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Studying the effect of combining two nonconventional treatments, gamma irradiation and the application of an edible coating, on the postharvest quality of tamarillo (*Solanum betaceum* Cav.) fruits

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A B S T R A C T

The effect of the combination of gamma irradiation with gamma rays and a commercial edible coating, Sta-Fresh 2505, on the postharvest quality of golden-yellow and purple-red tamarillo (*Solanum betaceum* Cav.) fruits was studied. Irradiation and edible coating were used because these are technologies that fulfill the consumer trend to buy fresh fruits while assuring food safety and prolonging shelf life.

Weight loss, pH, firmness, soluble solids content, respiration rate, pulp appearance, sensory hardness, aroma, and off-flavor were analyzed. The irradiated fruits and the irradiated fruits with edible coating were stored up to 10 weeks at 5 °C and 90% RH plus 7 days at 20 °C and 80% relative humidity (RH), to simulate shelf life. The combination of the edible coating and irradiation at 500 Gy maintained the postharvest properties of the fruit. Weight loss was reduced up to 48% compare to the control. Firmness and appearance were 70 and 40% higher than the control, respectively. The respiration rate was 30% lower than the control. The combination of gamma irradiation and edible coating had a synergetic effect on the postharvest quality of tamarillo.

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1. Introduction

1.1. Tamarillo

The tamarillo or tree tomato (*Solanum betaceum* Cav), is a non-climacteric edible fruit native of the Ecuadorian-Peruvian Andes, and it is grown in South America and in New Zealand (García, 2008). It is an important nutritional source of β-carotene (pro vitamin A), vitamin B6, vitamin C (ascorbic acid), vitamin E and iron (Lister, Morrison, Kerkhofs, & Wright, 2005).

Tamarillos are egg-shaped and pointed on both ends. Their weight vary between 50 and 120 g, their length between 4 and 10 cm, and their diameter between 3 and 5 cm (Feican, Encalada, & Larriva, 1999). The fruit has a distinctive sweet and tart flavor. Two zones can be differentiated internally: an external firm flesh, and the seed zone in the center of the fruit, named placenta. In this zone, a lot of seeds, which are surrounded by a jelly substance and enclosed in a membrane, are placed in two locula.

There are a great number of tamarillo cultivars, sorted by their color: yellow, golden, orange, and red, but the most common cultivars are the golden-yellow and purple-red tamarillos (Acosta-Quezada, Martínez-Laborde, Vilanova, & Prohens, 2011). The golden-yellow fruit has orange or purple skin, orange flesh and placenta, while the purple-red ones have purple skin and placenta and orange flesh.

1.2. Edible coating and irradiation

Both treatments are emerging technologies, which do not produce waste and had no harmful effects on the environment (Farkas, 2007). Also, neither edible coating nor irradiation at doses below 2.5 kGy produces changes in the nutritional content of the fruit, or leave any kind of toxic residue in it (IAEA, 2002). For those reasons, these two technologies are widely used to extend the shelf life of fruit. Sometimes, they are also used in combination with other treatments to improve its performance on the postharvest quality of the fruit (Arvanitoyannis & Stratakos, 2010). Nevertheless, there are no studies on the combination of coating and irradiation to preserve the postharvest quality of fruit, and there are few studies on treatments for preservation of tamarillo.

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2. Materials and methods

2.1. Fruit samples

The golden-yellow cultivar "anaranjado gigante" and the purple-red cultivar "morado gigante" were harvested at physiological development from a farm in Yaruquí (Imbabura, Ecuador), and subsequently transported to the Laboratory of Postharvest (Quito, Ecuador). Immediately after arrival, fruits were randomized, selected, cleaned and processed.

2.2. Chemicals

In order to clean the fruit, a solution of Citrex 2 mL/L were used, this chemical was purchased from Island Tech (Washington, USA).

H_2SO_4 standard solution and NaOH were purchased from Merck (Darmstadt, Germany).

2.3. Methodology

2.3.1. Determination of the dose effect on the global postharvest quality of tamarillos

Fourteen kg of tamarillo fruits were labelled and set in 14 baskets to be irradiated with a Co-60 source at doses of 250, 500, 1000, 1500, 2000, 2500 and 3000 Gy. After the irradiation was finished, firmness (McCormick Fruit Tech penetrometer, FT 327, Washington, USA), TSS (total soluble solids content) (Westover refractometer, RHB-32, Minnesota, USA), pH (Hanna Instruments pHmeter, HI3220, Washington, USA), appearance of the fruit and peduncle and fruit flavor were tested for each batch of fruit.

The appearance of the fruit and peduncle were analyzed in 1–5 scale, where 5 was scored to fruit with no damage and turgid and green fresh peduncles, and 1 was scored to fruit with very low turgor and damage and very withered penduncles.

