POSTHARVEST ETHYLENE TREATMENT FOR UNIFORM RIPENING OF WEST INDIAN TYPE AVOCADO FRUIT IN FLORIDA

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Abstract. A series of experiments were performed to determine the effects of postharvest application of ethylene on ripening uniformity and fruit quality of a late-season, West Indian-type avocado (‘Monroe’). Fruit from three harvest dates (early, mid, and late season) were treated with ethylene (100 ppm) at 13 or 20 °C for 12 or 24 hours, or held continuously in air at 13 °C. Avocados treated with ethylene (100 ppm) at 13 °C for 24 hours ripened more uniformly and had lower incidence of decay than those from the other treatments. Uniform ripening was defined as fruit within a given lot with less variability in firmness at the full-ripe stage. Fruit from all treatments exhibited no significant differences in peel color, dry matter, or oil content during ripening.

Ethylene plays a vital role in the ripening of climacteric fruits, and whether applied exogenously or produced naturally, initiates ripening and softening. The avocado (Persea americana Mill.) is one of the most rapidly ripening of fruits, often completing ripening within 5 to 7 d following harvest (Seymour and Tucker, 1993).

Ethylene treatment of detached mature avocado fruit promotes the onset of ripening (Eaks, 1966, 1980; Gazit and Blumenfeld, 1970; Zauberman and Fuchs, 1973; Zauberman et al., 1988). Treatment of mature ‘Hass’ avocados with 100 ppm ethylene for 24 h after harvest hastens the onset of ripening, making them ready to eat in 3 or 4 d (Eaks, 1966). A number of fruits, notably banana (Inaba and Nakamura, 1986), tomato (Jahn, 1975), pear (Chen et al., 1996), and mango (Barnmore, 1975), are commercially harvested prior to the onset of ripening and treated with ethylene gas to compress the ripening period and allow uniform ripening among fruits.

Avocados, especially West Indian types or their hybrids, have potential to be marketed as a premium-quality product. As with all avocado types, they do not ripen until harvested. However, this convenience creates difficulty in marketing avocados with uniform ripeness since the timing of ripening initiation can vary widely within fruit lots, depending upon the stage of maturation at harvest and the variety. Unlike Guatemalan types, Mexican types, or their hybrids, the influence of ethylene on the ripening of West-Indian type avocados has not previously been investigated. Programmed ripening would give shippers the ability to ship high quality, uniformly ripe avocados and lead to the implementation of a premium-quality avocado program.

The objectives of this research were to determine the effects of ethylene gassing temperature and duration on quality, time to ripen, ripening uniformity, and shelf life of the West Indian ‘Monroe’ avocado.

Materials and Methods

Plant Material. Avocado fruit, cv. Monroe, were selected for this study. A late-season avocado variety, ‘Monroe’ is a hybrid of West Indian and Guatemalan avocado types and is moderately cold sensitive (Crane et al., 1996; Hatton and Reeder, 1965). Fruit were obtained from a commercial packinghouse in Homestead, Florida, packed in fiberboard cartons, and transported to the Postharvest Horticulture Laboratory in Gainesville within 24 h of harvest. Individual experiments were carried out for fruit harvested at early (20 Nov. 1998), mid- (4 Dec. 1998), and late- (18 Dec. 1998) season dates. Fruit were selected for uniformity of weight (757 ± 31 g) and shape (diameter at equatorial region, 10.5 ± 0.7 cm).

Ethylene Treatment. Forty-eight fruit were placed in a 174 L chamber and treated with flow-through air or 100 ppm ethylene at a flow rate of 4 L-min. CO2 in the treatment chambers did not exceed 0.05%. Ethylene treatment was performed for two exposure periods (12 or 24 h), two temperatures (13 or 20 °C) and 85% relative humidity (RH). Following the ethylene treatment, all fruit were transferred to storage rooms at 13 °C (85% RH) and stored for 7 or 14 d. Control fruit (not exposed to ethylene) were maintained under identical storage conditions. After 7 d at 13 °C, fruit from each treatment were transferred to 20 °C (85% RH) and evaluated for fruit quality at the full-ripe stage (firmness values 10 to 15 N). Fruit quality was assessed on the basis of fruit firmness, peel color, pulp dry matter and oil content, and incidence of decay. Oil content was determined at harvest and at the full-ripe stage. Incidence of decay was measured as the percentage of fruit exhibiting decay at the stem-end or on the peel.

