

## PRE- AND POSTHARVEST APPLICATION OF RETAIN® TO 'RED LADY' PAPAYA FRUIT: EFFECTS ON HARVEST MATURITY, RIPENING AND QUALITY

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**Abstract.** Papaya (*Carica papaya* L.) is becoming an important fruit for fresh and processed products. Tropical fruits, such as papaya, encounter greater problems during transport and storage due to increased perishability. ReTain®, a commercial formulation of aminoethoxyvinylglycine (aviglycine HCL, or AVG), inhibits the synthesis of ethylene. AVG has been reported to delay abscission which increased fruit color, retarded softening, and increased vegetative growth when applied as a preharvest spray in apple; it also delayed softening and decreased ethylene production in peach when applied pre-or postharvest. The first experiment investigated the postharvest application of ReTain® (0, 250, 500, and 750 ppm) on subsequent fruit ripening and quality of 'Red Lady' papaya, an elongated, red-fleshed type. Fruits were harvested at colorbreak stage and held overnight at 20 °C (68 °F); the next day they were immersed, stored for 7 days at 13 °C, and then transferred to 20 °C and 90% relative humidity for ripening. The papaya fruit reached full-ripe stage >15 days after harvest and there were no significant differences between treatments for the quality parameters tested. Soluble solids content was 10.8 to 10.9 °Brix, total titratable acidity was 0.14 to 0.17% and pH was 5.2 to 5.3. Firmness was 13.2 to 17.4 N and variable due to the erratic presence of hard sections in the ripe pulp. In a related experiment, ReTain® was applied at 300 ppm (0.5 g) per papaya plant in a commercial orchard. The objective was to determine if ReTain® application delayed harvest maturity. For the next 21 days fruit maturation was assessed every three days until the fruit reached commercial harvest maturity (colorbreak). Preharvest ReTain® sprays had only a slight tendency to delay papaya fruit maturation under the conditions tested, not enough to be commercially important. Results from both studies indicated that AVG applications had little effect on delaying harvest maturity or postharvest ripening of 'Red Lady' papaya.

Papaya (*Carica papaya* L.) is a member of the family Caricaceae and is rapidly becoming an important fruit for fresh and processed products. In 2003 the United States produced 22,000 t of papaya and in 2002 imported over 88,000 t (FAOSTAT, 2004). For local markets, fruit may be harvested when the skin color reaches 80% yellow. Otherwise, fruit des-

tinued for storage or long-distance transportation is picked at the colorbreak stage, or the first appearance of yellow coloration. The fruit must be handled properly in order to avoid injuries causing leakage of latex, which stains the fruit and reduces consumer acceptance (Morton, 1987). Papaya fruit have a maximum storage life of 7 d under ambient tropical conditions (30 °C/86 °F); temperatures above 32.5 °C cause abnormal ripening (An and Paull, 1990). Storage at 12 to 16 °C results in best postharvest quality. Storage below 10 to 12 °C (50 to 54 °F) may cause chilling injury, depending upon the maturity stage (Chen and Paull, 1986).

Postharvest diseases are a critical factor in reducing market quality of papaya fruit and are the primary cause for losses that occur during shipment. A study conducted in Hawaii in 1986, on postharvest diseases in papaya, reported postharvest losses of 10 to 40% in surface shipments and of 5 to 30% in air shipments. Papaya fruit loss due to diseases reached 93% depending on postharvest handling and packing procedures (Alvarez and Nishijima, 1987). Diseases are of three general types: fruit surface rots, stem-end rots, and internal infections (Alvarez and Nishijima, 1987).

Physiologically, the papaya is a climacteric fruit with typical respiratory and ethylene patterns during ripening (Selvaraj et al., 1982). The promotion of plant senescence due to endogenous ethylene can be inhibited by several compounds including aminoethoxyvinylglycine (AVG), marketed as ReTain®. Research on the effectiveness of AVG has been conducted on a variety of agricultural products including apple, avocado, citrus, cocoa, kiwi, melon, peach, pear, and tomato. Commercially, AVG is primarily used as a preharvest spray, mostly in apples, to delay ethylene production and fruit ripening in the field. Preharvest application of AVG has been reported to delay softening in "Gala" (Layne et al., 2002) and "Delicious" apples (Williams, 1980). However, documentation of postharvest treatment with AVG is less common. Postharvest application can also be used to prevent deleterious effects of ethylene on fruit quality. Research has shown that 'Snow King' peaches dipped in 50 mg L<sup>-1</sup> AVG for 60 sec showed reduced softening and ethylene during storage at 20 °C (Garner et al., 2001). These studies were conducted to determine the effect of various concentrations of ReTain®, applied postharvest (0, 250, 500, and 750 ppm), on fruit ripening and quality as well as to determine if ReTain®, applied preharvest (300 ppm), delayed harvest maturity of 'Red Lady' papaya.

