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Physical properties of irradiated Sapodilla (*Manilkara zapota*)

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1. Introduction

Sapodilla is a nutritious exotic fruit commonly consumed in Northeastern Brazil [1,2]. Its post-harvest life is short due to its highly perishable nature (2 to 10 days), fast ripening, and moisture loss causing microbial spoilage and vulnerability to cold storage. Therefore, after harvesting it is necessary to maintain and increase shelf life with proper management to trade in more faraway markets with good quality [3,4]. Fruits such as sapodilla are a relevant component of human nutrition, being rich sources of sugars, vitamins, minerals, carotenoids, polyphenols, dietary fiber, and other phytochemicals that play a role in health. Therefore, it is vital to prevent the contamination of microorganisms to reduce nutrient degradation and maintain sensory and safety attributes [5].

Lately, the consumption increase of native, tropical fruits in the domestic market is mainly due to the great potential of exploiting the marketing for fresh consumption in the supermarkets in "Hortifruti stores" to serve the population that seeks fruits with nutritional properties [6-8]. Fresh fruits, tropical juices, and other derivatives trading in Brazil lack an effective strategy that allows for the conciliation of high-quality production with safety and traceability to provide and competitive the domestic and international markets [9]. Already, the degrees of deterioration, loss of quality linked to the effectiveness of the packaging system, and the environmental conditions of the exposed products during storage and transport affect the spreading of fruit on trades widely [10].

Food irradiation is one of the few food technologies capable of maintaining food quality and solving safety and protection problems without significantly affecting its organoleptic or nutritional characteristics. Beneficial effects include versatility, efficiency against bacteria, insects, and other pests; it is penetrating; the effectiveness of the process is achieved even with the product packaged (which limits the possibilities of infestation or recontamination). Furthermore, treatment does not involve chemicals or residues; and food treated can be immediately distributed in the food supply chain after treatment [11,12].

2. Methodology

2.1 Physical properties

The samples were obtained in the wholesale market of CEAGESP (Companhia de Entrepostos e Armazéns Gerais de São Paulo). Fruits were selected for color, size, and absence of mechanical and pest damage, then transported to Laboratory for Analysis and Detection of Irradiated Foods (LADIF) at the Radiation Technology Center (CTR), Energy and Nuclear Research Institute (IPEN/CNEN-SP). The sapodilla packs were irradiated (500 and 1000 Gy doses) at Multipurpose Irradiator (IPEN/CNEN-SP). Control and irradiated samples were analyzed on 1^{st}, 6^{th}, and 12^{th} storage days.

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. The viscosity samples irradiated homogenized portions and weighed at room temperature were evaluated. Irradiated and control samples' color was analyzed using a CR-400 colorimeter (Konica Minolta). The results were expressed by the CIELAB space (*Commission Internacionale de L'Eclairage*), and twenty 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. It was obtained the parameters L* (brightness), a* (red / green) and b * (yellow / blue intensity) [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 = 360º).

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

The samples' water activity (Table I) remained stable during twelve days of storage. The critical point for food is 0.6-0.7 aw as below this range microorganism' growth is difficult. aw affects the rate of chemical reactions such as lipid oxidation, protein hydrolysis, vitamin degradation, and biochemical reactions [14]. Note that the value is above 0.900, indicating a high aw, 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 and storage temperature as additional prevention methods. Moreover, the irradiated samples did not have a difference significant from control, and the higher dose (1000 Gy) still does not change the values even if there is an interaction of water radiolysis.

Table I: a_w results from 12 days after irradiation.

	Water activity (a_w)		
	Doses		
Storage	Non-irradiated	500	1000
1	0,969±0,005^{aA}	0,977±0,013^{aA}	0,970±0,005^{aA}
6	0,969±0,004^{aA}	0,978±0,013^{aA}	0,968±0,004^{aA}
12	0,971±0,002^{aA}	0,977±0,015^{aA}	0,970±0,001^{aA}

[1]Means followed by the same letter in the columns do not differ statistically from each other by the Tukey test (p> 0.05).

The luminosity range (L*) of the sapodilla pulp was greater than 45 for all samples, also, no significant difference among doses (Table II). All the samples showed positive a* (coloring close to red) with values up to 8.73±1.56 (1000 Gy). The b* values also showed positive values indicating approximate yellow color. The color of the samples (hº) is in the range of 68.27 to 74.97 and revealed a brownish color. At last, the intensity and tone of the color did not show significant changes during storage**.**

Table II: Color results of sapodilla irradiated.

Dose (Gy)	Storage	Color				
		L*	a*	b*	C*	hº
Non-irradiated	1	50,84±2,37^{aA}	4,16±1,22^{aA}	15,18±3,14^{aA}	23,02±0,55^{aA}	69,73±4,77^{aA}
	6	47,89±1,45^{aA}	4,31±1,09^{aA}	15,14±2,73^{aA}	19,24±3,70^{aA}	70,45±4,03^{aA}
	12	47,29±1,71^{aA}	5,41±1,02^{aA}	21,28±3,37^{aA}	18,44±2,55^{bA}	69,39±3,81^{aA}
500	1	46,81±1,56^{aA}	8,59±2,03^{aA}	15,74±4,10^{aA}	24,63±1,54^{aA}	68,96±4,51^{aA}
	6	49,72±7,77^{aA}	6,74±1,44^{aAB}	15,75±3,54^{aA}	20,43±4,65^{aA}	72,02±1,89^{aA}
	12	51,14±1,62^{aA}	6,41±0,08^{aAB}	19,22±4,45^{aA}	22,77±3,34^{aA}	68,27±2,96^{aA}
1000	1	50,39±2,84^{aA}	8,54±2,31^{aB}	21,50±1,85^{aA}	23,20±3,14^{aA}	74,97±1,66^{aA}
	6	47,88±2,22^{aA}	8,01±1,86^{aB}	19,94±1,59^{aA}	20,96±1,83^{aA}	74,24±2,34^{aA}
	12	50,79±1,96^{aA}	8,73±1,56^{aB}	22,76±1,20^{aA}	24,41±2,05^{aA}	73,72±1,60^{aA}

[1]A, B: Different capital letters in the columns indicate statistical difference by Tukey's test (P<0.05); a, b: Different lowercase letters in the lines indicate statistical difference by the Tukey test (P<0.05); Equal letters do not differ significantly from each other.

Texture tests were intended to evaluate the sapodilla pulp viscosity from an extrusion analysis. The average irradiated sample was 0.985, it was observed that there was no significant difference between the irradiated samples to control, and viscosity remained stable during 12 days.

4. Conclusions

Doses up to 1000 Gy do not significantly alter the physical properties of the sapodilla fruit, such as color, water activity, and pulp viscosity during storage. Consequently, the application of ionizing radiation in sapodilla shows promising results in the studied parameters. Even more, when to consider that the visual appearance and texture decisively interfere in consumer choice.

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