a similar mean of 73.6 for dragon fruits (*H. polyrhizus*). Likewise, Fernandes et al. (2010) obtained an overall mean of 79.42 in studies with organic dragon fruits (*H. undatus*) treated with gamma radiation. This variation is due to a decrease in acidity (Figure 4) from 0.37 to 0.09 g malic acid 100 g^{-1} during storage. Similarly, Chávez (2011) and Yah et al. (2008) reported that an increase in the maturation index was the result of a decrease in the acidity of dragon fruits.

The mean data of °Hue (Figure 5) showed a low variation. °Hue values close to 0° and 360° represent the red color and the color becomes more orange as the values approach 90°. Thus, the evaluated dragon fruits showed a properly red color, with an intensification of this color until the 6th day of storage, after which there was an increase in °Hue, with means moving away from the 0° angle, providing a reduction in the red intensity. According to Wybraniec & Mizrahi (2002) and Le Bellec et al. (2006), the red color of the peel in dragon fruits (*Hylocereus* spp.) is attributed to the betacyanin accumulation evidenced in this experiment due to the synthesis of this pigment until the 6th day of storage.

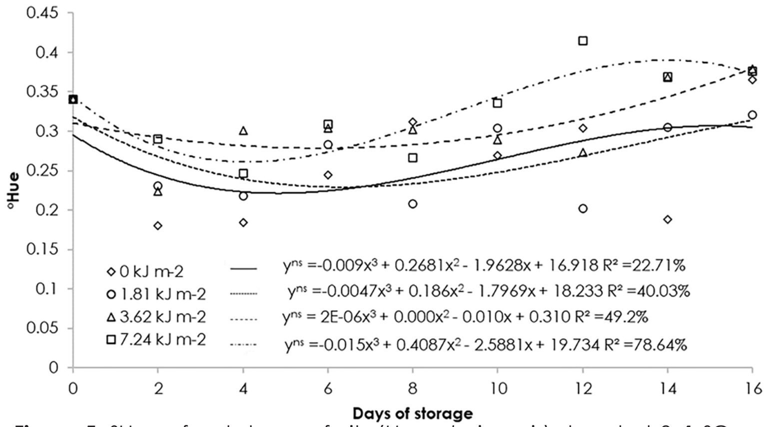

Figure 5. °Hue of red dragon fruits (*H. costaricensis*) stored at 8±1 °C and subjected to different ultraviolet-C radiation doses for 16 days. UEG/CCET, Anápolis, 2021. *Significant at a 5% probability. nsNot significant.

The red dragon fruits submitted to doses of 7.24 kJ m^{-2} showed higher stability of this parameter, with the highest coefficient of determination (R^2) (78.64%), but not significant, demonstrating efficiency in maintaining the initial fruit color. Khademi et al. (2013) observed no significant differences between UV-C treatments for °Hue of chilled 'Karaj' persimmons. Vicente et al. (2005) found that UV-C radiation (dose of 7 kJ m^{-2}) influenced the °Hue of peppers, reaching higher values than untreated fruits and indicating less development of the red color.

Chroma values (Figure 6) showed a significant interaction for the days of storage, with an increase in this parameter in the first days of analysis for all treatments, with a subsequent decrease. This drop for the control treatment was early compared to the other evaluated doses from the 8th day of analysis. According to Fernandes et al. (2014), the decrease in the colorimetric chroma index over the storage period is an indicator of a decrease in color tone or hue, in which lower values lead to less pure colors probably due to the emergence of other pigments arising from the maturation process or even senescence.