### Materials and Methods

#### Postharvest Test

**Plant Material.** Papaya (*Carica papaya* L.) cv. Red Lady fruits were obtained from a commercial grower in Homestead, Fla. Papaya fruit was harvested on September 24, 2003, packed in fiberboard cartons, and transported to the Postharvest Horticulture Laboratory in Gainesville within approximately 6 h of harvest. Approximately, 120 fruit were picked at color break stage from 5 randomized blocks (20 plants per block).

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*Experiment Setup.* Each papaya fruit was gently washed in 100 to 200 ppm chlorinated water for about 1 min, and then allowed to air dry. Fruits were then sorted to remove any over-ripe or damaged fruit. Treatment solutions were formulated using ReTain® (AVG) stated to have 85% purity as follows: 0 (tap water only, control), 250, 500, and 750 ppm. Five fruits, one from each block, were dipped in each treatment solution for 2 min, allowed to air dry. Once the fruits were dry they were boxed up again, to avoid mixing fruit from different field blocks. The fruits were then placed at 13 °C for 1 week to simulate commercial handling. After 1 week at 13 °C the fruits were transferred to 20 °C for ripening.

*Days to ripe.* Ripeness of individual papaya fruit was determined subjectively using a visual rating scale as follows; 0-25%, 25-50%, 50-75%, 100% orange. Fruits were considered to have reached table-ripe stage when they began to noticeably soften, which occurred at about 75% epidermal color change.

*Decay.* Ripe papaya fruit was evaluated for decay using the Horsfall-Barrett scale, which is a visual determination of the percent area of fruit surface affected by decay.

*Color.* Fruit skin (equatorial region) and flesh (centermost mesocarp) color were assessed as lightness (L\*, where 0 = black, 100 = white), hue angle (H, where 90° = yellow and 180° = green) and chroma (C, where the higher the value, the more intense the color) values using a chromameter (Minolta-CR-200, Japan). Two readings were made and averaged for both external and internal color.

*Firmness.* Pulp firmness was determined from the bioyield point, the maximum firmness value, using an Instron Universal Testing Instrument (Model 4411, Canton, Mass.). Each fruit was sliced equatorially (about 1 inch thick) and an 11-mm convex tip probe was extended into the slice until the bioyield point was reached. Then, the slice was peeled and seeded then the flesh was frozen at -20 °C (-4 °F) for later determination of total soluble solids (°Brix), total titratable acidity, and pH.

*SSC, TTA, pH.* The previously frozen papaya tissue samples were thawed, homogenized in a laboratory blender at high speed for 2 min. The homogenates were centrifuged at 11,000 rpm for 20 min, filtered through cheesecloth, and the soluble solids content (SSC) of the resulting clear juice samples was measured with a digital refractometer (Abbe Mark II -10480, Buffalo, N.Y.). The pH of the juice samples was determined using a pH meter (Corning, pH meter 140, Medfield, Mass.), that had been previously standardized to pH 4 and pH 7. Aliquots (6.00 g) of the juice were diluted with 50 mL distilled water and the total titratable acidity (TTA) determined by titration with 0.1 N NaOH to an end point of pH 8.2 with an automatic titrimeter (Fisher Titrimeter II, No. 9-313-10, Pittsburg, Pa.). The results were converted to percent citric acid using the following equation;  $[(\text{mL NaOH} \times 0.1 \text{ N} \times 0.064 \text{ meq} \cdot 6.00 \text{ g of juice}^{-1}) \times 100]$ .

*Statistical Analysis.* Data was subjected to analysis of variance and treatment means were compared using Duncan's Multiple Range Test ( $P < 0.05\%$ ).

