CONDITIONING ‘TAHITI’ LIMES TO REDUCE CHILLING INJURY

DONALD H. SPALDING and WILLIAM F. REEDER
U.S. Department of Agriculture,
Agricultural Research Service,
Subtropical Horticulture Research Station,
13601 Old Cutler Road,
Miami, FL 33158

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Abstract. ‘Tahiti’ (‘Persian’) limes (Citrus latifolia Tan.), conditioned by holding for 1 wk at 45, 50, 55, 60, or 70°F prior to storage for 2 wk at 35°F, developed less chilling injury than nonconditioned limes. Color was still acceptable in conditioned and nonconditioned limes at the end of the 3-wk test period, but decay development at 60 and 70°F was severe in nonconditioned limes chilled at 35°F. The percentage of acceptable fruit was 91% in conditioned, but only 32% in nonconditioned limes. Limes conditioned by exposure to 30 or 40% CO₂ for 1 day at 70°F developed more rind injury during chilling than nonconditioned limes.

Chilling injury (CI) is a time and temperature dependent problem which can seriously affect the marketability of ‘Tahiti’ limes held too long at 45°F and below (3). Chilling injury appears in the rind as small pitted areas or, in more serious cases, as brown, sunken areas of various sizes and shapes arising from the coalescence of small areas of injury. Development of a method to condition limes to withstand storage at chilling temperatures would be most useful for extension of normal shelf life, retention of green color, and protection against the browning of unwanted pests. Various methods, such as prestorage treatment with CO₂ or holding at a given temperature, have been extensively investigated for curing or conditioning grapefruit by Hatton and Cubbedge (1, 2). Early workers had noted that holding early season grapefruit for 5 days at 70°F reduced subsequent rind breakdown at refrigerated temperatures (3). Based on these clues, Hatton and Cubbedge (2) developed a method of conditioning grapefruit at 50 or 60°F for 1 wk prior to low temperature storage. Our objectives were to study how similar conditioning methods affect the development of CI in limes.

Materials and Methods

Washed and waxed limes were obtained on the day of picking from a commercial packinghouse in Dade County, Florida. Size 54 limes (54 limes/10-lb. flat) were used for all treatments. The limes were returned to the laboratory and those free of decay and blemishes were sorted by color into similar samples of 50 limes for each treatment. Rind color of limes was measured by comparison with color plates specially prepared to simulate the range of lime colors and having numerical ratings in which, for example, 6.58 is dark green and 1.00 is yellow (4). All limes selected met or exceeded the minimum color index of 3.18 (corresponding to USDA, PL-2, lower limit “mixed” used by federal inspectors), and met or exceeded all standards for U.S. No. 1 grade (6). Limes for each treatment were repacked in 10-lb. flats, with or without 1.5 mil polyethylene liners, the tops of which were folded over before the top of the flat was replaced.

In the first test, limes conditioned for 1 wk at 50°F before chilling were compared with nonconditioned limes packed in flats, with and without 1.5-mil polyethylene liners, and chilled at 35 or 40°F for 2 wk. The nonconditioned limes were held for 1 wk at 50°F after chilling to provide comparable postharvest temperature exposure for all treatments. Limes were then examined for color, decay and CI.

In the second test, polyethylene liners were used in all flats. Limes were conditioned by holding them at 45, 50, 55, 60 or 70°F for 1 wk prior to chilling for 2 wk at 35°F. Nonconditioned control limes were first chilled at 35°F for 2 wk, and then held at 45, 50, 55, 60 or 70°F. After storage, all limes were rated for color, decay and CI. Acceptable fruit met the minimum color standard, were free of decay and had no more than a trace of CI.

In the third test, limes were conditioned for 1 day at 70°F in an atmosphere of 30 or 40% carbon dioxide, maintained by “flow-through” mixtures of CO₂, O₂ and air as described by Hatton and Cubbedge (1, 2), prior to chilling in normal air for 2 wk at 35°F. Nonconditioned control limes were held in 0.3% CO₂ (normal air) for 1 day at 70°F prior to chilling with the conditioned limes. Fruit were then examined for CI.

Chilling injury was rated on the basis of rind symptoms using the following scale: O = none; 1 = trace (occasional spot, barely noticeable); 2 = slight (several small brown sunken areas or a single confluent area up to 1/2 inch in diameter; lime considered saleable); 3 = moderate (2 to 3 brown, sunken, confluent areas 1/4 to 1/2-inch in diameter or 1 area 1/2 to 5/4-inch in diameter or sufficient small areas (less than 1/4-inch in diameter) to produce an unsaleable appearance); and 4 = severe (2 areas over 1/2-inch in diameter or more than 3 areas 1/4 to 1/2-inch in diameter or 1 area over 3/4-inch in diameter).

Results and Discussion

Limes conditioned for 1 wk at 50°F developed less CI than nonconditioned limes held under comparable conditions (Table 1). Differences in CI were most apparent in limes stored at 35°F, since only slight CI developed in limes held at 40°F for 2 wk. No decay or color differences were noted during the period of this test (data not shown).
Table 1. Chilling injury to limes stored under various conditions.