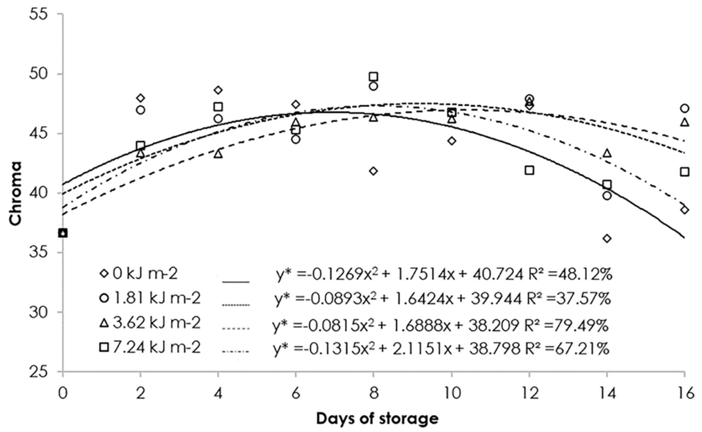

Figure 6. Chroma of red dragon fruits (*H. costaricensis*) stored at 8±1 °C and subjected to different ultraviolet-C radiation doses for 16 days. UEG/CCET, Anápolis, 2021. *Significant at a 5% probability. nsNot significant.

On the other hand, fruits treated with doses of 1.81 and 3.62 kJ m^{-2} after the 8th and 10th day of analysis, respectively, showed higher stability, which was a positive behavior for this color parameter. This behavior shows that the color remained with the saturation characteristic at the beginning of the experiment and tended towards a red hue.

The dose of 3.62 kJ m^{-2} showed a linear increase in betacyanins of the pulp of red dragon fruits (Figure 7). The behavior was cubic for the other treatments, with a trend to increase until the 6th day of analysis, showing a slight decrease in the content until the end of storage, but with mean values above those at the beginning of the experiment, showing an increase in the betacyanin content. This synthesis may be related to the treatment with UV-C radiation, as the absorption of UV or visible light excites the electrons of the pigment chromophore to a more energetic state, increasing the reactivity or reducing the activation energy for the molecule (Herbach et al., 2006). Treatments at doses of 1.81 and 7.24 kJ m^{-2} were more efficient in maintaining the initial contents of this variable during the storage period, although not significant.

Betacyanin contents of dragon fruit peels (Figure 8) were influenced by the different UV-C radiation doses, in which a quadratic behavior of the UV-C doses can be observed, except for the dose of 1.81 kJ m^{-2}, with cubic behavior. The fruits also showed oscillation of the mean betacyanin contents for most treatments throughout storage, culminating in a reduction at the end of storage.

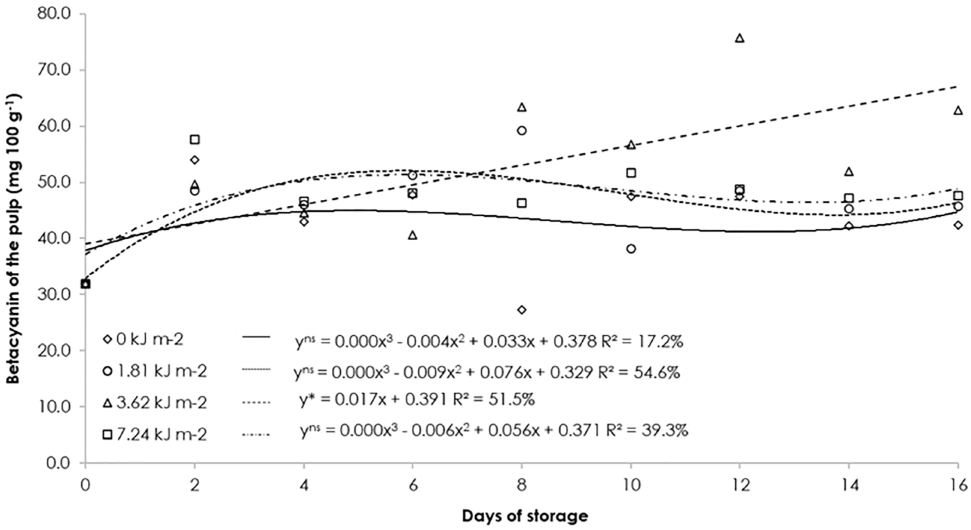

Figure 7. Betacyanin in the pulp of red dragon fruits (*H. costaricensis*) stored at 8±1 °C and subjected to different ultraviolet-C radiation doses for 16 days. UEG/CCET, Anápolis, 2021. *Significant at a 5% probability. nsNot significant.

