DETERMINATION OF OPTIMUM STORAGE CONDITIONS FOR ‘BABY’ SUMMER SQUASH FRUIT (CUCURBITA PEPO)

BETTY S. BREW, ADRIAN D. BERRY, STEVEN A. SARGENT*, NICOLE L. SHAW AND DANIEL J. CANTLIFFE
University of Florida/IFAS
Horticultural Sciences Department
P.O. Box 110690
Gainesville, FL 32611

Additional index words. Cucurbita pepo, chilling injury, yellow summer squash, storage

Abstract. There are many types of summer squash (Cucurbita pepo), with a wide range of colors, shapes, sizes and flavors. Summer squashes are harvested at immature stages as opposed to winter types that are harvested fully mature. While the lowest safe storage temperature for larger summer squash is 5°C, sensitivity of baby squash has not been reported. Tests were conducted using ‘baby’ yellow crooked-neck summer squash (cv. Sundray). Fruits were harvested prior to and just after bloom opening, with lengths ranging from 6 to 10 cm. Blooms were removed and fruits were placed in non-vented, polystyrene clamshell containers and stored at 5, 7 and 10°C for 14 days. To accelerate development of chilling injury, fruits were transferred to 20°C for 24 hours after 7 and 14 days of storage. Chilling injury symptoms included surface pitting, exudation of resinous material, and non-bleeding wounds. Based on subjective quality rating scales, fruits stored at external and internal tissue discoloration, water soaking, and decay. Map box 20°C and 14-h photoperiod for 3 weeks. Transplants were irrigated every other day with fertilizer solution (20 N/8.7 P/16.6 K) as well as micronutrient solution. Three-week-old transplants were planted into 3-gal, black polyethylene pots filled with pine bark. Plants were fertigated through individual pressure-compensating emitters at a flow rate of 33 mL·min⁻¹. Fertilizer rates remained the same throughout the season at 120 mL·min⁻¹ N, 50 mL·min⁻¹ P, 150 mL·min⁻¹ K along with micronutrients. Each plant was trellised vertically on twine (Shaw and Cantliiffe, 2005).

Over the years, baby vegetables have become very popular especially in the preparation of specialty dishes. Baby summer squash is eaten at less mature stages as compared to fully mature summer types. Summer squash types are graded ‘baby’ when they are less than 10 cm in length (Shaw and Cantliiffe, 2004) as opposed to more mature ones that range from 12 to 20 cm depending on the market (Molinari et al., 1999). Baby squash can be easily damaged because they are tender and highly perishable due to soft epidermis. As a result, they are extremely susceptible to mechanical injury, moisture loss, chilling injury and decay. Mature summer squash are also highly perishable and not suited for storage longer than two weeks (Hardenburg et al., 1986).

In order to maintain the quality of fresh fruits and extend postharvest shelf life, specific postharvest factors have to be carefully considered such as those which define the storage environment; temperature, relative humidity and atmospheric composition. Of these, adequate temperature management is the most important in the maintenance of fresh quality by ensuring a reduction in the rate of respiration, transpiration, enzymatic activity, and growth and spread of microorganisms (Brown, 1986). Quality refers to freedom from defects such as blemishes, mechanical injury, physiological disorders, decay, and water loss (Sargent et al., 2001). Quality appearance of fruits is the most important parameter that appeals to consumers in the fresh produce market worldwide. Although studies have shown optimum storage conditions for mature summer squash depending on cultivar, no report was found on baby summer squash (McCollum, 2004). The objective of this experiment was to determine the optimum storage temperature for yellow straight neck baby summer squash, by evaluating quality of fruits over a 14 d storage period while subjecting them to three different temperatures (5, 7, and 10°C) at 95% RH. Fruits were transferred to 20°C for 24 h to accelerate the development of chilling injury symptoms, and other quality parameters (firmness, shriveling of necks, water soaking, internal browning, and decay) were evaluated.

Material and Methods

Fruits were harvested from plants hydroponically grown in a passively ventilated greenhouse at the University of Florida/IFAS Protected Agriculture Project in Citra, Fla. Seeds were sown in Styrofoam trays filled with 3 parts sphagnum peat: 2 parts vermiculite. Transplants were grown in chambers at 25°C and 14-h photoperiod for 3 weeks. Transplants were irrigated every other day with fertilizer solution (20 N/8.7 P/16.6 K) as well as micronutrient solution. Three-week-old transplants were planted into 3-gal, black polyethylene pots filled with pine bark. Plants were fertigated through individual pressure-compensating emitters at a flow rate of 33 mL·min⁻¹. Fertilizer rates remained the same throughout the season at 120 mL·min⁻¹ N, 50 mL·min⁻¹ P, 150 mL·min⁻¹ K along with micronutrients. Each plant was trellised vertically on twine (Shaw and Cantliiffe, 2005).

