

# Physical–chemical analyses of irradiated papayas (*Carica papaya* L.)

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## Abstract

Papaya is cultivated in Espírito Santo State/Brazil and as it stands up to irradiation, it is important to validate this technology, since it is already being applied in some countries. Penetration energy, ratio (relation between soluble solids and titrable acidity) and skin color were evaluated to verify the influence of four different doses of irradiation (0.0, 0.5, 0.75 and 1.00 kGy) on papayas, during 21 days. As a result for the skin color and the penetration energy, it was found that in the first days after irradiation, these variables increased with increase in radiation dose; however, after a time lapse, the tendency inverted and the irradiated fruits had a slower ripening process. For the ratio, a very important variable that it is responsible for the fruit taste, no difference was found between irradiated and the control fruit. Color and texture measurements are dependent on the storage temperature.

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## 1. Introduction

Brazil is a large papaya producer, being the second international exporter, behind Mexico (FAO, 2004). Papaya is a tropical fruit listed in our country as important to be exporter but just around 3% of total produced are exported. Although Brazilian papaya is produced all year around that is an advantage in the trade, some restrictions are imposed as phytosanitary barriers (Souza, 2002). Food irradiation process is a good treatment to control insects and to reduce deterioration of fruits (Loaharanu, 1992). Several studies have demonstrated the potential of radiation process to preserve fruits (Moy, 1986, 1989; Hallman, 1999; ICGFI, 1991; Paull, 1996).

The objective of this work was to verify the physical–chemical changes on irradiated papaya at four different doses irradiated during a storage period representing shipping of the fruit to external trade.

## 2. Methodology

Golden variety of papayas, from Linhares, Espírito Santo, Brazil, harvested from November/2003 to January/2004, were used in the experiments. Fruits were harvested at the first yellow color in the “color breaking” and had an average weight around 420–500 g. All fruits were washed in chlorinated water (112 ppm) and submitted to thermal treatment (immersed in hot water at 48 °C for 20 min, followed by natural drying at 12–14 °C for 15 min) according to the standard process of the producer.

Fruits were irradiated in a Cobalt-60 industrial plant (Companhia Brasileira de Esterilização, SP, Brazil) with a dose rate of 0.3 kGy/h, at four different doses: 0.0 kGy (control); 0.50 kGy; 0.75 kGy and 1.00 kGy. For each dose, 60 fruits were used, totalizing to 240. All fruits were maintained in a controlled chamber at  $9.8 \pm 0.2$  °C and  $80.8 \pm 3.0\%$  RH for 14 days and after that at  $24.8 \pm 0.1$  °C and  $80.4 \pm 3.2\%$  RH until the end of the experiment.

Physical–chemical analyses were performed on eight fruits of each dose collected randomly at 1 day before irradiation (DBI), 3 days after irradiation (DAI), 7 DAI and 14 DAI. Then fruits were transferred to a new storage

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temperature (24.8 °C) and analyzed every 2 days: 17 DAI, 19 DAI and 21 DAI.

2.1. Physical–chemical analyses

Color of the fruit skin was measured using a colorimeter (CR 300 Minolta), to acquire *a*, *b* and *L* parameters from the CIE Lab. System. The penetration of energy of the fruit’s pulp was measured using a texture analyzer (TA-TX2I, Stable Micro Systems) applying a penetration test (probe?): 5 mm/s pre-test speed, 1 mm/s test speed, 10 mm/s post-test speed and 8 mm penetration distance. pH was measured in centrifuged pulp using a pH-meter (Micronal, model B274). The titrable acidity was measured and the soluble solids (°Brix) were measured by refractometry (Atago refractometer, model ATC-1E), with temperature correction according to AOAC methods (1995).

3. Results and discussion

3.1. Color

The parameters *a*, *b* were transformed in Hue angle, to evidence the skin color transformation from green to yellow. The Chroma and Lightness were also analyzed but no significant differences were founded (*p* > 0.05). ANOVA indicated that both irradiation dose and storage time

significantly (*p* < 0.05) influenced the Hue angle. In fact, at 9.8 °C Hue mean values for control samples were higher than those for irradiated samples, as can be observed in Table 1. At 9.8 °C, the control fruits presented the Hue mean values higher than the irradiated ones. A higher Hue angle means that the fruits skin was greener. This may happen due to the free radicals that are formed during irradiation and can change the chlorophyll structure responsible for the green color of the skin. This situation inverted when fruits were stored at 24.8 °C condition and the irradiated fruits had a slower yellow skin color development, remaining green for a longer period.

3.2. Penetration energy

The penetration energy results of fruit pulp followed the same tendency of Hue angle variable. While fruits were maintained at 9.8 °C, the irradiated papayas were softeners, indicating an advanced ripening stage. But when they were changed to the 24.8 °C storage condition, the non-irradiated fruits (control) became softeners than the irradiated ones. A predictive model (Eq. (1)) was obtained by fitting the experimental data:

$$\begin{aligned} \text{Energy (mJ)} = & (415.831 - 21.2002 \times \text{Period} - 347.218 \\ & \times \text{Dose} + 19.9389 \times \text{Period} \times \text{Dose}) \\ & \pm 40.300 \quad 0.00 \leq \text{Dose (kGy)} \leq 1.00 \\ & - 1 \leq \text{Period (Days)} \leq 21. \end{aligned} \tag{1}$$

Fig. 1 represents the response surface for energy of penetration of papayas as a function of absorbed dose during 21 days of the experiment.

