Quality of Strawberries Packed in Different Consumer Units and Stored Under Simulated Air-Freight Shipping Conditions

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Abstract. Strawberries, Fragaria x ananassa Duchesne cv. Tufts, were packaged in 3 different consumer units and evaluated following storage at simulated air-freight time/temperature conditions during shipment to Western Europe. Berries in a rigid plastic basket with solid plastic cover lost significantly less weight than those stored in mesh plastic baskets with and without covers. There were no significant differences in pulp firmness among the packaging treatments. For all treatments, there was less berry deterioration after storage for 48 hours than for 72 hours at both 1.1°C and 4.4°C, but in all units a high percentage of berries developed serious expressions of bruising during storage.

Air shipment to Western Europe is a relatively new marketing development for the Florida strawberry industry. Current strawberry packaging practices for this market are the same as those used for the domestic market. Pickers place twelve 0.47-liter (1 U.S. pint) plastic mesh baskets in a shipping container (flat) and overfill until the top edges of individual baskets are covered (Fig. 1a). A 1980 survey (2) of 15 European receivers of U.S. strawberries in 5 countries found that most preferred that berries be packaged in 10 to 12 individually covered consumer units per shipping container, with net weights of either 250 or 500 g/unit, and with the net weight per unit guaranteed on delivery.

Moulton in 1947 (3) and Anderson and Hardenburg in 1959 (1) reported on the effects of packaging strawberries in various types of baskets and film overwraps to improve freshness and shelf-life. During the past 2 decades, many changes have occurred in both the materials available for prepackaging and in transportation modes for distribution of strawberries. In addition, many improved cultivars are now available.

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The objectives of this study were to determine: 1) the time/temperature profile to which Florida strawberries are subjected between packinghouse and Western European destinations; and 2) the effects of various consumer packaging units on berry quality when subjected to 4 time/temperature schemes simulating export distribution.

Air temperatures were monitored during handling and shipping from packinghouse to destination in Western Europe in 4 different air shipments. The berries were placed in cold storage at about 3°C immediately after harvest. For transport, 208 flats of berries were loaded into a model LD–3 air-freight shipping container, which was also precooled in the same cold-storage facility prior to loading with berries. Two Ryan temperature recorders were placed in each shipment, one in a flat of berries 3 layers from the bottom and the other in a flat 3 layers from the top. The boxes were stacked 14 layers high and those with temperature recorders were located at the vertical center of the LD–3. After filling, the LD–3 remained in cold storage until transport by refrigerated truck to the Miami, Fla. airport. Time of arrival and length of time at each transfer point were recorded. Temperature recorders were recovered during unloading at each European destination.

To achieve the 2nd objective, strawberries were obtained from a commercial grower/shipper at Dover, Fla. Berries used in the 3 tests were harvested from the same field, but at different pickings. The field was picked at 3-day intervals, but test berries were obtained at 6-day intervals.

Berries less than three-quarters red (sur-

Fig. 1. Traditional and experimental strawberry packages. a Traditional packing of Florida strawberries. b PT-1: rigid plastic mesh basket with no cover. c PT-2: solid-oriented polystyrene plastic basket and cover. d PT-3: rigid plastic mesh basket with solid-oriented polystyrene plastic cover.
Table 1. Strawberry exposure temperatures* and time at transfer points during distribution from shipping point to destination.

