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Ripening of 'Tainung 1' Papaya Fruit Delayed by 1-Methylcyclopropene

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In order to investigate the effects of postharvest application of 1-methylcyclopropene (1-MCP) on the ripening of 'Tainung 1' papaya, an experiment was carried out at the Embrapa Cassava & Tropical Fruits Research Center in Cruz das Almas, Bahia State, Brazil. Fruit were harvested at the color break stage, washed and immersed in water with 100 ppm free chlorine for 3 minutes and air dried. Fruit were treated with gaseous 1-MCP (100 or 300 nL·L^{-1}), obtained by dilution of the commercial powder (SmartFresh®) in water in hermetically sealed chambers (186 L) during 12 hours at 22 °C. Control fruits were held in air. Subsequently, fruits were allowed to ripen at 27 °C and 80% relative humidity. Quality evaluations were assessed on four fruit replicates on the day of harvest and every 3 days during 12 days for epidermal color, pulp firmness, soluble solids content, and total titratable acidity. 1-MCP effectively delayed epidermal color development and strongly affected pulp firmness. Treated fruits reached the >75% yellow stage 6 days later than the control for both concentrations. Control fruit softened rapidly (in 3 days), while fruit treated with 1-MCP at 100 nL·L^{-1} did not soften significantly until after 12 days of storage; those treated with 300 nL·L^{-1} showed the first sign of softening after 12 days. The results showed that 1-MCP is highly effective in delaying ripening of 'Tainung 1' papayas. The effects were stronger with 300 nL·L^{-1}.

Papaya (*Carica papaya* L.) is originally from southern Mexico and Central America, but has now spread to tropical and subtropical regions all over the world (Crane, 2005). Brazil is the main papaya producer in the world (25%), followed by Mexico (10%). The United States has only 0.2% of the world production (Food and Agriculture Organization of the United Nations, 2007), which is concentrated in Hawaii and a small industry in Florida (Crane, 2005).

Two groups of papayas can be distinguished. The first group consists of small, pear-shaped and low-weight fruits, including 'Rainbow', 'Kapoho', and 'Sunrise', the main varieties grown in Hawaii (National Agricultural Statistics Service, 2006). The second consists of larger and heavier fruits, including 'Tainung 1', the main large-type papaya grown in Brazil, 'Red Lady', and 'Maradol'.

One of the latest and most successful postharvest technologies is the compound 1-methylcyclopropene (1-MCP), a potent inhibitor of the ethylene receptor that is highly effective in delaying ripening and/or extending shelf-life of many horticultural products (Blankenship and Dole, 2003). The commercial use of 1-MCP began with ornamental crops, expanding its registered and legal use to many fruits and vegetables, such as apple, avocado, papaya, and tomato (Watkins, 2006).

Very low concentrations of 1-MCP (90 and 270 nL·L^{-1}) were effective in delaying ripening of 'Sunrise Solo' papayas, increasing the shelf-life by 2 d (Jacomino et al., 2002). A longer shelf-life extension (15 d) was noticed for 'Solo' papayas when fruits were treated with 1-MCP at a very high concentration, 25 µL·L^{-1} (Hofman et al., 2001). Fruits at the color break stage are more affected by this inhibitor, but papayas in more advanced stages of maturity can be affected as well, as shown for 'Sunrise Solo' (Ergun and Huber, 2004) and 'Golden' (Bron et al., 2006). The purpose of this study was to investigate the effects of a postharvest application of 1-MCP on ripening of 'Tainung 1' papaya.

Materials and Methods

PLANT MATERIAL. Papaya (*Carica papaya* L.) cv. Tainung 1 fruit were obtained from an experimental area at the Embrapa Cassava & Tropical Fruits Research Center in Cruz das Almas, Bahia State, Brazil. Fruit at the color break stage (<10% yellow) were harvested early in the morning and immediately transported to the Postharvest Laboratory at the same institution.

EXPERIMENTAL SETUP. On the same day of harvested, the fruit were selected for uniform color and absence of wounds, washed with tap water, immersed in water with 100 ppm free chlorine for 3 min and air dried. Fruits were treated in hermetically sealed chambers (186 L) during 12 h at 22 °C with gaseous 1-MCP (100

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or 300 nL·L^{-1}), obtained by dilution of the commercial powder (SmartFresh®, 0.14% a.i.) in water. Control fruits were held in air. Subsequently, fruits were allowed to ripen at 27 °C and 80% relative humidity to simulate ambient handling conditions in this region. Quality evaluations were assessed on four fruit replicates on the day of harvest and every 3 d for 12 d.

Epidermal color. Fruit epidermal color was determined according to a visual rating scale according to the percentage of yellow of the skin, as follows: 1 (<10%); 2 (10% to 25%); 3 (26% to 50%); 4 (51% to 75%); 5 (>75%). Mean values were obtained from three experienced workers.