Fruit firmness. Firmness was determined on whole, unpeeled fruit using an Instron Universal Testing Instrument (Model 4411, Canton, MA, USA) fitted with a flat-plate probe (5 cm in diameter) and 50 kg load cell. After establishing zero force contact between the probe and the equatorial region of the fruit, the probe was driven with a crosshead speed of 10 mm-min1. The force was recorded at 2.5 mm deformation and was determined at two equidistant points on the equatorial region of each fruit.

Peel color. Individual fruit were marked at the equatorial region (2 regions per fruit), and color at the same location was recorded every other day as L*, hue angle, and chroma value with a Minolta Chroma Meter CR-2000 (Minolta Camera Co., Ltd., Japan). The chroma meter was calibrated with a white standard tile. The color was reported as hue angle (°), with a value of 90° representing a totally yellow color and 180°
a totally green color. The results are presented as lightness (L*), chroma (C*), and hue angle (°).

**Pulp dry matter and oil content.** Each fruit was cut into longitudinal slices, and the peel and seed discarded. A pulp sample (5 g) from the longitudinal slice was weighed, dried at 60°C in an oven for 48 h, and then re-weighed. Oil content was determined using modifications to the procedure of Folch et al. (1957). Mesocarp tissue (0.5 g) from the equator of each fruit was homogenized with 15 mL of chloroform methanol (2:1, v/v) for 1.5 min using a Polytron (Kinematica Gmbh Karens, Lunzern, Switzerland) homogenizer at speed setting #7. The samples were filtered through GF/C filter paper (Whatman) and re-extracted with 15 mL of chloroform methanol (2:1, v/v). Twenty-five percent of the total volume of 0.88% KCl was added, and the samples were transferred to a separatory funnel. The lower, lipid-containing layer was removed and washed with 25% of total volume of distilled H2O. The samples were dried with anhydrous sodium sulfate for 12 h and re-extracted with 15 mL of chloroform methanol (2:1, v/v). Twenty-five percent of the total volume of 0.88% KCl was added, and the samples were transferred to a separatory funnel. The lower, lipid-containing layer was removed and washed with 25% of total volume of distilled H2O. The samples were dried with anhydrous sodium sulfate for 12 h and filtered into tarred test tubes. The solution was evaporated with an Evapomix (Buchler Instruments, Inc.) maintained below 50 °C for 12 h. The tubes were again weighed for estimation of total oil content.

**Statistical analysis.** The experiments were conducted in a completely randomized design. Statistical procedures were performed using the PC-SAS software package (SAS Institute, 1985).

**Results and Discussion**

**Fruit firmness.** Initial firmness of early, mid-, and late-harvest fruit averaged 177 ± 53, 176 ± 27, and 198 ± 26 N, respectively. By comparison, avocado fruit at the full-ripe stage typically exhibit firmness values in the range of 10 to 15 N. In early-harvest fruit, although firmness declined rapidly during storage, ethylene and air-treated fruit exhibited no statistical differences in average firmness values after 7 d at 13 °C or 7 d at 13 °C followed by 4 d at 20 °C (Table 1). After 14 d at 13 °C, avocados from all ethylene treatments were significantly softer (around 13 N) than air-treated fruit (33 N) and exhibited less variability in firmness. Although control fruit reached full-rripe firmness within 2 d of transfer to 20 °C after 14 d at 13 °C, over 50% of the fruit showed decay prior to reaching the full-ripe stage (data not shown). In mid-harvest fruit, firmness declined dramatically during storage for 7 or 14 d at 13 °C, but differences between ethylene-treated and air-treated fruit were not evident (Table 2). Non-uniform ripening was noted among air-treated fruit stored for 7 d at 13 °C followed by 3 d at 20 °C or 14 d at 13 °C. In late-harvest fruit, ethylene and air-treated fruit exhibited significant (P < 0.05) differences in average firmness values after storage for 7 or 14 d at 13 °C (Table 3). As with air-treated fruit from the early and middle harvest dates, fruit held in air for 7 d at 13 °C followed by 3 d at 20 °C or 14 d at 13 °C exhibited high variability in firmness (Table 3). Ethylene-treated fruit stored for 7 d at 13 °C followed by 3 d at 20 °C or 14 d at 13 °C were softer and showed significantly more uniformity in firmness than air-treated fruit stored under similar conditions (Table 3).

**Peel color and decay incidence.** At harvest, the avocado peel was moderately green (hue angle = 126.4, 124.1, and 126.5 for early-, mid-, and late-harvest fruit, respectively, where pure yellow = 90 and pure green = 180) and showed little change during storage (Tables 1, 2, and 3). At the full-ripe stage, there were no significant differences in peel color among fruit from all treatments (Tables 1, 2, and 3). Changes in hue angle constituted the major alteration of color coordinates during storage. The decline in hue angle represented the change from green to yellow. Although the peel of ripe fruit from all treatments showed a slight loss in greenness, the pulp had acceptable appearance, aroma, and taste.