<table>
<thead>
<tr>
<th>Time lapse (hr)</th>
<th>Transfer point</th>
<th>Upper area of LD-3</th>
<th>Air temp. range</th>
<th>Lower area of LD-3</th>
<th>Air temp. range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Berries placed in LD-3*</td>
<td>10.0</td>
<td>9.4–11.0</td>
<td>8.3</td>
<td>7.2–9.4</td>
</tr>
<tr>
<td>5</td>
<td>LD-3 placed in truck</td>
<td>7.2</td>
<td>5.0–9.4</td>
<td>7.2</td>
<td>5.0–9.4</td>
</tr>
<tr>
<td>10</td>
<td>LD-3 placed in truck</td>
<td>7.2</td>
<td>4.4–10.0</td>
<td>6.7</td>
<td>3.3–9.4</td>
</tr>
<tr>
<td>15</td>
<td>LD-3 placed in truck</td>
<td>7.2</td>
<td>4.4–11.0</td>
<td>6.1</td>
<td>3.3–8.9</td>
</tr>
<tr>
<td>20</td>
<td>LD-3 removed from truck*</td>
<td>10.0</td>
<td>7.2–13.0</td>
<td>6.7</td>
<td>3.3–9.4</td>
</tr>
<tr>
<td>25</td>
<td>LD-3 left Miami by air</td>
<td>14.0</td>
<td>10.0–18.0</td>
<td>8.3</td>
<td>5.6–11.0</td>
</tr>
<tr>
<td>30</td>
<td>LD-3 arrived destination*</td>
<td>15.0</td>
<td>12.0–18.0</td>
<td>11.0</td>
<td>7.8–16.0</td>
</tr>
<tr>
<td>35</td>
<td>LD-3 arrived destination*</td>
<td>14.0</td>
<td>11.0–18.0</td>
<td>12.0</td>
<td>7.8–16.0</td>
</tr>
<tr>
<td>40</td>
<td>Berries cleared from LD-3*</td>
<td>14.0</td>
<td>13.0–16.0</td>
<td>10.0</td>
<td>8.3–12.0</td>
</tr>
</tbody>
</table>

*Avg. of 4 shipments.

*Berries placed in LD-3 at cold storage facility of shipper, remaining in cold storage until loading in refrigerated truck for transport to Miami airport.

*Berries not held under refrigeration after removal from truck.

*Three shipments to Frankfurt, West Germany, and one to London, England.

*At Frankfurt, berries removed from LD-3 immediately after clearing Customs; at London, berries removed about 4 hr after clearing Customs.

Table 2. Pulp firmness, weight loss, and unacceptable bruising of strawberries in 3 different packages when stored for different lengths of time at different temperatures.

<table>
<thead>
<tr>
<th>Package treatment</th>
<th>24 hr at 1.1°C plus</th>
<th>48 hr at 10°C</th>
<th>24 hr at 4.4°C plus</th>
<th>48 hr at 10°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hr at 10°C</td>
<td>48 hr at 10°C</td>
<td>24 hr at 10°C</td>
<td>48 hr at 10°C</td>
</tr>
<tr>
<td>Firmness (N)</td>
<td>Weight loss (%)</td>
<td>Unaccept. bruised (%)</td>
<td>Firmness (N)</td>
<td>Weight loss (%)</td>
</tr>
<tr>
<td>PT-1</td>
<td>3.11 a*</td>
<td>2.15 a</td>
<td>56 a</td>
<td>3.74 a</td>
</tr>
<tr>
<td>PT-2</td>
<td>3.60 a</td>
<td>0.87 b</td>
<td>54 a</td>
<td>4.05 a</td>
</tr>
<tr>
<td>PT-3</td>
<td>3.34 a</td>
<td>2.03 a</td>
<td>52 a</td>
<td>3.78 a</td>
</tr>
</tbody>
</table>

*See Fig. 1.

*Weight change (g)/fresh weight (g)] × 100.

*Moderate and severe bruising ratings were combined and judged unacceptable for marketing.

*Mean separation within columns by Duncan’s multiple range test, 5% level.
bruised were judged to be unacceptable for marketing. The percentage of unmarketable berries for each PT was not affected by treatment (Table 2). In lots held 24 hr at 1.1 and 4.4°C plus 48 hr at 10°C, there were considerably fewer marketable berries than in those held 24 hr at 10°C. Deterioration of surface tissue at apparent sites of bruising was the most common cause of berries being rated as not acceptable after storage. Watery, dull, pinkish, slightly indented areas developed, although the berries were visually free of bruising when prepared for testing. Most of this bruising apparently occurred during the picking operation, but was not visible until the berries were kept at 10°C. No decay was detected at this final evaluation.

Freshness, based on visual subjective impressions, was not different among treatments at each of the time/temperature storage periods; however, berries held at 1.1°C for 24 hr plus 24 hr at 10°C appeared fresher than those held at 4.4°C for 24 hr plus 24 hr at 10°C for each packaging treatment.

