



## Physical properties of irradiated red pitaya (*Hylocereus costaricensis*) during storage

Luz M. Rondan-Flores<sup>1\*</sup>, Bianca G. Negrão<sup>1</sup>, João Pedro A.A. Barros<sup>1</sup>,  
Daili A. S. Barreira<sup>1</sup>, Anna Lucia C.H. Villavicencio<sup>1</sup>

<sup>1</sup> *lrondanf@alumni.usp.br, Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP), Centro de Tecnologia das Radiações, São Paulo, SP, Brasil*

### 1. Introduction

Worldwide, the consumption of exotic fruits has attracted consumers and among them is the red pitaya, also known as the dragon fruit, which comes from the tropical forests of Central and South America, India and Malaysia and is one of a vast group of exotic fruits with good marketing potential [1].

The pitaya fruit has nutritional and functional characteristics that make its cultivation considered promising [2]. Both the pulp and the peel are an important source of fiber with attractive digestive attributes. Their physical and chemical characteristics can vary from species to species due to high genetic diversity [3]. In addition, research carried out on pitaya reveals the presence of bioactive compounds, including phenolic compounds such as flavonoids, which contribute to the fruit's antioxidant capacity [4,5]. The beneficial effects of these compounds are related to the prevention of degenerative diseases such as colon cancer and diabetes, the reduction of bacterial infections, and cardiovascular diseases [6]. In addition, red pitaya has the betalain group of phenolic compounds, which are divided into betaxanthins (yellow color) and betacyanins (violet color) [7,8].

The food industry is facing great pressure to become more sustainable. Innovative technologies such as food irradiation for food safety are a greener alternative to more energy-intensive thermal processes [9], and efforts must be made to expand their use to avoid significant economic losses due to damaged or contaminated food and save thousands of lives [10]. Ionizing radiation, due to its high energy, is capable of penetrating matter, ionizing atoms, breaking chemical bonds and causing damage to biological tissues. On the other hand, the use of ionizing radiation has innumerable applications that have various benefits for society and individuals. Irradiation with ionizing radiation is a technique used in food preservation that consists of exposing food, packaged or not, and the aim of this process is to increase the shelf life of food by reducing the natural losses caused by physiological processes (sprouting, ripening and ageing) [11]. This technique can also be used to eliminate insects, pathogenic bacteria, viruses, fungi and yeasts, without causing damage to the food, making it safe for the consumer [12].

As for post-harvest, the pitaya is a tropical fruit that deteriorates relatively easily under ambient conditions, and as a result, the post-harvest shelf life is short, approximately 6 to 8 days under natural conditions. Storage temperature and time influence the physiological processes of the pitaya, increasing the useful life of the fruit, especially at a temperature of 8 °C, which resulted in better quality [13,14].

The aim of this study was to evaluate the physical properties (texture, color, and water activity) in the post-harvest preservation of red-fleshed pitaya fruits during refrigerated storage after being subjected to different doses of gamma radiation in order to preserve nutritional quality and promote greater food safety, and also to identify the best doses of radiation in fresh pitaya to extend shelf life.

## 2. Methodology

The samples were obtained from the CEAGESP (Companhia de Entrepósitos e Armazéns Gerais de São Paulo) wholesale market. The fruit was randomly selected and free of mechanical damage, and transported to the LADIF (Laboratório de Análise e Detecção de Alimentos Irrradiados) of the CTR (Centro de Tecnologia das Radiações) of IPEN/CNEN-SP (Instituto de Pesquisas Energéticas e Nucleares). The red pitaya boxes were irradiated (doses of 1 and 3.5 kGy) in the Multipurpose Irradiator (IPEN/CNEN-SP). The control and irradiated samples were analyzed after 7 and 14 days of storage.

The texture was analyzed using a Stable Micro Systems TA-XT2 texturometer with a compression capacity of 50 kg and a test speed of 50 mm/s. Irradiated and control samples' color was analyzed using a CR-400 colorimeter (Konica Minolta). The results were expressed by the CIELAB space (Commission Internationale de L'Eclairage), and nine random readings of the samples were performed for each dose of gamma irradiation. The results were expressed in CIELAB and CIE L\*C\*h color space which are the most used systems for the evaluation of color in food. The parameters L\* (brightness), a\* (red/green) and b\* (yellow/blue intensity) were obtained [13]. Chroma C\* (saturation or color intensity), and Hue angle (amount of color in which red-purplish = 0°, yellow = 90°, green = 180°, blue = 270°, and black = 360°).

