ABSTRACT

One hundred percent of Lula avocados stored in a controlled atmosphere (CA) of 2% \( \text{O}_2 \) + 10% \( \text{CO}_2 \) at 45° F. were in acceptable condition after storage for 20 or 40 days. All fruit stored in air were decayed after 40 days at either 45° or 50°. After both storage periods, avocados from CA storage were superior to those from air storage. A temperature of 45° was generally as good or better than 50° for use in CA storage.

Decay, external darkening, and percentage weight loss were significantly lower in fruit held in an atmosphere of 2% \( \text{O}_2 \) + 10% \( \text{CO}_2 \) than in air.

INTRODUCTION

Tests have been conducted for several years at Miami to develop successful methods of utilizing controlled atmosphere (CA) storage of Florida avocados. Hatton and Reeder (2) initially reported limited success with CA storage of Lula avocados in research conducted in 1965. Successful storage in 1966 of Lula avocados in 1% \( \text{O}_2 \) + 9% \( \text{CO}_2 \) at 50° F. was also reported (3).

Prior to 1968, all CA storage tests with avocados were conducted with a closed system in which the atmospheres within the storage chambers were recirculated. In 1968 a test was initiated to evaluate a constant-flow system in order to eliminate any effect from ethylene evolving from the fruit in the storage chambers. Premixed gas was obtained from a commercial source; however, instead of the 1% \( \text{O}_2 \) + 9% \( \text{CO}_2 \) level which was ordered, the gas received contained 1.2% \( \text{O}_2 \) + 9.6% \( \text{CO}_2 \).

Analysis of the gas exhausted from the storage chambers showed an \( \text{O}_2 \) content of 0.3% to 1.0% and a \( \text{CO}_2 \) content of 10.0% to 10.5%.

The flow rate of 100 ml/min was not high enough to prohibit the \( \text{O}_2 \) levels from dropping and the \( \text{CO}_2 \) levels from rising within the storage chambers due to the respiration of the fruit. Avocados held under the reduced levels of 0.3% to 1.0% \( \text{O}_2 \) for 30 and 45 days developed 64% and 32% injury, respectively. In the 1965 test (2), several fruit had displayed injury after storage in atmospheres containing 1.0% to 1.5% \( \text{O}_2 \). Subsequent tests were planned using a constant-flow system containing 2% \( \text{O}_2 \) so that respiration of the fruit would not reduce the \( \text{O}_2 \) level below 1.0% to 1.5% where injury would likely occur. An atmosphere containing 10% to 10.5% \( \text{CO}_2 \) appeared satisfactory in the 1968 tests, and a level of 10% was considered acceptable for future testing.

MATERIALS AND METHODS

Lula avocados were harvested commercially from a grove in the Homestead, Florida area on February 2, 1970. The fruit was randomized, weighed, and divided into samples of 20 fruits each. Six samples of fruit were placed in chambers containing air, three at 50° F., and three at 45°. Comparable samples of fruit were placed in CA storage chambers at 50° and 45°. All chambers were of 116-liter volume, exclusive of fruit. Premixed gas of 2% \( \text{O}_2 \) and 10% \( \text{CO}_2 \) was ordered from a commercial source; however, analysis of the gas received showed 2% \( \text{O}_2 \) and 9.5% \( \text{CO}_2 \). The premixed atmosphere was flowed through the CA chambers at a rate of 200 ml/min. Respiration within the chambers altered the atmosphere surrounding the fruit so that the gas which was exhausted contained 2% \( \text{O}_2 \) and 10% \( \text{CO}_2 \). The storage temperature used in previous CA research on avocados in Miami was 50°; in this test 45° was used to further reduce respiration levels during storage. Relative humidity, measured with an electric hydrometer, ranged from 95% to 100% in all chambers.

After periods of 20 and 40 days, samples of 20 fruits each were removed from the air and CA chambers at both storage temperatures. Avocados were scheduled to be withdrawn from storage after 60 days; however, malfunctioning of the refrigeration equipment resulted in elevated temperatures shortly after the 40-day test.
storage period, at which time the experiment was terminated. Data were recorded on weight loss, decay, and appearance upon removal from storage. Overall acceptability of the fruit was based on freedom from decay and external discoloration. Fruit considered unacceptable upon removal from storage was recorded and discarded and the remaining sound fruit was placed at 70° F. to soften. The avocados were checked daily to determine the state of softness and data were again recorded on weight loss, decay, appearance and acceptability when the fruit was soft.

Decay and external discoloration ratings were based on the total percentage of aggregate surface area affected: (0) None; (1) Trace, 1%-10%; (2) Slight, 11%-25%; (3) Moderate, 26%-50%; and (4) Severe, over 50%. Avocados with moderate and severe decay or external discoloration were considered unacceptable. Sound avocados, from each sample of fruit when soft, were evaluated by staff members for the presence of any off-flavors.

Statistical analysis of data was made after each storage period by mean separation of the functional analyses of variance and multiple comparisons (1).

RESULTS AND COMPARISON

The results of this test comparing storage of Lula avocados in 2% \(O_2\) + 10% \(CO_2\) and in air at 45° and 50°F. are summarized in Table 1.

Overall acceptability.—Storage of Lula avocados under a constant flow of 2% \(O_2\) + 10% \(CO_2\) at 45° F. resulted in 100% acceptable fruit. A storage temperature of 45° F. appeared slightly better than 50° for periods of 20 or 40 days although the differences were significant only in CA after 40 days. No off-flavors were detected in samples of any sound avocados regardless of atmosphere or storage temperature.