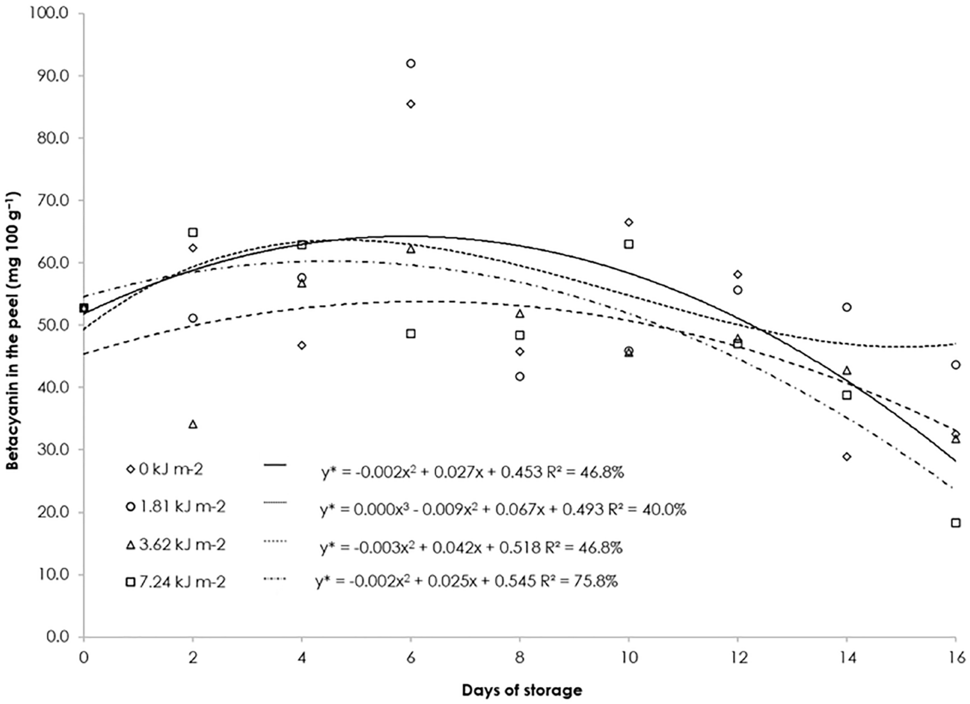

Figure 8. Betacyanin in the peel of red dragon fruits (*H. costaricensis*) stored at 8±1 °C and subjected to different ultraviolet-C radiation doses for 16 days. UEG/CCET, Anápolis, 2021. *Significant at a 5% probability.

The fruits submitted to the dose of 1.81 kJ m^{-2} showed the highest means at the end of the experiment despite the low coefficient of determination, with an initial content of 52.72 mg 100 g^{-1} and 43.64 mg 100 g^{-1} on the 16th day of analysis. It shows that low UV-C radiation doses can be satisfactory in the maintenance of betacyanin in the peel of red dragon fruits, delaying the degradation of this pigment by delaying fruit ripening.

Treatments at 0 and 7.24 kJ m^{-2} showed a higher trend to decrease from the 12th day of analysis, expressing the degradation of betacyanins, which is related to internal factors that affect the stability of betalains, which are primarily the action of enzymes, mostly represented by β-glycosidases, polyphenol oxidases, and peroxidases, which are protoenzymes classified as oxi-reducers and present mainly in the vacuoles of plant cells (Yong 2014; Neelwarne & Rudrappa, 2012). Kluge et al. (2006) also observed a gradual reduction in betacyanin contents with storage time in minimally processed beets considering two types of cuts.