The water activity was performed using an AquaLab 4TE model equipment, with ten readings for each dose. The results were analyzed using the program GraphPad Prism (version 8.0), which was also used for the elaboration of tables and graphs. The comparisons among the data were performed using two-way ANOVA, with a statistical significance limit of by Tukey test ( $p < 0.05$ ).

## 3. Results and Discussion

Table I shows the strength and elasticity properties of the non-irradiated and irradiated peel for storage times of 7 and 14 days. It can be seen that for the same storage time (7 days), the strength property showed a reduction of close to 67 and 28% for doses of 1.0 and 3.5 kGy, respectively, while for 14 days, there was also a reduction of 4 and 39%, respectively. For the elasticity property, there was an increase of 43 and 4 for doses of 1.0 and 3.5 kGy when compared to non-irradiated, for the same storage time (7 days). For 14 days, there was an increase of 107 and 69% for 1.0 and 3.5 kGy, respectively. These results suggest that the lower dose of 1.0 kGy had a greater influence than the dose of 3.5 kGy on elasticity, indicating that high doses can damage characteristics that favor the preservation of pitaya during the storage process.

Table I: Texture of irradiated pitaya.

Dose (kGy)	Storage (Days)	Skin Strength (g)	Elasticity (mm)
Non-irradiated	7	945.57±31.80	2.95±0.50
	14	760.38±20.14	2.39±0.13
1,0	7	311.89±4.23	4.23±0.61
	14	727.90±20.54	4.94±1.42
3,5	7	678.69±27.13	3.06±0.64
	14	461.53±32.65	4.03±1.21

Table II shows the results for the color properties of pitaya as a function of storage time and irradiation dose. The luminosity range (L\*) of the pitaya indicated that the lowest value was for a dose of 1.0 kGy, with a storage time of 7 days (29.8). For the positive a\* parameter (coloration close to red), the same result was observed for the 1.0 kGy dose, showing the lowest intensity, while for 3.5 kGy it was observed that for 7 days there was no difference with the non-irradiated and for 14 days a reduction. This last result suggests that the higher dose of irradiation preserves this parameter during the 7-day period, but fails to maintain the same

characteristics after 14 days. Similar results were observed for the other parameters ( $b^*$ ,  $C^*$  and  $h^\circ$ ). In general, it can be seen that irradiation with a dose of 1.0 kGy had a reduction in the intensity and tone of the color, which was more evident for the shortest storage time (7 days). This result suggests that after 14 days, the fruit itself is able to regain some of its color, as if recovering from the irradiation process. For 3.5 kGy, the characteristics were also preserved at 7 days, but at 14 days there was a reduction in all the color indicators.

Table II: Color results of pitaya irradiated.

Dose (kGy)	Storage (Days)	Color				
		$L^*$	$a^*$	$b^*$	$C^*$	$h^\circ$
Non-irradiated	7	37.01±4.29	43.13±2.16	11.35±1.63	44.63±1.98	14.78±2.36
	14	38.69±2.51	42.12±2.45	12.63±2.25	44.02±2.42	16.69±3.00
1.0	7	29.84±1.77	25.37±2.26	3.71±1.11	25.65±2.33	8.29±2.05
	14	31.35±4.24	30.23±4.13	6.82±2.60	31.08±4.11	12.71±5.00
3.5	7	39.24±2.12	42.39±3.99	10.89±1.49	43.82±3.59	14.59±2.95
	14	38.77±3.36	31.96±2.42	7.84±1.78	32.96±2.33	13.85±3.24

Table III shows the results of the water activity at the pitaya samples, showing that they remained stable during 14 days of storage. The critical point for food is 0.6-0.7  $a_w$ , since below this range it is difficult for microorganisms to grow.  $a_w$  affects the rate of chemical reactions such as the oxidation of lipids, the hydrolysis of proteins, the degradation of vitamins, and biochemical reactions [16]. It should be noted that the value is higher than 0.976, which indicates a high  $a_w$  and greater susceptibility to the growth of microorganisms due to the amount of free water available, showing the microbiological risk and the need to apply packaging temperature and storage as additional prevention methods. In addition, the irradiated samples did not show a significant difference compared to the control, and for the highest dose (3.5 kGy) there was no change in the values, even though there is an interaction of the radiolysis of the water.

Table I:  $a_w$  results from 14 days after irradiation

Storage	Water activity ( $a_w$ )		
	Non-irradiated	1kGy	3.5kGy
7	0.985±0.011 <sup>a</sup>	0.976±0.002 <sup>a</sup>	0.979±0.001 <sup>a</sup>
14	0.980±0.001 <sup>a</sup>	0.981±0.004 <sup>a</sup>	0.983±0.002 <sup>a</sup>

#### 4. Conclusions

The results of the texture analysis suggest that a dose of less than 1.0 kGy had a greater influence on elasticity than a dose of 3.5 kGy. In addition, the irradiation influences the color of pitaya fruit, which is affected by storage time. Despite these results, further studies are needed to identify the effects of irradiation on other properties, which can be significantly beneficial for preserving properties and compounds, as well as increasing the shelf life of this fruit.