Fruits were carefully hand harvested (using small, sharp pruning shears) to prevent bruising or abrasions. Fruits were from either pre- or post-opened blossoms and were sorted by size (6 to 10 cm in length; average equatorial diameter of 1.8 cm). Fruits were transported about 20 miles to the Horticulture Postharvest Laboratory at the University of Florida in Gainesville. Fruits were sorted and placed in non-vented, polystyrene clamshells. In selecting the type of clamshell to be used for the storage test, a pretest was conducted to determine the type and size to be used for the actual test. Clamshells were evaluated based on number of holes (for vented) and non-vented (without holes). Based on the results (data not shown), shallow locking-lid containers (unvented) were
selected, with dimensions 16.5 cm × 14.3 cm × 3.0 cm (base); 15.7 cm × 14.9 cm × 3.2 cm (lid) (Reynolds Food Packaging, Minn.). After transfer to designated storage temperatures (5, 7 or 10°C), fruits were rapidly cooled by leaving the clamshells open for an hour and then closed. Cooling of summer squash after harvest reduces the rate of water loss and is essential for maximum postharvest life (McCollum, 2004).

Respiration. Respiration rates (CO₂ production) were determined by storing individually weighed fruits (average weight = 4 g) in 120 mL Wheaton vials (one fruit per vial). Vials with loose caps were stored at four temperatures of 5, 7, 10, and 20°C with two replicates (vials) per storage temperature. To obtain headspace samples, the capped lids (fitted with rubber septa) were sealed for approximately 60 min prior to sampling. Two headspace samples (0.5 mL) were withdrawn per vial and respiration rates were measured by injecting samples into a GowMac, 580 series gas chromatograph equipped with a thermal conductivity detector. Readings were taken at 2-d intervals on days 1, 3, 5, and 7 and averaged to obtain final values expressed as mg CO₂·kg⁻¹·h⁻¹.

Overall visual quality assessments. An average of 12 fruits per clamshell were removed from each storage temperature after 7 and 14 d and transferred to 20°C for 24 h. Fruits were evaluated on day of transfer and again after 24 h at 20°C. Visual quality was assessed using a subjective rating scale (Table 1). Subsets of these fruits were also used for destructive tests for firmness and moisture content. Fruits that were not used for firmness or moisture content determinations were left in storage until day 21 to assess microbial growth and decay symptoms.

Firmness. To determine firmness a double-bladed knife with 11 mm separation between blades was used to slice fruits at the equatorial region to produce slices of equal thickness (n = 3 fruits per storage temperature). The Instron Universal Testing Instrument (Model 4411, Canton, Mass.) equipped with a 3-mm diameter probe (crosshead speed of 50 mm·min⁻¹ a 5-kg load cell and a 7-mm displacement) was then used to assess the firmness of sliced fruit in the mesocarp region. Firmness was determined immediately after harvest (when fruits were field fresh), and after each storage regime as defined in the previous section.

Moisture content. Moisture content was determined from three fruits per treatment at each of the above-mentioned sample times. Slices from each fruit were weighed, placed in aluminum pans and dried at 64°C until a constant weight was obtained (final dry weight). Percent moisture content was calculated using the following formula:

\[
\text{% moisture content} = \frac{\text{(initial fresh wt - final dry wt) / initial fresh wt} \times 100}
\]

Data analysis. Data were analyzed using SAS statistical software program (SAS Institute Inc. Carey, N.C.) and subjected to Duncan's multiple range Test using a P-value of <0.05.

Results and Discussion

Respiration. Respiration rates increased with increased storage temperature but decreased during storage. After 1 d storage, the average respiration rate was highest at 20°C with 151 mg CO₂·kg⁻¹·h⁻¹ and lowest at 5°C with 41 mg CO₂·kg⁻¹·h⁻¹ (Table 2). Respiration rates for all temperatures were highest on day 1 and lowest on day 7. The results are fairly consistent with previous research (Hardenburg et al., 1986; McCollum, 2004) which indicated respiration rates from 27 to 37 mg CO₂·kg⁻¹·h⁻¹ for fruits stored at 5°C, 65 to 68 mg CO₂·kg⁻¹·h⁻¹ for 10°C and 153 to 175 mg CO₂·kg⁻¹·h⁻¹ for 20°C. However these reports did not specify the cultivar, source or stage of the fruits used in their research.

Overall visual assessment. Chilling injury symptoms have been reported in summer squash fruits stored below 5°C (Ryall and Lipton, 1979). Chilling injury symptoms observed in this study included surface pitting, shriveling of the necks, watersoaking and browning of both the internal and external surface tissues. However, chilling injury symptoms were observed in fruits stored at 5 and 7°C after d plus 24 h at 20°C. Fruits stored at 10°C showed no signs of chilling injury after d or 7 d plus 24 h at 20°C. Fruits were rated on a scale of 1 to 5 with 1 being unmarketable and 5 being field fresh (see Table 1). Fruits stored at all three temperatures were rated as 4 on day 7, before transfer to 20°C. After 24 h at 20°C, fruits stored at 5 or 7°C were rated as 3, and those stored 10°C were rated as 4. On day 14 fruits stored at 5°C were rated as 2 before transfer and as 1 after 24 h at 20°C, while fruits at 7°C were rated as 1 before and after transfer (Fig. 1).