Total carotenoids (Figure 9) showed the occurrence of significance for the interaction of the tested factors. The treatments submitted to UV-C radiation presented an increase in this content until the 6th day, with a decrease later only for 3.62 and 7.24 kJ m^{-2}. The dose of 1.81 kJ m^{-2} maintained mean values higher than the other treatments in the last days of storage (14th and 16th day of analysis), possibly due to the reduction of physiological changes caused by the defense mechanism stimulated by UV-C radiation, providing certain stability (Sanches et al., 2017a). The highest carotenoid contents are justified by the synthesis of these pigments, as a result of the physiological processes of senescence, with a higher carotenoid accumulation and chlorophyll degradation, as no significant content was observed in the evaluated fruits for the chlorophyll parameter (Sanches et al., 2017b).

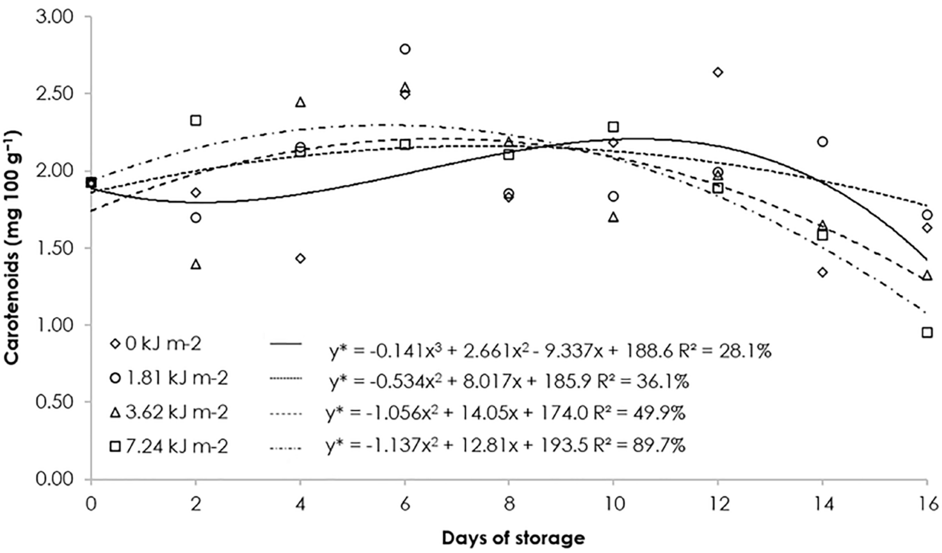

Figure 9. Carotenoids in the peel of red dragon fruits (*H. costaricensis*) stored at 8±1 °C and subjected to different ultraviolet-C radiation doses for 16 days. UEG/CCET, Anápolis, 2021. *Significant at a 5% probability.

The control treatment (0 kJ m^{-2}) showed instability during the evaluated period, with a low coefficient of determination. The lowest decrease was observed at the highest applied radiation dose (7.24 kJ m^{-2}). Lima et al. (2009) studied irradiated muriti (*Mauritia flexuosa* L.) fruits and observed a reduction in carotenoids with increasing gamma radiation doses. Campos & Vieites (2009) evaluated the conservation of 'Pitenza' tomatoes and observed that the highest UV-C radiation doses provided the highest means of total carotenoids during storage. Dias et al. (2014) also verified the occurrence of an increase in the concentration of carotenoids during the storage period of blackberries, being significant when the fruits were submitted to UV-C radiation.

Conclusions

The dose of 1.81 kJ m^{-2} provided a positive effect for the parameters maturation index, chroma, betacyanins in the pulp and peel, and carotenoids, standing out in the maintenance of dragon fruit quality. Regarding postharvest conservation, red dragon fruits treated or not with UV-C radiation packed in LDPE can be maintained refrigerated for up to 21 days without showing deterioration.

Acknowledgments

To the Coordination for the Improvement of

Higher Education Personnel (CAPES) for the scholarship granted during the Masters. This study was financed in part by the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES) – Finance Code 001 (Agreement No. 817164/2015 CAPES/PROAP).

