Diphenyl Absorption and Decay in ‘Dancy’ and ‘Sunburst’ Tangerine Fruit

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Abstract. Effects of storage time, temperature, fruit preparation, time of harvest and number of diphenyl pads per carton with ‘Dancy’ (Citrus reticulata Blanco) and ‘Sunburst’ a seedling from ‘Robinson’ x ‘Osceola’, each C. reticulata x (C. paradisi Macf. x C. reticulata) tangerines were studied to determine the amount of diphenyl absorbed and extent of decay. Storage of ‘Dancy’ and ‘Sunburst’ at 4°C for up to 4 weeks with 1 or 2 diphenyl pads resulted in diphenyl residues less than the U.S. legal tolerance of 110 ppm. However, storage of both cultivars for 2 weeks at 21°C with 2 diphenyl pads resulted in residues exceeding this tolerance limit. Decay and diphenyl residues both tended to be higher for ‘Dancy’ than for ‘Sunburst’. ‘Dancy’ tangerines stored for 4 weeks at 21°C all decayed. Statistical examination of 2 harvests of ‘Sunburst’ showed that early harvested fruit were less susceptible to decay but prone to absorb higher amounts of diphenyl.

Diphenyl is a vapor-phase fungistat that must be present in the free vapor form to be effective (2, 14). Growth and spore development of some fungi are inhibited so long as an atmosphere of free vapor form to be effective (2, 14). Growth and spore development of some fungi are inhibited so long as an atmosphere of diphenyl vapor persists. Diphenyl absorbed by citrus fruit will not control decay, mycelial growth or sporulation of the common fungi inhabiting the surface of the peel (7).

Factors affecting the amount of diphenyl absorbed by citrus fruit have been identified as storage temperature (3, 9, 10), diphenyl dosage (9, 11), packaging methods (5, 15), placement of diphenyl sheets in the cartons (12), cultivar (4, 10), maturity (17) and physiological state of the fruit (8, 10, 17). One of the more important constraints for marketing fresh fruit, however, is the residue limit of the pesticide. The legal diphenyl residue tolerance for citrus fruit marketed within the United States, Canada and Sweden, is 110 ppm, whereas 70 ppm is the legal tolerance for citrus fruit sold in Japan and countries belonging to the European Economic Community. Substantial monetary losses have occurred with exported citrus fruit because the legal tolerance limit of diphenyl was exceeded (17).

Previous investigations (3, 4) have shown that under similar storage conditions tangerines absorb more diphenyl than oranges, grapefruit, lemons or limes. Because of the commercial importance of tangerines, a comparative study was conducted with ‘Dancy’ and ‘Sunburst’ to evaluate the effects of temperature,
length of storage, number of diphenyl pads per carton, harvest date, and the condition of the fruit on the amount of diphenyl absorbed and the percentage of decay.

Materials and Methods

Tangerines used in these studies were naturally colored ‘Sunburst’ and ‘Dancy’. ‘Sunburst’, a citrus hybrid classified as a tangerine, resulted from a cross of sibling hybrids ‘Robinson’ × ‘Osceola’ (6). ‘Sunburst’ trees were 6 years old and were grafted to Carrizo citrange [C. sinensis (L.) Osbeck × Poncirus trifoliata (L.) Raf.]. This tangerine was hand harvested without clipping at Whitmore Foundation Farm, Leesburg, Florida, November 13, 1979 (Harvest I) and December 4, 1979 (Harvest II). ‘Sunburst’ was analyzed for °Brix, percent total (titratable) acid as anhydrous citric acid and Brix:acid ratio. ‘Dancy’ was obtained directly from the packingline of Haines City Cooperative Growers Association, Haines City on December 19, 1979.

‘Sunburst’ and ‘Dancy’ were handled separately at the Agricultural Research and Education Center, Lake Alfred as described below. Fruit were randomized and divided. Half of each sample was washed and then waxed with a solvent-type wax; the other half was unwashed and unwaxed. Fruit (60 per treatment) were packed in standard cartons (4/5 bushel = 28 liters) in which the ventilation holes were taped closed. Random-sized fruit were packed with 0, 1 or 2 diphenyl pads (2.2 g diphenyl per 28 cm by 43 cm pad) and stored at 4°C (40°F) or 21°C (70°F) for 2 and 4 weeks. Sampling of fruit for chemical analysis was conducted according to a procedure previously described (9).