Table 1  
Means of Hue angle of papayas skin as a function of absorbed dose and storage time

Dose (kGy)	Hue angle of skin				
	3 DAI	7 DAI	14 DAI	19 DAI	21 DAI
0.00	116.27 <sup>ax</sup>	114.19 <sup>bx</sup>	112.02 <sup>bx</sup>	86.59 <sup>cx</sup>	82.86 <sup>cx</sup>
0.50	112.11 <sup>ay</sup>	108.62 <sup>by</sup>	105.40 <sup>cy</sup>	88.30 <sup>dy</sup>	86.92 <sup>dy</sup>
0.75	112.58 <sup>ay</sup>	107.88 <sup>by</sup>	106.95 <sup>by</sup>	89.29 <sup>cy</sup>	85.11 <sup>dx</sup>
1.00	112.60 <sup>ay</sup>	110.11 <sup>by</sup>	106.89 <sup>cy</sup>	93.15 <sup>dz</sup>	86.25 <sup>exy</sup>

DAI means days after irradiation.  
Means values followed by different letters (a, b, c, d, e) in the same row are significantly different (*p* < 0.05).  
Means values followed by different letters (x, y, z) in the same column are significantly different (*p* < 0.05).

3.3. Ratio (soluble solids (°Brix) per acidity titrable)

Ratio is an important parameter that indicates sweetness versus acidity of the fruit. This parameter is commercially used to determine maturity and quality of the fruits. As we can observe in Table 2, a tendency of increase (*p* < 0.05) of ratio were noticed after the 14th day, when the temperature of storage changed from 9.8 to 24.8 °C. Radiation had small influence in ratio values (*p* < 0.05).

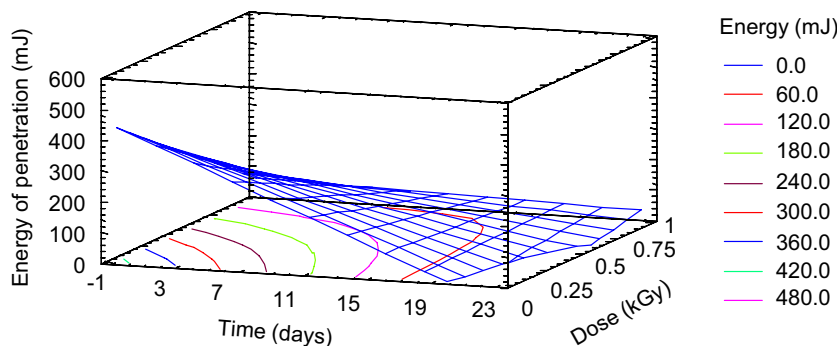


Fig. 1. Response surface of energy of penetration of irradiated papayas as a function of absorbed dose and storage time.

Table 2

Means of ratio (soluble solids per titrable acidity) as a function of absorbed dose, during storage time

Dose (kGy)	Ratio (soluble solids/titrable acidity)					
	3 DAI	7 DAI	14 DAI	17 DAI	19 DAI	21 DAI
0.00	108.39 <sup>ax</sup>	91.30 <sup>ax</sup>	123.93 <sup>bx</sup>	134.46 <sup>bx</sup>	120.25 <sup>bx</sup>	124.67 <sup>bx</sup>
0.50	97.33 <sup>ax</sup>	101.61 <sup>ax</sup>	109.72 <sup>ay</sup>	125.17 <sup>bx</sup>	126.14 <sup>bx</sup>	137.74 <sup>bx</sup>
0.75	99.58 <sup>ax</sup>	104.26 <sup>ax</sup>	89.78 <sup>az</sup>	122.57 <sup>bx</sup>	121.33 <sup>bx</sup>	117.61 <sup>bx</sup>
1.00	113.84 <sup>ax</sup>	106.60 <sup>ax</sup>	111.40 <sup>ay</sup>	127.15 <sup>ax</sup>	114.57 <sup>ax</sup>	117.74 <sup>ax</sup>

DAI means days after irradiation.

Means values followed by different letters (a, b, c, d, e) in the same row are significantly different ( $p < 0.05$ ).

Means values followed by different letters (x, y, z) in the same column are significantly different ( $p < 0.05$ ).

#### 4. Conclusion

Since color change of the fruit skin is the parameter that better represents the fruit ripening for the consumers, the irradiation of the doses of 0.75 and 1.00 kGy was responsible for a 2 days ripening delay. In the first days after irradiation, texture of papayas was softer but at the end of storage time, the firmness of irradiated fruits was better than controls. Ratio values were more storage time dependent than radiation process.

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