References

AOAC. Association of Official Analytical Chemists. 2016. *Official methods of analysis.* 19th Edition, Washington: AOAC.

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant physiology* 24: 1-15.

Bal, E., Kok, D. 2010. Effects of UV-C treatment on kiwifruit quality during the storage period. *Journal of Central European Agriculture* 10: 375-382.

Bastos, D.C., Pio, R., Scarpare filho, J.A., Libardi, M.N., Almeida, L.D., GaluchI, T.P.D., Bakker, S.T. 2006. Propagação da pitaya 'vermelha' por estaquia. *Ciência e Agrotecnologia* 30: 1106-1109.

Bonewati, A., Bunga, A.K., Nuriani, T. 2017. Hasil tanaman buah naga berdaging merah (*Hylocereus costaricensis* Britton & Rose) dengan aplikasi pupuk organik dan npk anorganik. *Ecosystem* 16: 395-406.

Campos, A.J., Vieites, R.L., Neves, L.C., Silva Moura, M.L., Moura, E.A., Correio, K.G.M.D.A. 2015. Qualidade do tomate 'PITENZA' com utilização da radiação ultravioleta (UV-C). *Revista Agroambiente Online* 9: 300-307.

Campos, A.J., Vieites, R.L. 2009. Ultravioleta (UVC) na conservação da qualidade de tomate. *Revista Eletrônica de Agronomia* 16: 20-26.

Carvalho, C.A.C., Souza Álvares, V., Cunha, C.R., Lima, A.A., Moreno, A.L., Maciel, V.T. 2015. Efeito do pré-resfriamento de frutos de cupuaçu na aceitação sensorial do néctar. *Revista Agroambiente Online* 9: 91-95.

Chang, P.T., Hsieh, C.C., Jiang, Y.L. 2016. Responses of 'Shih Huo Chuan'pitaya (*Hylocereus polyrhizus* (Weber) Britt. & Rose) to different degrees of shading nets. *Scientia horticulturae* 198: 154-162.

Chávez, R.M. 2011. *Relaciones entre genotipo, productividad y calidad de fruto en pitahaya (Hylocereus spp.)* 66 p. (Dissertação de Mestrado) - Institución De Enseñanza e Investigación en Ciencias Agrícolas, Montecillo, Texcoco, México.

Cordeiro, M.H.M., Silva, J.M., Mizobutsi, G.P., Mizobutsi, E.H., Mota, W.F. 2015. Caracterização química, física e nutricional da pitaia-rosa de polpa vermelha. *Revista Brasileira de Fruticultura*, Jaboticabal 37: 20-26.

Dias, L.W., Brunes, A.P., Cruz, D.B., Almeida, A.S., Azevedo, M.L. 2014. A radiação UV-C proporciona uma melhor manutenção dos teores de carotenoides totais em amora-preta. *Enciclopédia Biosfera* 10: 8-14.

Duarte, M.H., Queiroz, E.D.R., Rocha, D.A., Costa, A.C., Abreu, C.M.P.D. 2017. Quality of pitaya (*Hylocereus undatus*) submitted to organic fertilization and stored under refrigeration. *Brazilian Journal of Food Technology* 20: 1-11.

Fernandes, L.M.S., Vieites, R.L., Cerqueira, R.C., Lima Braga, C., Sirtoli, L.F., Amaral, J.L. 2010. Características pós-colheita em frutos de pitaya orgânica submetida a diferentes doses de irradiação. *Biodiversidade* 9:15-22.

Fernandes, L.S., Corrêa, P.C., Finger, F.L., Silva Junqueira, M., Fonseca, K. S. 2014. Efeito de antioxidantes sobre o escurecimento de batatas baroa minimamente processadas. *Engenharia na Agricultura* 22: 195-204.