The ambient temperatures during the Florida strawberry season may consistently be in the 27°C range; therefore, it is important to precool strawberries to 4°C and maintain that temperature until berries are loaded on board air freighters. Pulp temperatures may well approach 16°C on arrival in Western Europe, even when berries are precooled to 4°C prior to shipping. Therefore, berries should be handled as rapidly as possible at transfer points and during other operations when they are not held under controlled refrigeration. Berries shipped in PT2 should arrive in Western European markets with less weight loss than those shipped in PT1 or PT3.

**Literature Cited**


**Cultivar Variation in Yield Components of Strawberries**

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**Abstract.** Differences were observed both within and between strawberry cultivars in the relative importance of yield components. Most cultivars had high coefficients among yield, crown density at harvest, and fruit number/crown, but there was variation among cultivars in the coefficients between yield and fruit weight.

Several population and growth characteristics may influence strawberry yield, including density, yield/plant, fruit number/plant, fruit size, crowns/plant, and peduncles/plant. These have been shown to be under both genetic and environmental controls.

Crown density is often the most critical determinant of total yield in a strawberry field, but fruit numbers and fruit size have also been shown to be important. In this study, we examined the composition of yield in 12 strawberry cultivars that are grown in the eastern and midwestern United States. We were interested in whether the relative importance of different yield components vary across cultivars traditionally grown in matted rows.

The experiments were performed at the Sodus Horticultural Research Farm of Michigan State Univ. at Sodus. A complete description of the site has been reported previously.

On April 15 and 16, 1980, dormant, spring-dug plants of 12 cultivars were planted in 3-m plots at spacings of 45, 60, and 75 cm within rows and 1.5 m between rows. Twenty-five fruits/crown. The coefficients between fruit number/crown and mean fruit weight (P3 4 ) were negative in 'Badgerbelle', 'Delite', 'Redchief', and 'Stoplight' had the fewest. Fruit of 'Earliglow', 'Midway', and 'Redchief' were the lightest.

There was also substantial variation in path coefficients among cultivars (Table 2). Midway' and 'Badgerbelle' showed little relationship between initial and final crown numbers (P4 5 ), while 'Delite', 'Earliglow', 'Raritan', and 'Scott' had significant associations. Initial crown numbers were not associated significantly with fruit weight (P1 2 ) in 'Guardian', 'Holiday', 'Raritan', and 'Scarlet'. The coefficients between fruit number/crown and mean fruit weight (P3 4 ) were negative in 'Badgerbelle', 'Bounty', and 'Scarlet', and positive in 'Earliglow' and 'Midway'. Initial crown numbers were associated significantly with fruit numbers/crown (P3 5 ) in 'Delite', 'Scott', and 'Stoplight'. 'Badgerbelle', 'Delite', 'Earliglow', 'Guardian', 'Redchief', and 'Scott' had significant negative relationships between final crown density and fruit number/plant (P3 2 ).

All the cultivars showed strong relationships between yield and initial crown numbers (P3 2 ), final plant numbers (P3 2 ), and fruit numbers (P3 5 ). Only 'Bounty' and 'Scarlet' had significant coefficients between fruit weight and yield (P4 5 ). The coefficient between fruit numbers and yield (P3 5 ) was highest in 'Badgerbelle', 'Earliglow', 'Delite', 'Guardian', 'Midway', 'Redchief', 'Scarlet', and 'Delite', while 'Earliglow', 'Midway', and 'Redchief' were the lightest.

There was also substantial variation in path coefficients among cultivars (Table 2). Midway' and 'Badgerbelle' showed little relationship between initial and final crown numbers (P4 5 ), while 'Delite', 'Earliglow', 'Raritan', and 'Scott' had significant associations. Initial crown numbers were not associated significantly with fruit weight (P1 2 ) in 'Guardian', 'Holiday', 'Raritan', and 'Scarlet'. The coefficients between fruit number/crown and mean fruit weight (P3 4 ) were negative in 'Badgerbelle', 'Bounty', and 'Scarlet', and positive in 'Earliglow' and 'Midway'. Initial crown numbers were associated significantly with fruit numbers/crown (P3 5 ) in 'Delite', 'Scott', and 'Stoplight'. 'Badgerbelle', 'Delite', 'Earliglow', 'Guardian', 'Redchief', and 'Scott' had significant negative relationships between final crown density and fruit number/plant (P3 2 ).

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