Pulp firmness. Measurements were taken in two opposite points in the equatorial region with a hand-held penetrometer (model FT 327; Effegi, Torino, Italy) equipped with an 8-mm convex tip probe. A disc of skin was removed with a peeler and the tip was penetrated until the scribed line of the tip and the maximum force for penetration was recorded. The same person did the measurements throughout the experiment to reduce variation between evaluations. After firmness measurement, fruits were peeled and deseeded and immediately processed in a juicer (model RI6720; Walita, São Paulo, Brazil) to obtain homogenized pulp juice for subsequent determination of soluble solids content and total titratable acidity.

Soluble solids content and total titratable acidity. About three drops of the homogenized pulp juice were dropped in the hand-held refractometer (model RT-30 ATC; Instrutherm, São Paulo, Brazil) for direct quantification of soluble solids content (%). Three grams of the homogenized pulp juice were diluted with 30 mL distilled water, and the solution was titrated with 0.1 N NaOH until pH 8.2 with a semi-automatic titrimeter (model Dosimat 775; Metrohm, Herisau, Switzerland). The results were expressed in percent citric acid.

Experimental design and statistical analysis. The experiment was run in a completely randomized design with four replicates of one fruit. Data were subjected to analysis of variance and treatment means were compared using Tukey's test ($P < 0.05$). All statistical analyses were performed with the statistical package SISVAR (Ferreira, 2000).

Results and Discussion

Color development. The 1-MCP effectively delayed epidermal color development, with a stronger effect at the highest concentration (Fig. 1). Treated fruits reached >75% yellow (score 5) 6 d after the control for both concentrations used. The greatest increase in epidermal color score in control fruits occurred during the first 3 d of ripening, when 62.5% of the yellowing occurred. For the concentration of 100 nL·L^{-1} the fastest changes in epidermal color (56.3%) happened 6 d later than control fruits, from 6 to 9 d of storage. For the fruit treated with 300 nL·L^{-1}, the greatest changes (62.5%) occurred during the last period of evaluation, from 9–12 d of storage.

Retention of green color is a common effect of 1-MCP, but since the color is related to marketable appearance of the product, irreversible color retention is not desirable (Watkins, 2006). A deleterious effect of 1-MCP at 500 nL·L^{-1} on fruit appearance was observed for 'Williams' bananas, when fruits had uneven coloring and blotchy appearance (Harris et al., 2000). Color break 'Sunrise Solo' papayas had slower yellowing when treated with 1-MCP at 90 or 270 nL·L^{-1} 1-MCP, without affecting final color development (Jacomino et al., 2002). In the present study, all the fruits reached full color development. It is possible to conclude that 1-MCP delayed this ripening event without affecting its extension, a property that can be a great advantage for the market.

Pulp firmness. There was a clear difference in firmness between control and treated fruits (Fig. 2). Control fruits softened rapidly. More than 80% of the softening occurred during the first 3 d of storage, while those treated with 100 nL·L^{-1} did not soften significantly until the end of this study, when an average of almost 40% of pulp softening was observed from 9 to 12 d of storage. The highest concentration of 1-MCP had even stronger effects, delaying softening until the last period of evaluation, when only 19% of the softening was noticed.

Bron et al. (2006) observed that 1-MCP can retain firmness of 'Golden' papayas even in more advanced stages of maturity and also that the effect of the product on firmness was stronger than for color. In the present study, the fruits showed full color development, while the pulp firmness was still strongly affected by 1-MCP. Pulp from treated fruits clearly had normal color development, but also developed a rubbery texture where the pulp was more elastic and firmer than normally ripened fruits. This was similar to the observations made for the smaller types of papaya 'Gold' and 'Rainbow' when treated with 1-MCP at

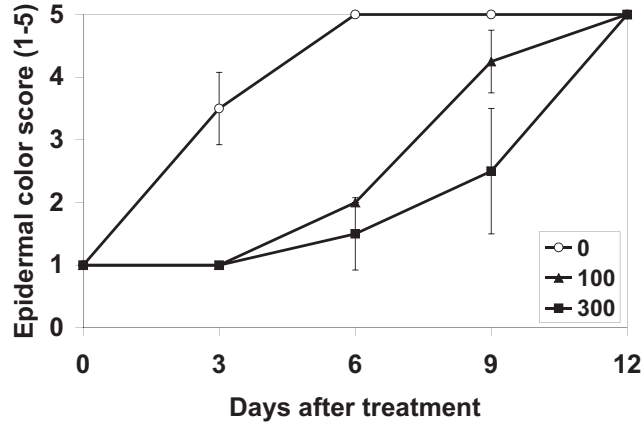

Fig. 1. Epidermal color score of 'Tainung 1' papaya fruits treated with 1-MCP (0, 100, or 300 nL·L^{-1}) during storage at 27 °C. Vertical bars represent standard deviations of the means.