Decay.—Decay levels during storage in CA and softening at 70° F. were low, with no significant difference between fruit stored at 45°

### Table 1.—Characteristics of Lula avocados after storage for 20 and 40 days in 2% \(O_2\) + 10% \(CO_2\) and in air at 45° and 50° F.1/

<table>
<thead>
<tr>
<th>Storage atmosphere2/ and temperature</th>
<th>Acceptable fruit when soft</th>
<th>Decay after softening when soft</th>
<th>External darkening when soft</th>
<th>Time to soften at 70°F</th>
<th>Weight loss during storage</th>
<th>Weight loss when soft</th>
</tr>
</thead>
<tbody>
<tr>
<td>°F</td>
<td>Percent</td>
<td>Rating</td>
<td>Rating</td>
<td>Days</td>
<td>Percent</td>
<td>Percent</td>
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<td></td>
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<tr>
<td>Air - 70</td>
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<td>0.25</td>
<td>0.00</td>
<td>6.9</td>
<td>----</td>
<td>8.2</td>
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<td>20 Days</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>CA - 45</td>
<td>100a</td>
<td>0.10a</td>
<td>0.35a</td>
<td>4.8a</td>
<td>1.4a</td>
<td>7.1a</td>
</tr>
<tr>
<td>CA - 50</td>
<td>95a</td>
<td>0.25a</td>
<td>0.25a</td>
<td>4.5b</td>
<td>1.6a</td>
<td>7.5a</td>
</tr>
<tr>
<td>Air - 45</td>
<td>65b</td>
<td>1.25b</td>
<td>2.75b</td>
<td>2.7c</td>
<td>1.7a</td>
<td>6.0b</td>
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<td>Air - 50</td>
<td>55b</td>
<td>1.50b</td>
<td>3.50b</td>
<td>2.4d</td>
<td>2.5b</td>
<td>6.0b</td>
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<tr>
<td>CA - 45</td>
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<td>0.15a</td>
<td>0.75a</td>
<td>4.6a</td>
<td>1.6a</td>
<td>7.5a</td>
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<td>0.90a</td>
<td>0.60a</td>
<td>4.1a</td>
<td>2.4b</td>
<td>7.9a</td>
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<tr>
<td>Air - 45</td>
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<td>4.00b</td>
<td>4.00b</td>
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<tr>
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<td>4.00b</td>
<td>4.00b</td>
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</tbody>
</table>

1/ Statistical analysis based on 20 fruit per treatment for each storage period. Data followed by different letters were significantly different at the 1% level (Duncan's Multiple Range Test).

2/ CA refers to an atmosphere of 2% \(O_2\) + 10% \(CO_2\).

3/ Includes fruit which were decayed when removed from storage and discarded.

4/ Ratings based on total percentage of aggregate surface area affected: (0) None; (1) 1%-10%; (2) 11%-25%; (3) 26%-50%; and (4) over 50%.
or 50° for 20 or 40 days. Lula avocados stored in air developed considerable decay at both 45° and 50° after 20 days and all fruit were decayed after 40 days. 

External darkening.—A dark grayish-brown discoloration of the skin was noted in some fruit after storage and subsequent softening. This darkening appeared to be an external symptom of chilling injury. Only a trace of internal chilling injury was noted in any CA-stored fruit. Air-stored fruit exhibiting severe skin discoloration often did show internal damage. No significant difference was found in the amount of discoloration between avocados stored at 45° and 50° F. After 40 days, anthracnose decay on avocados stored in air was so severe that it was difficult to distinguish between discoloration and the decay.

Time to soften.—Lula avocados stored at 45° F. for 20 days softened significantly more slowly when held at 70° than did comparable fruit stored at 50°. After 20 days, avocados stored in CA at both 45° and 50° softened significantly more slowly than did fruit stored in air at either temperature.

Percentage weight loss.—After the 40-day storage period, the percentage weight loss during storage at 45°F. was lower than the weight loss at 50°. After 20 days, avocados stored in CA at both 45° and 50° lost less weight than fruit stored in air at either temperature although this difference was not significant at 45°. In contrast, the total percentage weight loss of fruit after softening was greater in fruit which had been stored in CA. The increased weight loss during softening of avocados previously stored in CA is related to the time required for the fruit to soften; fruit which softened more slowly were subject to physiological weight losses due to respiration and transpiration for longer periods of time. Analysis of the relationship between the number of days for fruit to soften at 70° and the percentage weight loss during softening was highly significant (r=0.741, 14d.f.)

LITERATURE CITED

PROSPECTS FOR CASHEW ADVANCEMENT IN COLOMBIA AND VENEZUELA

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The potential of the cashew as an economic crop for Colombia and Venezuela depends on the realization of the problems involved and a firm resolution to apply to their solution the modern techniques vital to the success of any other horticultural and processing venture.

I want to take this opportunity to present a few guidelines based on recently received reports (5, 6, 9, 10) and correspondence and my own observations during a tour of cashew-growing areas in Colombia and Venezuela in July, 1969.

The paper on this subject which I presented at the 17th Annual Meeting of the Tropical Region of the American Society for Horticultural Science, held in Cali, Colombia, and which is pending publication (7), stresses the economic advantage, from the standpoint of labor costs, of planting high-yielding trees producing jumbo-sized nuts, instead of nuts of average size or smaller. It is necessary to add a word of caution: It has been found in nut-size-and-quality studies abroad that very large nuts may have air pockets between the cotyledons or between the kernel and shell. Therefore, weight must be considered jointly with size. In determining quality of seed for planting, superior nuts are those which sink in a solution of 1 1/2 lbs. of sugar in 1 gal. of water (8). It would be well to utilize the same test of nut weights in making selections for propagation.

When accumulating seeds from various sources over a period of time, it is well to be aware that seeds wrapped in polyethylene or stored in sealed tins retain viability for as long