#### Preharvest Test

*Experiment setup.* The experiment was conducted in a commercial 'Red Lady' papaya orchard in Homestead, Fla., where the plants were grown under black plastic mulch and drip-irrigated. The purpose of the experiment was to determine if

a preharvest AVG spray on full-grown but immature papaya fruit could slow maturation allowing for a prolonged harvest period. Eight blocks containing both treatments were randomly assigned to plants within a uniform part of the orchard. There were eight replicate plants/treatment and two fruit were tagged per plant for observation.

On October 22, 2003 AVG, applied at 300 ppm (0.5g per plant), was sprayed to cover the entire trees with a Solo backpack mist blower. Silwet L-77 adjuvant was added to the spray mixture at 0.05% to improve AVG uptake. The spray solutions used well-water from the local area.

*Days to maturity.* Visual observations of fruit color change (commercial maturation) on the sprayed and control plants were taken every three days for 21 d to determine if the treated fruits matured slower. The following scale was used at each observation time to rate papaya fruit color; 0 = Dark green, 1 = Light green, 2 = 1-30% yellow, 3 = 31-99% yellow, 4 = 100% yellow. Fruit with a color rating between 2.5 and 3.5 were considered optimum for harvest. The fruit are normally hand harvested, by crews using ladders, and packed into corrugated cartons in the orchard. On the 21st day after treatment fruits were evaluated for the last time and then harvested and photographed.

## Results and Discussion

#### Postharvest Test

*Days to ripe.* There were minor differences between treatments and blocks with respect to the days to reach table-ripe stage. However, fruit from all treatments reached table-ripe stage in approximately 14 d from harvest (Table 1). Therefore, the AVG treatments did not provide a commercially significant delay in ripening for the papaya fruit tested.

*Decay.* No statistical differences in incidence of decay due to AVG treatment were found (Table 1). The decay values ranged from 1.5 to 1.7 and were based on the Horsfall-Barrett scale, where 1 = 0.1 to 3% of product affected.

*Color.* There were no significant differences in external or internal color (Hue angle) for papaya due to treatment. Hue angles measured at table-ripe stage were in the range from 0° = red, 45° = orange and 90° = yellow. Values for both external (70.6° to 71.9°) and internal (42.4° to 43.3°) color parameters were similar for each treatment, indicating no deleterious effect due to treatment (Table 2).

*Firmness.* The firmness values at table-ripe stage ranged from 13.2 N to 17.3 N and were not significantly different (Fig. 1). Variability in the firmness data was due to differences in the type of internal tissue. During firmness measurement we noticed that about 20% of all the fruits contained from

Table 1. Days to table-ripe and decay ratings for papaya.

AVG (ppm)	Days to ripe	Decay
0	14.2 b <sup>y</sup>	1.7 a <sup>z</sup>
250	14.3 ab	1.6 a
500	14.6 a	1.5 a
750	14.4 ab	1.7 a

<sup>y</sup>Values based on the Horsfall-Barrett scale, where 1 = 0.1 to 3% of product surface affected.

<sup>z</sup>Columns with different letters are significantly different at  $P < 0.5$ , according to Duncan's Multiple Range Test.

Table 2. External and internal color (Hue angle) and firmness for table-ripe papaya.

AVG (ppm)	Hue Angle		Firmness (N) <sup>z</sup>
	External color	Internal color	
0	71.7 a <sup>y</sup>	42.4 a	17.3 a
250	71.9 a	42.4 a	14.1 a
500	71.4 a	43.3 a	13.2 a
750	70.6 a	43.0 a	14.4 a

<sup>z</sup>1 Newton = 0.224 lb-f.

<sup>y</sup>Columns with different letters are significantly different at P < 0.5, according to Duncan's Multiple Range Test.

one to five hard sections of pulp tissue around the cavity. These sections appeared as water soaked areas but were not always visible prior to firmness measurement, resulting in some abnormally high firmness values.

The only other report of hard areas in ripe papaya flesh is that of a physiological disorder termed hard core by Chen and Paull (1986) and attributed to chilling injury. In that report solo-type papayas at the mature-green stage were subjected to chilling temperature regimes. Upon reaching the ripe stage the authors found white, hard areas in the flesh that did not soften during ripening. In this present test, however, the fruits were never exposed to temperatures below 13 °C; therefore, the cause remains unknown.