According to McCollum (2004), summer squash chilling injury symptoms may not become evident until transfer to non-chilling temperatures. This was supported by the data found in this research since fruits stored at 5 and 7°C only developed injury symptoms after 24 h at 20°C. Decay symptoms appeared on fruits after 14 d of storage (data not shown). By 21 d, 90% of fruits at 5 and 7°C had visible decay symptoms characterized by light and dark brown patches on fruit surface as well microbial growth at both the blossom and stem ends of the fruits. All fruits at 5 and 7°C exhibited shriveling of necks and surface pitting with symptoms more severe in fruits stored at 7°C. Fruits stored at 10°C had 50% decay at both the blossom and stem ends by 21 d. 'Beit Alpha' cucumbers, which belong to the same family as summer squash, also exhibited more severe chilling injury symptoms and poorest quality when stored at 7°C (Villalta et al., 2003). Use of unvented clamshell containers may have favored the development of decay due to formation of condensation in the container during storage.

Protoverubances or bumps on the fruit surface were observed on 80% of fruits stored at 10°C. The development of bumps was also reported by Sargent et al. (2002) on 'Beit Alpha' cucumbers after 14 d of storage at 10 and 12.5°C. The authors speculated that these bumps may have been caused by the high internal turgor pressure exerted on the senescing

Table 1. Appearance rating scale used for quality assessment of fruits.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Unusable</td>
</tr>
<tr>
<td>2</td>
<td>Unmarketable</td>
</tr>
<tr>
<td>3</td>
<td>Fair</td>
</tr>
<tr>
<td>4</td>
<td>Good</td>
</tr>
<tr>
<td>5</td>
<td>Field fresh</td>
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epidermal tissue. Samples of mycelial growth and dark brown surface tissues were taken from fruit surfaces and diagnosed at the Florida Extension Plant Disease Clinic, University of Florida as Choanephora cucurbitarium and Fusarium spp.

Firmness. Fruit firmness decreased during storage particularly after transfer to 20°C for 24 h, however there were no significant differences among storage temperatures at each storage period. Firmness decreased 5% by 7 d and 17% by 14 d for all storage temperatures (Fig. 2). Firmness values for all temperatures on 14 d plus 24 h at 20°C decreased significantly from the initial firmness values by approximately 16%. Chilled fruits have increased rates of water loss upon transfer to non-chilling temperatures (McCollum, 1989) and this affects the firmness of fruits.

Moisture Content. Storage temperature did not have a significant effect on fruit moisture content over the storage period. Moisture content (fresh wt. basis) decreased by an average of 3.1% and 2.5% for all three storage temperatures after transfer to 20°C for 24 h from their 1 d and 7 d readings respectively (Table 3). Trends were not the same for moisture content on day 14. This inconsistency cannot be explained. Individual fruits also lost moisture over time and the same trend was observed (data not shown). Surface shriveling on fruits stored at 5 and 7°C was also evidence of moisture loss, since according to Wilson et al. (1999) many fruits and vegetables become shriveled after losing only a small percentage of their original weight.

Table 2. Average respiration rates of yellow summer squash at different temperature and storage duration.

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Storage duration days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>41.5 b</td>
</tr>
<tr>
<td>7</td>
<td>47.0 b</td>
</tr>
<tr>
<td>10</td>
<td>52.5 b</td>
</tr>
<tr>
<td>20</td>
<td>150.9 a</td>
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Columns with different letters are significantly different at p < 0.05, according to the Duncan's multiple range test with n = 2.

Fig. 1. Overall appearance ratings for fruits stored at different temperatures over the storage period based on subjective assessment. Note: 7 d + 24 h = 8 d; 14 d + 24 h = 15 d.

Fig. 2. Firmness of fruits at different temperatures over the storage period. Note: 7 d + 24 h = 8 d; 14 d + 24 h = 15 d.

Table 3. Average moisture content for different temperature treatments over storage period.

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Moisture content (fresh wt. basis) during storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 d</td>
</tr>
<tr>
<td>5</td>
<td>95.6 a</td>
</tr>
<tr>
<td>7</td>
<td>95.6 a</td>
</tr>
<tr>
<td>10</td>
<td>95.6 a</td>
</tr>
</tbody>
</table>

Columns with different letters are significantly different at P < 0.05, according to Duncan's multiple range test (n = 3). 7 d + 24 h = 8 d; 14 d + 24 h = 15 d.

Conclusions and Recommendations

Baby summer squash fruit (cv. Sunray) can be stored up to 7 d at 5 to 10°C with minimal chilling injury symptoms. However, optimal quality and marketability can be retained for up to 14 d when fruits are stored at 10°C. Beyond 14 d, fruits begin to show signs of microbial growth rendering them unmarketable. From these results, it can be concluded that baby summer squash is more sensitive to chilling injury than summer squash fruit harvested at larger sizes. Subsequent tests will be conducted with the same cultivar for storage temperatures above 10°C using ventilated clamshells to reduce condensation within the container. Other squash types, such as zucchini, will also be tested.

Literature Cited


