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EXPOSURE OF GREEN TOMATOES TO HOT WATER AFFECTS RIPENING AND
REDUCES DECAY AND CHILLING INJURY

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thermal treatment.

Abstract. Commercially packed mature-green Florida ‘Sanibel’,
‘Florida47’, and ‘SunPride’ tomatoes (Lycopersicon esculen-
tum Mill.) that had not been treated with ethylene were im-
mersed in water at 24°C (ambient control) or 44 to 54°C for
various times. Tomatoes were evaluated for ripeness stage,
decay, heat injury and chilling injury symptoms, and surface
color following 2 weeks of storage at 2 or 12°C and subse-
sequently for up to 10 days of ripening at 20°C. Treatment for 60-
90 min at 44, 46, or 48°C, or 2.5-30 min at 54°C caused heat in-
jury symptoms (ripening inhibition, stem end creasing, tissue
collapse, increased decay). Exposure to 50°C for 2.5 min did
not cause any detectable heat injury, whereas the 5 or 10 min
at 50°C or 2.5 min at 52°C treatments were associated with only
slight incidence and severity of heat injury. All four of those
treatments prevented chilling injury symptom development
and reduced decay incidence. Exposure to 50°C water for 2.5,
5, or 10 min stimulated ripening-related color development af-
after 12°C storage, but, after 2°C storage, color development of
hot water-treated tomatoes was delayed, although normal.
Heat treatments tended to magnify maturity variability within a
lot of tomatoes, with less mature fruit apparently more sensi-
tive to ripening inhibition and heat injury.

Postharvest heat treatments have the potential to reduce
decay, control insect pests, slow ripening, and increase toler-
ance to chilling injury for many fruits and vegetables (Klein
and Lurie, 1992; Lurie, 1998). Commodities may be heated
by water, forced air, or vapor heat. Hot water is the fastest way

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to increase fruit temperature and probably is the most practical method for tomatoes since heated dump tanks are already a standard feature of tomato packhouses. Hot water treatments have been developed for control of plant pathogenic microorganisms (Barkai-Golan and Phillips, 1991) and for quarantine treatment of various plant products for insect disinfection (Couey, 1989; Paull, 1994). In general, hot water treatments for decay control are short (<10 min) at 50-60°C and insect disinfection treatments are longer (≥1 h) at 40-50°C. The difference is not only due to differences in heat tolerance among plants, insects, and microorganisms, but also because decay pathogens are usually located on or near the plant surface, while juvenile stages of many insects of quarantine significance are found in inner tissues of fruits.

Tomatoes have been reported to tolerate different exposures to heat. Inaba and Grandaal (1988) used a mathematical model based on electrolyte leakage as an indicator of tissue injury to suggest that mature-green '908' (i.e. 'Sunny') tomatoes could be exposed to 45, 50, or 55°C water for 166, 105, or 34 min, respectively, without injury. Mature-green 'Vibelco' tomatoes tolerated exposure to 42 or 46°C water for 90 min (Hakim et al., 1997), with 46°C more effective in reducing chilling injury over up to 6 weeks at 2°C. Mature-green 'Sunbeam' tomatoes were not visibly injured by exposure to 39, 42, or 45°C water for 60 min (McDonald et al., 1999), with 42°C being the most effective in reducing decay associated with a 2-week storage at 2°C. McDonald et al. (1996) also found that immersion in 42°C water for 60 min led to reduced decay development among mature-green 'Agriset' tomatoes that were stored for 2 weeks at 2°C then allowed to ripen. In contrast, the same treatment led to increased decay in 'Agriset' fruit stored for 2 weeks at 13°C, suggesting that heat injury had occurred.

The purpose of the work reported here was to determine if hot water treatments of shorter duration and at higher temperatures than those previously reported might have potential to be developed as more practical treatments for reducing mature-green tomato sensitivity to chilling injury and for slowing tomato ripening at nonchilling storage temperatures.