Diphenyl in cyclohexane was analyzed by gas-liquid chromatography with a Hewlett Packard Model 5880A gas chromatograph equipped with a flame ionization detector and a 5880A Level Four computing system. A glass column (1.83 m in length and 2 mm i.d.) packed with 3% OV 225 on 100/200 mesh Supelcoport (Supelco, Bellefonte, PA) was used to resolve diphenyl from other components. The injection port temperature was 200°C, detector temperature 220°C and nitrogen flow was 60 ml/min. Samples of 3 μl were injected on-column at 130°C and programmed at 10°C/min to a maximum of 190°C.

Results and Discussion

Chemical analysis of ‘Sunburst’ showed the following: Harvest I (11.1° Brix, 1.24% acid, Brix:acid ratio = 9.0) and II (12.1° Brix, 1.05% acid, Brix:acid ratio = 12.1). Analysis of ‘Dancy’ tangerines showed 10.2° Brix, 0.66% acid and Brix:acid ratio = 15.9.

Storage of washed-and-waxed and unwashed ‘Dancy’ tangerines at 4°C for 2 and 4 weeks (Table 1) showed no significant difference in percentage of decayed fruit when packed with either 0, 1 or 2 diphenyl pads. After 2 weeks, the amount diphenyl absorbed by both the washed-and-waxed and unwashed samples was significantly higher in cartons containing 2 pads; whereas after 4 weeks, a significant difference was noted only with the unwashed samples. Unwashed samples showed lower amounts of absorbed diphenyl than the washed-and-waxed fruit. The purpose of comparing washed to unwashed fruit was to determine whether commercial washing and waxing caused a disturbance of the natural wax barrier and, thereby, an increase or decrease in the absorption of diphenyl. Standard packinghouse procedures entail washing and waxing but these hygienic and cosmetic treatments should not predispose the fruit to absorb higher amounts of diphenyl than non-treated fruit. Pretreating and packaging should enhance salability (cosmetic appearance), minimize decay and limit the amount of pesticide residue absorbed by the fruit.

Table 1. Effects of fruit treatment, number of diphenyl pads, and weeks of storage on decay percentage and diphenyl content of ‘Dancy’ tangerines stored at 4°C.

<table>
<thead>
<tr>
<th>No. pads</th>
<th>Washed/waxed (%)</th>
<th>Unwashed (%)</th>
<th>Washed/waxed (ppm)</th>
<th>Unwashed (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-week storage</td>
<td></td>
<td>4-week storage</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>6.0 a</td>
<td>8.0 a</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>12.0 a</td>
<td>2.7 a</td>
<td>29.2 a</td>
<td>17.6 a</td>
</tr>
<tr>
<td>2</td>
<td>6.0 a</td>
<td>6.7 a</td>
<td>41.3 b</td>
<td>32.9 b</td>
</tr>
</tbody>
</table>

Values represent means for 3 replications. Means in the same column followed by the same letter are not different at the 5% level (Duncan’s multiple range test). Strict interpretation of some variance data for decay indicates a range encompassing negative decay percentages; for these data, decay is undefined for values less than zero. The nonnormality of these data may be reduced by arc sine transformation.

Effects of a stress temperature (21°C) on the percentage of fruit decay and the amount of diphenyl absorbed by ‘Dancy’ are recorded in Table 2. Washed-and-waxed and unwashed ‘Dancy’ stored for 2 weeks showed high rates of decay. Decay percentages for the washed-and-waxed fruit showed a downward trend with the addition of diphenyl pads but the difference was nonsignificant. Unwashed fruit packed with 1 and 2 pads, however, showed statistically lower percentages of decay than fruit packed without pads. Storage for 4 weeks resulted in complete decay regardless of treatment; diphenyl pads did not mitigate the extent of this decay. Diphenyl absorption by ‘Dancy’ fruit stored 2 weeks was very high; a significant difference was noted between cartons containing 1 and 2 pads. Except for the unwashed fruit packed with 1 pad, all other fruit exceeded the U.S. legal tolerance of 110 ppm for diphenyl and, therefore, could not have been sold. Diphenyl content was not determined on fruit stored for 4 weeks because all decayed.

Two harvests of ‘Sunburst’ tangerines were investigated because previous investigations (9, 11, 13, 17) indicated less mature fruit absorb more diphenyl than more mature fruit and susceptibility to decay increases with maturity (16). ‘Sunburst’ tangerines, as represented by Harvest II, were harvested 2 weeks later (December 4) than the ‘Sunburst’ of Harvest I. Decay percentages for washed-and-waxed and unwashed ‘Sunburst’ were relatively low compared to ‘Dancy’.

Table 2. Effects of fruit treatment, number of diphenyl pads, and weeks of storage on decay percentage and diphenyl content of ‘Dancy’ tangerines stored at 21°C.