<table>
<thead>
<tr>
<th>Prestorage conditioning</th>
<th>Storage time and temp</th>
<th>Polyethylene liner</th>
<th>Chilling injury index</th>
<th>Fruit with chilling injury (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>3 wk 50°F</td>
<td>Yes</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>None</td>
<td>2 wk 40°F + 1 wk 50°F</td>
<td>Yes</td>
<td>0.58</td>
<td>8</td>
</tr>
<tr>
<td>None</td>
<td>2 wk 35°F + 1 wk 50°F</td>
<td>No</td>
<td>1.00</td>
<td>36</td>
</tr>
<tr>
<td>1 wk 50°F</td>
<td>2 wk 40°F</td>
<td>No</td>
<td>0.04</td>
<td>0</td>
</tr>
<tr>
<td>1 wk 50°F</td>
<td>2 wk 35°F</td>
<td>Yes</td>
<td>0.70</td>
<td>22</td>
</tr>
</tbody>
</table>

*Each figure is based on 50 fruit.  
†Chilling injury rated as O = none, 1 = trace, 2 = slight, 3 = moderate and 4 = severe.  
‡Fruit with trace injury were not included.

Chilling injury was less in limes held in flats with polyethylene liners when the amount of CI was slight; however, in the case of the severe CI which developed in nonconditioned limes at 35°F, the liners did not prevent CI.

Chilling injury in the second test was much less in conditioned than in nonconditioned limes, regardless of the conditioning temperature. (Table 2). Conditioned limes remained free of CI or developed only trace amounts under the test conditions. The lowest amounts of CI were found in limes conditioned at 50°F, 55°F, or 60°F for 1 wk. These results support those reported by Hatton and Cubbedge (2) for the conditioning of grapefruit.

Degreening or color loss in limes increased with temperature, as expected. Color loss in conditioned limes did not differ significantly regardless of temperature, but color loss in nonconditioned limes differed significantly at 60 and 70°F (Table 2). There was, however, no significant difference in the color of conditioned and nonconditioned limes held at the same temperatures. Limes held at the recommended 48 to 50°F (3) will generally turn yellow in 3 to 4 wk. Storage and shipping at 45°F is generally considered a safe compromise between the development of CI at lower temperatures and the increased yellowing and disease development at higher temperatures. Color is important during marketing because the consumer expects limes to be green and receivers worry about saleability if the limes are too yellow.

Decay also increased with temperature and was significantly most severe in nonconditioned limes held at 70°F after chilling. Decay following CI is common due to the growth of microorganisms in the damaged tissue. The rots observed were mainly those caused by Penicillium digitatum Sacc., Penicillium italicum Wemher, and Geotrichium candidum Lk. ex Pers.. Decay development was inhibited at temperatures of 55°F or below, regardless of whether or not the limes had been injured by chilling.

Most conditioned fruit were acceptable for sale and consumption at the end of the tests, whereas most nonconditioned fruit were unacceptable. Rejection of fruit was mainly on the basis of chilling injury and decay, rather than loss of green color.

Limes conditioned by holding in 30 or 40% CO2 for 1 day at 70°F prior to chilling at 35°F for 2 wk developed 64% and 92% CI, respectively, compared to 40% CI in nonconditioned limes. The greater incidence of CI in the rinds of conditioned limes may be due to injury caused by treatment with carbon dioxide which then augments the CI. Limes may be injured by CO2 levels greater than 10% (5).

Temperature conditioning, but not carbon dioxide conditioning, retarded CI development. Additional work is needed to determine how long conditioned limes can remain free of CI and how factors such as size, time of picking, maturity and seasonal conditions affect the response of limes to conditioning.

Table 2. Chilling injury, color change, decay and acceptability of Tahiti limes conditioned at various temperatures prior to chilling at 35°F.

<table>
<thead>
<tr>
<th>Factors evaluated</th>
<th>Conditioned fruit</th>
<th>Nonconditioned fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45°F  50°F  55°F  60°F  70°F</td>
<td>45°F  50°F  55°F  60°F  70°F</td>
</tr>
<tr>
<td>Chilling injury</td>
<td>0.6  0.1  0.2  0.2  0.4</td>
<td>2.8  2.4  2.2  2.2  2.5</td>
</tr>
<tr>
<td>Color</td>
<td>3.8  3.8  3.6  3.6  3.4</td>
<td>4.1  3.8  3.7  3.5  3.2</td>
</tr>
<tr>
<td>Decay</td>
<td>0.7  0.0  0.7  1.3  6.7</td>
<td>0.2  1.3  2.7  17.5 41.3</td>
</tr>
<tr>
<td>Acceptable fruit</td>
<td>83%  97%  95%  96%  85%</td>
<td>24%  29%  35%  36%  37%</td>
</tr>
</tbody>
</table>

*Each figure is the mean of 3 replications, using 50 fruit per treatment in each replication.  
†Fruit were preconditioned for 1 wk at 45, 50, 55, 60 or 70°F, and then chilled for 2 wk at 35°F.  
‡Nonconditioned fruit were first chilled for 2 wk at 35°F, and then held for 1 wk at 45, 50, 55, 60 or 70°F.  
§Chilling injury rated as 0 = none, 1 = trace, 2 = slight, 3 = moderate and 4 = severe.  
¶Color rated in comparison with color plates in which yellow is 1.00 and “good green” (USDA, PL-2, 1962) is 4.71. Initial fruit color was 4.37.  
‖Decay refers to percentage of limes showing visible rot.  
¶Acceptable fruit refers to percentage that meet the minimum color index of 3.18, are free of decay and have no more than a trace (barely noticeable) of chilling injury.

Literature Cited