*SSC, TTA and pH.* There were no differences in SSC, TTA or pH between the various AVG treatments (Table 3). The values ranged from 10.7 to 10.9 °Brix for SSC, 5.2 to 5.3 for pH, and 0.14 to 0.17% for TTA, and fruits had typical aroma and flavor as noted by informal taste tests.

#### Preharvest Test

Although there was a slight tendency for slower color change (Fig. 2) and delayed harvest maturity (Fig. 1) in the treated fruit, data analysis (t-test) showed no significant differences due to AVG treatment. AVG treatment would likely not have resulted in an extended harvest period for the orchard.

The results of this research determined that preharvest sprays (300 ppm) and postharvest dips of AVG (250, 500, and 750 ppm) had no significant effects on harvest maturity, rip-

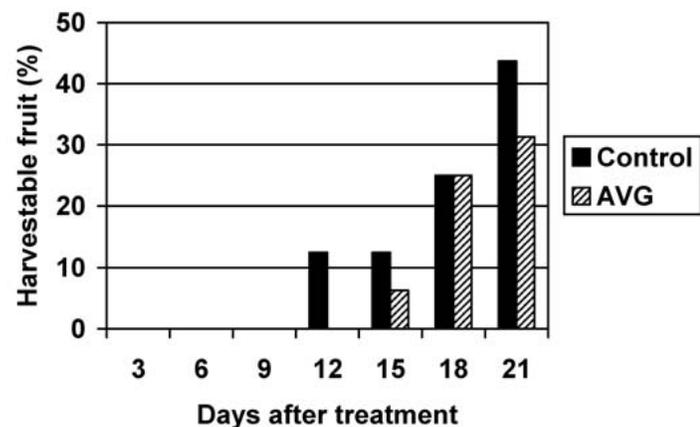


Fig. 1. Papaya fruit maturation based on the number of harvestable fruit after AVG treatment (300 ppm).

Table 3. Chemical analysis for table-ripe papaya.

AVG (ppm)	SSC <sup>z</sup> (°Brix)	TTA (%)	pH
0	10.8 a <sup>y</sup>	0.15 a	5.3 a
250	10.9 a	0.16 a	5.2 a
500	10.7 a	0.14 a	5.2 a
750	10.8 a	0.17 a	5.2 a

<sup>z</sup>SSC = Soluble Solids Content; TTA = Total Titratable Acidity (citric acid equivalent).

<sup>y</sup>Columns with different letters are significantly different at P < 0.5, according to Duncan's Multiple Range Test.

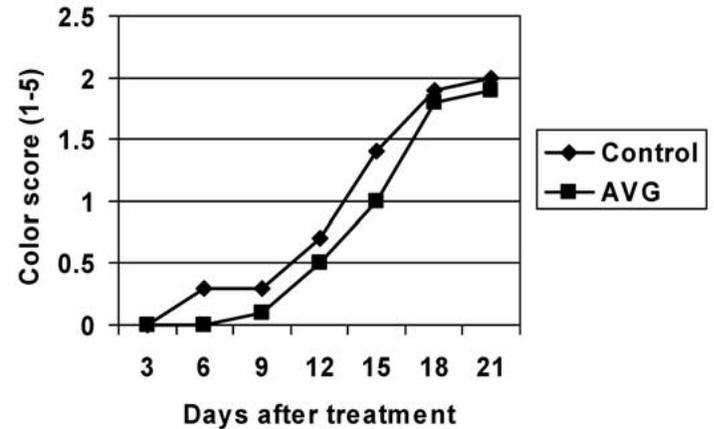


Fig. 2. Rate of papaya fruit color change prior to reaching harvest maturity (AVG treatment = 300 ppm).

ening time or table-ripe quality of 'Red Lady' papaya. Under the conditions tested, AVG did not prove to be commercially viable to delay ripening and therefore prolong shelf life of papaya fruit. Future tests should evaluate different AVG rates for pre- and postharvest studies as well as the use of adjuvants to improve uptake and application times. The incidence and severity of hard sections needs to be documented during marketing of 'Red Lady' papayas, and its physiological basis should be further investigated.

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