Herbach, K.M., Rohe, M., Stintzing, F.C., Carle, R. 2006. Structural and chromatic stability of purple pitaya (*Hylocereus polyrhizus* [Weber] Britton & Rose) betacyanins as affected by the juice matrix and selected additives. Food Research International 39: 667-677.

Hirsch, G.E., Facco, E.M.P., Rodrigues, D.B., Vizzotto, M., Emanuelli, T. 2012. Caracterização físico-química de variedades de amora-preta da região sul do Brasil. *Ciência Rural* 42: 942-947.

Hoa, T.T., Clark, C.J., Waddell, B.C., WoolF, A.B. 2006. Postharvest quality of dragon fruit (*Hylocereus undatus*) following disinfesting hot air treatments. *Postharvest Biology and technology* 41: 62-69.

IAL. Instituto Adolfo Lutz, I. 2008. *Métodos físicos-químicos para análise de Alimentos*. São Paulo, Brasil. 1020 p.

Istianingsih, T., Efendi, D. 2013. Pengaruh umur panen dan suhu simpan terhadap umur simpan buah naga Super Red (*Hylocereus costaricensis*). *Jurnal Hortikultura Indonesia* 4: 54-61.

Khademi, O., Zamani, Z., Poor Ahmadi, E., Kalantari, S. 2013. Effect of UV-C radiation on postharvest physiology of persimmon fruit (Diospyros kaki Thunb.) cv. 'Karaj' during storage at cold temperature. *International Food Research Journal* 20: 247-253.

Kluge, R.A., Costa, C.A., Vitti, M.C.D., Graças Ongarelli, M., Jacomino, A.P., Moretti, C.L. 2006. Armazenamento refrigerado de beterraba minimamente processada em diferentes tipos de corte. *Ciência Rural* 36: 263-270.

Le Bellec, F., Vaillant, F., Imbert, E. 2006. *Pitahaya* (*Hylocereus* spp.): a new fruit crop, a market with a future. *Fruits* 61: 237-250.

Lima, C.A., Faleiro, F.G., Junqueira, N.T.V., Cohen, K.O., Guimarães, T.G. 2013. Características físico-químicas, polifenóis e flavonoides amarelos em frutos de espécies de pitaias comerciais e nativas do cerrado. *Revista Brasileira de Fruticultura* 35: 565-570.

Lima, A.L.S., Lima, K.D.S.C., Coelho, M.J., Michele, J., Silva, R.L.D.O.G., Pacheco, S. 2009. Avaliação dos efeitos da radiação gama nos teores de carotenoides, ácido ascórbico e açúcares do fruto buriti do brejo (*Mauritia flexuosa* L.). *Acta amazônica* 39: 649-654.

Lichtenthaler, H.K. 1987. Chlorophylls and carotenoids: pigment photosynthetic biomembranes. *Methods Enzymology* 148: 362-385.

Menezes, T.P., Ramos, J.D., Lima, L.C.O., Costa, A.C., Nassur, R.C.M.R., Rufini, J.C.M. 2015. Características físicas e físico-químicas de pitaia vermelha durante a maturação. *Ciências Agrárias* 36: 631-644.

Neelwarne, B., Rudrappa, T. 2012. Peroxidases and Other Enzymes from Red Beet Hairy Roots. *Red Beet Biotechnology* 12: 283-333.

Neves, L.C., Benedette, R.M., Silva, V.X.D., Vieites, R.L., Roberto, S.R. 2008. Dano de frio em limas-ácidas Tahiti, colhidas em diferentes épocas e submetidas a tratamentos térmicos e bioquímicos. *Revista Brasileira de Fruticultura* 30: 377-384.

Nilsson, T. 1970. Studies into the pigments in beetroot (*Beta vulgaris* L. ssp. *vulgaris* var. *rubra* L.). *Lantbrukshogskolans annaler* 36: 179-219.