Early harvest avocados stored continuously for 7 d at 13 °C exhibited no symptoms of decay (Table 1). Following an additional 4 d at 20 °C to reach the full-ripe stage, fruit from the 24-h ethylene treatment at 13 °C had the lowest incidence of decay compared with control and other ethylene treatments (Table 1). Surface decay of ethylene-treated and air-treated fruit stored for 14 d at 15 °C was observed, but was not severe (Table 1). Mid-harvest fruit from the 24-h ethylene treatment at 13 °C had the lowest incidence of decay of all treatments after 7 d at 13 °C followed by 3 d at 20 °C or 14 d at 13 °C (Table 2). Air-treated fruit stored for 7 d at 13 °C followed by 3 d at 20 °C exhibited the highest decay incidence (50%) of all treatments (Table 2). Late-harvest fruit from the 24-h ethylene treatment at 13 °C also had the lowest incidence of decay after 7 d at 13 °C and 3 d at 20 °C, or after 14 d at 13 °C (Table 3).

**Pulp dry matter content and oil content.** Initial pulp dry matter content (DMC) of early-, mid-, and late-harvest fruit averaged 16.7, 17.9, and 16.7%, respectively. In early-harvest fruit, there were no significant differences in DMC among treatments after 7 or 14 d storage at 13 °C or 7 d at 13 °C followed by 4 d at 20 °C (Table 1). The DMC of fruit from all treatments decreased slightly compared with DMC of freshly harvested fruit. In mid-harvest fruit, there were no significant differences in DMC among treatments for avocados after 7 d at 13 °C, whereas there were significant (P < 0.05) differences in DMC among treatments after 14 d at 13 °C (Table 2). After 14 d at 15 °C, fruit from the air treatment and the 24-h ethylene treatment at 13 °C lost significantly more dry matter (lower DMC) than the other treatments. In late-harvest fruit, there were no significant differences in DMC among treatments, although DMC for fruit from all treatments slightly decreased after 14 d at 13 °C compared with DMC of freshly harvested fruit (Table 3).

Initial oil content (%) of early-, mid-, and late-harvest fruit averaged 5.4, 5.4, and 5.3%, respectively, and did not change significantly during storage (Tables 1, 2, and 3), in agreement with the report that oil synthesis is essentially complete when avocado fruit are immature (Platt and Thomson, 1992) and is not metabolized during ripening (Dolendo et al., 1966). Unlike the Mexican and Guatemalan type avocados which have higher oil content (about 15 to 30%), estimating pulp oil using dry matter content was not feasible with the West Indian-type 'Monroe' due to the wide variability in oil content between individual fruit, as noted by Hatton et al. (1964). There were no significant differences in oil content among treatments after 7 d at 13 °C followed by 3 or 4 d at 20 °C and 14 d at 13 °C (Tables 1, 2, and 3). Comparing fruit from the three harvest dates, after 7 d storage at 13 °C, ethylene-treated avocados from the early harvest required 4 d at 20 °C to reach the full-ripe stage (10 to 15 N), whereas those from the middle- and late-harvests required 3 d at 20 °C (Tables 1, 2, and 3). This observation is consistent with reports that avocado fruit at more advanced maturity at harvest respond more rapidly to ethylene (Biale, 1960; Burg and Burg, 1965; Eaks, 1966; Hansen and Blanpied, 1968). However, after 14 d storage at 13 °C, ethylene-treated fruit from the three harvest dates were already soft.
Table 1. Fruit quality evaluation for ‘Monroe’ avocados from early-harvest (20 Nov. 1998) stored for 7 d at 13 °C and transferred to 20 °C or stored for 14 d at 13 °C with different ethylene treatments. Data are means ± standard deviation of 6 independent samples.