2.3.2. Treatments application order

In this experiment, groups of 200 tamarillos were treated with irradiation at 1000 Gy and coated with the Sta-Fresh 2505 coating. The first group of fruits were irradiated and then coated, and the second group were coated and then irradiated, with the aim of determine if the order of application had any effect on the properties of firmness, weight loss, TSS, pH, appearance of the fruit and peduncle, and fruit flavor. After treatment, all samples were stored at 20 °C and 80% RH. Thirty tamarillos of each treatment were analyzed, after 2, 3, 4, 5 and 6 week of storage.

2.3.3. Purple-red tamarillos radiosensitivity

Due to an internal damage in the pulp of purple-red tamarillos during the previous experiment, it was decided to test lower doses to prevent this effect. For this purpose a batch of 200 tamarillos for each dose were irradiated at doses of 250, 500 and 750 Gy and, then, stored at 20 °C and 80%RH. After 2, 3, 4, 5 and 6 week of storage 30 tamarillos for each dose were analyzed. The overall sensory quality of the fruit and the appearance of the fruit and the peduncle, firmness, weight loss, TSS, pH and internal appearance of the fruit were evaluated.

2.3.4. Effect of coating-irradiation combination on fruit quality

Purple-red and golden-yellow tamarillos were irradiated at 500 Gy. Another group of tamarillos were coated with Sta-Fresh 2505 coating. A third group of tamarillos were irradiated at 500 Gy, and then coated with Sta-Fresh 2505 coating. Also, a control group, consisting on non-treated fruit, was stored along with the rest.

All treated samples were stored for up to 10 weeks at 5 °C and 90% RH. Physico-chemical and sensory fruit quality was assessed every two weeks at 5 °C plus a shelf life period of one week at 20 °C and 80% HR to simulate shelf life. A batch of 40 fruits was analyzed to determine the internal and external appearance, the appearance of the peduncle, firmness, soluble solids, pH, respiration rate (CO_2/O_2 rapid analyzer, Post-Harvest Research, VIA- 510), aroma, sensory hardness and flavor.

3. Results and discussion

3.1. Determination of the dose

Total soluble solids, pH, appearance of the fruit and peduncle and fruit flavor did not change due to radiation at any irradiation dose. In contrast, the dose had a significant effect on firmness. The higher firmness of the golden-yellow tamarillos was 35.7 N for the control fruit, and the lowest was 23.9 N for fruit irradiated at 3000 Gy. Furthermore, the firmness of this cultivar had no difference ($p > 0.05$) for doses below 2000 Gy. While the higher firmness of the purple-red tamarillos was 34.1 N for the tamarillos irradiated at 500 Gy, and the lowest was 22,0 N for the tamarillos irradiated at 3000 Gy. Moreover, the firmness of this cultivar had no statistically significant ($p > 0.05$) for doses below 1000 Gy, at higher doses the firmness decreased significantly, as presented in Fig. 1. Thus, the dose chosen for the next experiments was 1000 Gy, and the cultivar selected was the purple-red because it presented the highest change on firmness.

The effect of irradiation on the firmness of fruit can be positive or negative; it depends on both the fruit and the dose. In this way, irradiation could increase the loss of firmness by damaging cell membranes if the dose were too high for a particular fruit, or it could decrease the loss of firmness by slowing certain metabolic processes if the dose were appropriate for the fruit (Silva, Villar, & Pimentel, 2012). This experiment showed that any dose above 1000 Gy would damage the fruit so its firmness would decrease significantly.

3.2. Treatments application order

The order of application of the treatments had not a significant effect on the firmness, weight loss, TSS, pH, appearance of the fruit and peduncle, and fruit flavor. However, during storage, a visual damage in the pulp of the tamarillos was noticed. To determine the dependence of this damage with the irradiation dose, the lower doses were studied in the next experiment.

3.3. Purple-red tamarillos radiosensitivity

During storage the weight loss of the irradiated tamarillos at all doses were significantly ($p < 0.05$) lower than the control. After five weeks of storage, the weight loss of the irradiated tamarillos was 34.5% for 250 Gy, 42.3% for 500 Gy, and 48% for 750 Gy (Fig. 1). The loss of firmness was also lower in the irradiated fruits than in the control samples. The loss of firmness was 51.8% lower than the control for the tamarillos irradiated at 250 Gy, 25.0% lower for a dose of 500 Gy, and the firmness of the tamarillos irradiated at 750 Gy had no significant difference ($p > 0.05$) with the control. As can be seen at this range of dose, with higher doses the loss of weight and the decay of firmness was slower.

An internal damage in the pulp was detected during experimentation. The flesh around the loculos of the purple-red tamarillos, which is normally orange, got a purplish color, as it is shown in Fig. 2. This damage could have been caused by a leakage of the pigments that gives the color to the placenta, due to damage in the cell wall of the membrane that encloses the placenta (Fan, Sokorai,

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