<table>
<thead>
<tr>
<th>No. pads</th>
<th>Washed/waxed (%)</th>
<th>Unwashed (%)</th>
<th>Washed/waxed (ppm)</th>
<th>Unwashed (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-week storage</td>
<td></td>
<td>4-week storage</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>58.0 a</td>
<td>67.3 a</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>43.3 a</td>
<td>46.7 b</td>
<td>153.7 a</td>
<td>96.7 a</td>
</tr>
<tr>
<td>2</td>
<td>35.3 a</td>
<td>48.7 b</td>
<td>227.1 b</td>
<td>144.4 b</td>
</tr>
</tbody>
</table>

Values represent means for 3 replications. Means in the same column followed by the same letter are not different at the 5% level (Duncan’s multiple range test).


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for both Harvests I and II after storage at 4°C (Table 3). Addition of diphenyl pads had little effect on lessening decay except for those fruit stored 4 weeks (unwashed of Harvest I; washed/waxed of Harvest II). Fruit packed with 2 pads generally absorbed more diphenyl than those packed with 1 pad. Unwashed fruit, regardless of harvest, absorbed less diphenyl than those that were washed and waxed. ‘Sunburst’ of Harvest II absorbed less diphenyl than fruit of Harvest I.

Decay percentages for washed-and-waxed and unwashed ‘Sunburst’ fruit (Harvest I) stored for 2 weeks at 21°C showed no significant difference with more than one diphenyl pad (Table 4). However, addition of diphenyl pads reduced decay of fruit (washed/waxed and unwashed) stored for 4 weeks. Highest decay occurred in cartons without diphenyl pads and lowest in cartons with 2 pads. Diphenyl absorption was extremely high for those tangerines from Harvest I and, as expected, fruit from cartons with 2 pads. Diphenyl absorption was significantly lower than in the washed and waxed fruit, regardless of treatment. This effect, i.e., higher diphenyl absorption by washed and waxed compared to unwashed fruit, was previously noted with ‘Honey’ (C. reticulata hybrid) tangerines (9).

‘Sunburst’ from Harvest II showed diphenyl absorption and percentage decay patterns similar to Harvest I ‘Sunburst’ but the magnitude of the changes was strikingly different. Washed and waxed fruit stored for 2 and 4 weeks showed higher decay percentages and lower diphenyl absorptions than similarly treated ‘Sunburst’ fruit from Harvest I. Similarly, unwashed fruit from Harvest II absorbed less diphenyl and generally showed more decay than similarly treated fruit of Harvest I.

Data of 2 ‘Sunburst’ harvests stored at 21°C show decay of Harvest I was statistically lower than Harvest II in 7 out of 12 treatments (0,1,2 pads with washed and unwashed fruit) (Table 5). Tangerines from Harvest I absorbed statistically higher amounts of diphenyl than Harvest II in 7 out of 8 treatments, confirming findings from previous work with grapefruit (17) and ‘Honey’ tangerines (9) which showed that older or more mature fruit absorb less diphenyl than did less mature fruit. Two important factors must be considered in the marketing of fresh tangerines: fruit harvested early in the season are generally less susceptible to decay than fruit of a later harvest, but those early-harvested tangerines are more prone to absorb excessive amounts of diphenyl.

‘Dancy’ and ‘Sunburst’ tangerines are commercially stored and shipped at low temperatures because of higher absorption of diphenyl and an excessive decay rate at the higher temperatures. Comparative examination of ‘Dancy’ and ‘Sunburst’ (2 harvests) indicated ‘Dancy’ was more susceptible to decay, corroborating a previous study (6) which reported postharvest losses of ‘Sun-
Table 5. Comparative examination of decay percentage and diphenyl absorption for Harvest I versus Harvest II ‘Sunburst’ at 21°C storage by the t statistic for 2 means.

<table>
<thead>
<tr>
<th>Diphenyl Pads (no.)</th>
<th>Storage (weeks)</th>
<th>Level of significance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Washed &amp; waxed</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>0</td>
<td>4</td>
<td>NS</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>NS</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

Decay percentages for Harvest I are significantly lower than Harvest II at the level of significance shown.

burst’ were less than that of ‘Dancy’.

Washing and waxing fruit prior to shipment to commercial markets is a normal packinghouse procedure, and is intended to reduce water loss and to improve the fruit’s cosmetic appearance (imparts a gloss to the surface). Our results indicate that commercial washing, which removes part or all of the natural epicuticular wax coating of the fruit (1), and waxing increases absorption of diphenyl. Unwashed fruit absorbed less diphenyl than did washed and waxed with comparable treatments (temperature, storage time, number of pads).

References Cited