<table>
<thead>
<tr>
<th>Ethylene treatment</th>
<th>Storage time and temperature</th>
<th>7 d at 13 °C</th>
<th>7 d at 13 °C + 4 d at 20 °C</th>
<th>14 d at 13 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp (°C)</td>
<td>Time (h)</td>
<td>Fruit firmness (N)</td>
<td>Decay incidence (%)</td>
<td>Dry matter (%)</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>41.8 ± 17.5 (N)</td>
<td>0</td>
<td>15.4 ± 1.6</td>
</tr>
<tr>
<td>13</td>
<td>12</td>
<td>46.1 ± 16.0 (N)</td>
<td>0</td>
<td>17.0 ± 1.1</td>
</tr>
<tr>
<td>13</td>
<td>24</td>
<td>44.5 ± 12.8 (N)</td>
<td>0</td>
<td>16.8 ± 2.6</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td>39.4 ± 7.6 (N)</td>
<td>0</td>
<td>15.2 ± 1.1</td>
</tr>
<tr>
<td>20</td>
<td>24</td>
<td>26.9 ± 7.1 (N)</td>
<td>0</td>
<td>15.6 ± 1.4</td>
</tr>
</tbody>
</table>

Table 2. Fruit quality evaluation for ‘Monroe’ avocados from mid-harvest (4 Dec. 1998) stored for 7 d at 13°C and transferred to 20 °C or stored for 14 d at 13 °C with different ethylene treatments. Data are means ± standard deviation of 6 independent samples.

<table>
<thead>
<tr>
<th>Ethylene treatment</th>
<th>Storage time and temperature</th>
<th>7 d at 13 °C</th>
<th>7 d at 13 °C + 4 d at 20 °C</th>
<th>14 d at 13 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp (°C)</td>
<td>Time (h)</td>
<td>Fruit firmness (N)</td>
<td>Decay incidence (%)</td>
<td>Dry matter (%)</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>47.3 ± 32.6 (N)</td>
<td>0</td>
<td>16.3 ± 2.1</td>
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<tr>
<td>13</td>
<td>12</td>
<td>36.1 ± 10.7 (N)</td>
<td>0</td>
<td>17.7 ± 0.9</td>
</tr>
<tr>
<td>13</td>
<td>24</td>
<td>29.3 ± 4.5 (N)</td>
<td>0</td>
<td>16.2 ± 0.9</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td>29.6 ± 20.8 (N)</td>
<td>0</td>
<td>16.5 ± 1.7</td>
</tr>
<tr>
<td>20</td>
<td>24</td>
<td>27.6 ± 3.9 (N)</td>
<td>0</td>
<td>17.5 ± 1.5</td>
</tr>
</tbody>
</table>

Table 3. Fruit quality evaluation for ‘Monroe’ avocados from late-harvest (18 Dec. 1998) stored for 7 d at 13 °C and transferred to 20 °C or stored for 14 d at 13 °C with different ethylene treatments. Data are means ± standard deviation of 6 independent samples.

<table>
<thead>
<tr>
<th>Ethylene treatment</th>
<th>Storage time and temperature</th>
<th>7 d at 13 °C</th>
<th>7 d at 13 °C + 4 d at 20 °C</th>
<th>14 d at 13 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp (°C)</td>
<td>Time (h)</td>
<td>Fruit firmness (N)</td>
<td>Decay incidence (%)</td>
<td>Dry matter (%)</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>95.8 ± 32.8 (N)</td>
<td>0</td>
<td>15.8 ± 1.6</td>
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<tr>
<td>13</td>
<td>12</td>
<td>61.7 ± 55.9 (N)</td>
<td>0</td>
<td>16.3 ± 2.3</td>
</tr>
<tr>
<td>13</td>
<td>24</td>
<td>51.3 ± 25.5 (N)</td>
<td>0</td>
<td>16.2 ± 1.4</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
<td>50.8 ± 39.5 (N)</td>
<td>0</td>
<td>16.8 ± 2.2</td>
</tr>
<tr>
<td>20</td>
<td>24</td>
<td>28.3 ± 6.0 (N)</td>
<td>0</td>
<td>18.4 ± 2.5</td>
</tr>
</tbody>
</table>
Air-treated fruit from the three harvest dates stored for 14 d at 13 °C were somewhat firm (32.9 ± 18.9 N and 42.2 ± 33.0 N, respectively) and required 2 to 3 d at 20 °C for all fruit to reach the table ripe stage. Previous experiments with ‘Booth 7’ avocados also revealed that a 12-h ethylene treatment at 20 °C allowed the avocados to remain acceptably firm with uniform ripening after subsequent storage at 12 °C for 14 d (unpublished data).

In conclusion, this study showed that ‘Monroe’ avocados exposed to ethylene at 13 °C for 24 h ripened more uniformly than fruit treated at 20 °C for 12 h or air-treated fruit. After 14 d of storage at 13 °C, fruit from this treatment ripened normally while maintaining marketable fruit firmness, had good quality, and also had lower incidence of decay. Ethylene treatment did not affect fruit quality as determined by peel color, dry matter content, and oil content.

**Literature Cited**


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**PERFORATION-MEDIATED MODIFIED ATMOSPHERE PACKAGING OF SWEETCORN**

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