Noboa, A., Vasco, C., Valencia-Chamorro, S. 2016. Efecto de la radiación gamma en la calidad poscosecha de la pitahaya ecuatoriana (*Selenicereus megalanthus*). *Agronomía Colombiana* 34: 1111-1113.

Nunes, S. 2015. *Irradiação gama e UV-C na qualidade pós-colheita de mirtilo*. 2015. 94 f. (Dissertação de Mestrado)- Universidade Federal de Lavras, Lavras, Brasil.

Obenland, D., Cantwell, M., Lobo, R., Collin, S., Sievert, J., Arpaia, M.L. 2016. Impact of storage conditions and variety on quality attributes and aroma volatiles of pitahaya (*Hylocereus* spp.). *Scientia Horticulturae* 199:15-22.

Pinto, W.S., Dantas, A.C.V.L., Fonseca, A.A.O., Ledo, C.A.S.L., Jesus, S.C., Calafrange, P.L.P., Andrade, E M. 2003. Caracterização física, físicoquímica de frutos de genótipos de cajazeira. *Pesquisa Agropecuária Brasileira* 38: 1059-1066.

Purwanto, E.G.M. 2011. Kajian Penyimpanan Buah Naga (*Hylocereus costaricensis*) dalam Kemasan Atmosfer Termodifikasi. *Jurnal Keteknikan Pertanian* 25: 127-132.

Rinaldi, M.M., Vieira, E.A., Fialho, J.F., Malaquias, J.V. 2015. Efeito de diferentes formas de congelamento sobre raízes de mandioca. *Brazilian Journal of Food Technology* 18: 93-101.

Sanches, A.G., Costa, J.M., SILVA, M.B., Moreira, E.G.S. Cosme, S.S. 2017b. Tratamentos químicos na manutenção da qualidade pós-colheita em frutos de pitanga (*Eugenia uniflora* L.). *Nativa* 5: 257-262.

Sanches, A.G., Costa, J.M., Silva, M.B., Moreira, E.G.S., Santana, PJ.A. Cordeiro, C.A.M. 2017a. Aspectos qualitativos e amadurecimento do araçá amarelo tratado com radiação UV-C. *Nativa* 5: 303-310.

Schiavon, A.V., Leivas, G.L., Delazeri, E.E., Alves, A.S., Melo-Farias, P.C., Antunes, L.E.C. 2021. Características físico-químicas de amora-preta 'Tupy' colhidas em diferentes estádios de maturação e mantidas sob refrigeração. *Scientific Electronic Archives* 14: 39-46.

Scott, G., Rupar, M., Fletcher, A.G.D., Dickinson, M., Shama, G. 2017. A comparison of low intensity UV-C and high intensity pulsed polychromatic sources as elicitors of hormesis in tomato fruit. *Postharvest Biology and Technology* 125: 52-58.

Stevens, C., Khan, V.A., Wilson, C.L., Lu, J.Y., Chalutz, E., Droby, S. 2005. The effect of fruit orientation of postharvest commodities following low dose ultraviolet light-C treatment on host induced resistance to decay. *Crop Protection* 24: 756-759.

Vicente, A.R., Pineda, C., Lemoine, L., Civello, P.M., Martinez, G. A., Chaves, A. R. 2005. UV-C treatments reduce decay, retain quality and alleviate chilling injury in pepper. *Postharvest Biology and Technology* 35: 69-78.

Wybraniec, S., Mizrahi, Y. 2002. Fruit flesh betacyanin pigments in *Hylocereus cacti. Journal of Agricultural and Food Chemistry* 50: 6086-6089.

Yah, A.R.C., Pereira, S.S., Veloz, C.S., Sañudo, R.B., Duch, E.S. 2008. Cambios físicos, químicos y sensoriales en frutos de pitahaya (*Hylocereus undatus*) durante su desarrollo. *Revista Fitotecnia Mexicana* 31: 1-5.

Yong, G. 2014. *Enzymatic Engineering.* Alpha Science International Ltda., Beijing, China: Science Press; Oxford, U.K. 368 p.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.