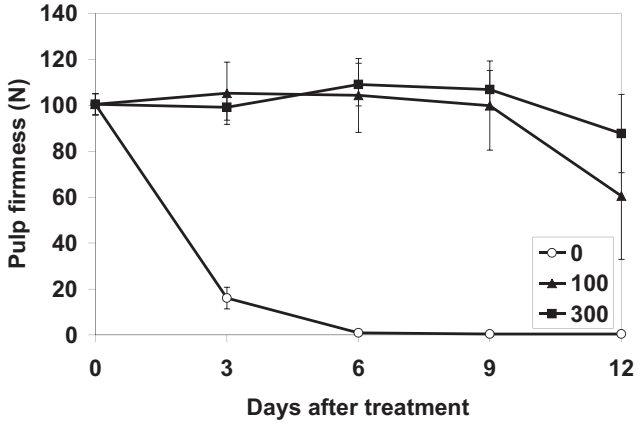

Fig. 2. Pulp firmness of 'Tainung 1' papaya fruits treated with 1-MCP (0, 100, or 300 nL·L^{-1}) during storage at 27 °C. Vertical bars represent standard deviations of the means.

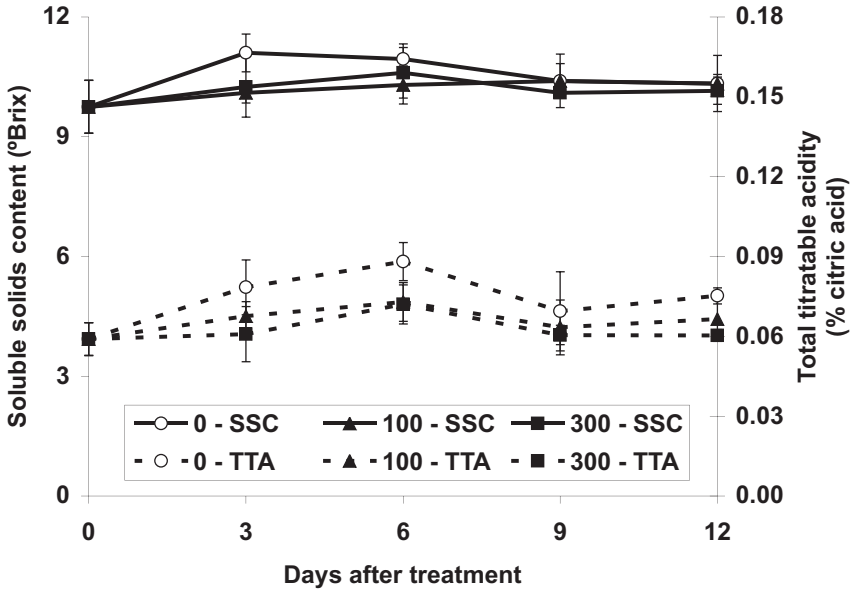

Fig. 3. Soluble solids content (full line) and total titratable acidity (dashed line) of 'Tainung 1' papaya fruits treated with 1-MCP (0, 100 or 300 nL·L^{-1}) during storage at 27 °C. Vertical bars represent standard deviations of the means.

the color break stage (Manenoi et al., 2007). According to Jiang et al. (2003), the development of this texture might be related to the inhibition of pulp pectinesterase activity. The results of the present study suggest that softening, a complex event during ripening, might be more ethylene-dependent than color development in 'Tainung 1' papaya.

Soluble solids content and total titratable acidity. There were no significant differences among treatments in the soluble solids contents, and only a slight difference in total titratable acidity with the lower acidity in the fruits treated with 300 nL·L^{-1} (Fig. 3). No differences for these attributes were found for 'Golden' (Bron et al., 2006) and 'Sunrise Solo' (Jacomino et al., 2002), although in the later variety a significant difference in titratable acidity was observed in fruits treated with 1-MCP at 9 μL·L^{-1} (Ergun and Huber, 2004). The use of postharvest dips of the ethylene inhibitor AVG (up to 750 ppm) in the large-type papaya 'Red Lady' did not promote significant differences in these two attributes when compared to the control (Berry et al., 2004).

The incidence of decay was delayed in fruits treated with 1-MCP compared to control (data not shown). Similar findings were observed for pre-ripe (10% to 20% yellow) 'Sunrise Solo' papayas treated with 1-MCP at 9 μL·L^{-1} (Ergun and Huber, 2004) and for 'Golden' and 'Rainbow' papayas; the latter exhibited decay later than untreated fruit (Manenoi et al., 2007). In contrast, the severity of external blemishes and rots in 'Solo' papayas increased when treated with 1-MCP (Hofman et al., 2001).

The results observed in this study indicate that 1-MCP is highly effective in delaying ripening of 'Tainung 1' papayas and this might be of commercial importance. The effects were stronger at the highest 1-MCP concentrations. Nevertheless, future research should give special attention to ripening stage, since fruits did not soften properly under the conditions of this study.

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