#### Acknowledgements

The authors would like to thank CNEN and CNPq, IPEN-CNEN/SP for the structure and financial support. In addition, the authors wish to thank Mr. Ailton of CEAGESP for his kindness in providing the red pitaya fruit.

## References

- [1] Q. Hua, C. Chen, N.T. Zur, H. Wang, J. Wu, J. Chen, Z. Zhang, J. Zhao, G. Hu, Y. Qin, Metabolomic characterization of pitaya fruit from three red-skinned cultivars with different pulp colors, *Plant Physiology and Biochemistry*, v. 126, pp. 117-125 (2018).
- [2] Y. Wu, J. Xu, Y. He, M. Shi, X. Han, W. Li, X. Zhang, X. Wen, Metabolic Profiling of Pitaya (*Hylocereus polyrhizus*) during Fruit Development and Maturation, *Molecules*, v. 24, pp. 1114 (2019).
- [3] M.H.M. Cordeiro, J.M. Da Silva, G.P. Mizobutsi, E.H. Mizobutsi, W.F. Da Mota, Caracterização física, química e nutricional da pitaya-rosa de polpa vermelha, *Revista Brasileira de Fruticultura*, v. 37, pp. 20-26 (2015).
- [4] J. Taira, E. Tsuchida, M.C. Katoh, M. Uehara, T. Ogi, Antioxidant capacity of betacyanins as radical scavengers for peroxy radical and nitric oxide, *Food Chemistry*, v. 166, pp. 531-536 (2015).
- [5] G.C. Tenore, E. Novellino, A. Basile, Nutraceutical potential and antioxidant benefits of red pitaya (*Hylocereus polyrhizus*) extracts, *Journal of Functional Foods*, v. 4, pp. 129-136 (2012).
- [6] A. Tindade, A. Reis, L. Sabbo, D. Trindade, P. Paiva, A. Duarte, Pitaia: perspectivas e dificuldades de uma “nova” cultura, *Agrotec*, v. 30, pp. 32-34 (2019).
- [7] F. Fathordoobady, A. Singh, D.D. Kitts, A.P. Singh, Hemp (*Cannabis Sativa L.*) extract: Antimicrobial properties, methods of extraction, and potential oral delivery. *Food Reviews International*, v. 35, pp. 664-684 (2019).
- [8] S.H.E.K. Nanayama, Caracterização físico-química e extração dos pigmentos presentes em cascas de pitaia, Dissertação (Mestrado Profissional em Tecnologia de Alimentos) Universidade Tecnológica Federal do Paraná (2020).
- [9] F. Chemat, E. Vorobiev, *Green Food Processing Techniques, Transformation and Extraction*. 1. ed. Academic Press, pp. 586 (2019).
- [10] R.G. MOREIRA, M.E. CASTELL-PEREZ, Fundamentals of Food Irradiation. *Innovative Food Processing Technologies - A Comprehensive Review*, pp. 1-18 (2021).
- [11] M.I.A. Elias, Avaliação da segurança alimentar de framboesas irradiadas por feixe de elétrons, Dissertação (Mestrado em Microbiologia Aplicada), Universidade de Lisboa, Lisboa (2019).
- [12] I. Rossi, Q.M.A. Hasan, A review of irradiation technologies on food and agricultural products. *International Journal of Scientific and Technology Research*, v. 9, pp. 4411-4414 (2020).
- [13] A. Nerd, Y. Mizrahi, Effect of ripening stage on fruit quality after storage of yellow pitaya, *Postharvest Biology and Technology*, v. 15, pp. 99-105 (1999).
- [14] B.W. Magaña, A.M. Balbín., G.J. Corrales, C.A. Rodríguez, V. Saucedo, Crescenciano. Principales características de calidad de las pitahayas (*Hylocereus undatus haworth*), frigoconservadas em atmosferas controladas, *Revista Ciências Técnicas Agropecuárias*, v. 15, pp. 52-56 (2006).
- [15] “Commission Internationale de L'Eclairage”. <http://www.cie.co.at/> (2019).
- [16] P. Pittia, P. Antonello, Safety by control of water activity: drying, smoking, and salt or sugar addition. *Regulating Safety of Traditional and Ethnic Foods*, pp. 7-28 (2016).