Materials and Methods

Commercially picked, mature-green 'Sanibel', Florida47', and 'SunPride' tomatoes were obtained from packinghouses in Homestead and Ruskin, Florida. The tomatoes were selected on the day of harvest and packed in standard shipping containers without being run over the packing line or treated with ethylene. They were shipped by refrigerated truck (12°C) to Gainesville, arriving on the day after harvest. Upon arrival in Gainesville, the tomatoes were sorted to remove any fruit showing red color or with defects, and uniform samples of 6 × 6 size (64-72 mm diameter; Fla. Tomato Comm., 1998) fruit were selected for treatment. Fruit were treated in water using a laboratory scale fruit heating system (Model HWH-2, Gaffney Engineering, Gainesville, Fla.) capable of maintaining water temperatures up to 55°C, to a stability within <0.0°C of the initial water temperature for the first 4-5 min after submerging up to 32 kg of fruit with an initial fruit temperature of 20°C. Thereafter, the system is capable of maintaining the water to a stability within ±0.1°C. 'Sanibel' fruit were treated for 60, 90, or 120 min at 24 (ambient), 44, 46, or 48°C; 'Sanibel' and 'Florida47' fruit were treated for 10, 20, or 30 min at 24, 50, 52, or 54°C; and 'Florida47' and 'SunPride' fruit were treated for 2.5, 5, or 10 min at 24, 50, 52, or 54°C. Following water treatment, the tomatoes were stored at either 2°C (chilling temperature) or 12°C (nonchilling temperature) for 2 weeks. After 2 weeks storage, the fruit were transferred to 20°C and 20 fruit per time-temperature combination were evaluated for ripeness stage, decay, injury, and color at transfer and after 4, 7, and 10 d at 20°C. Decay was evaluated as incidence, while severity of heat injury and chilling injury were rated as 1 = none; 2 = trace, 3 = slight, 4 = moderate, and 5 = severe based on development of symptoms. Symptoms of heat injury included stem-end creasing, ripening inhibition, water-soaking and tissue collapse. Chilling injury symptoms were uneven or blotchy color development and pitting with decay. Fruit color reflectance was measured near the blossom end of each fruit with a Hunter ColorQuest spectrophotometer (Hunter Assoc. Lab., Reston, VA) calibrated to a white standard plate in the L*a*b* color system (Lightness, red-green, and yellow-blue, respectively). Measurements were made with a 25-mm sample port, 10° viewing angle, and CIE illuminant D65. The a* and b* values were used to calculate hue angle and chroma (McGuire, 1992). Statistical analysis was done via SAS for PC (SAS Institute Inc., Cary, NC) with data subjected to analysis of variance (PROC ANOVA) and treatment means separated by Duncan's Multiple Range Test at P = 0.05.

Results

When 'Sanibel' tomatoes were treated with 44, 46, or 48°C water for 60, 90, or 120 min, from 40 to 100% of those fruit were damaged by the heat (data not shown). Chilling injury and decay were found in 80-90% of the control (24°C water) tomatoes that had been stored at 2°C for 2 weeks and then ripened at 20°C, while none of the heated fruit that had been stored at either 2 or 12°C or the controls at 12°C developed chilling injury. However, decay development followed the appearance of heat injury symptoms in hot water-treated fruit. Based on these results, we decided to investigate shorter hot water treatments.

Among 'Sanibel' tomatoes treated with water for 10, 20, or 30 min at 24, 50, 52, or 54°C, there was no evidence of either heat injury or chilling injury at the time of transfer from 2 or 12°C to 20°C (Tables 1 and 2), however, most of the hot water-treated fruit developed moderate symptoms of heat injury within 4 d at 20°C and exhibited moderate to severe symptoms by 10 d. The fruit exposed to 50°C water for 10 min had only slight heat injury after 2 weeks at 2 or 12°C plus 4 d at 20°C, which increased to moderate severity by 10 d at 20°C (Tables 1 and 2). Chilling injury was moderate to severe in the controls stored at 2°C but was essentially eliminated by all of the hot water treatments (Table 2). Decay incidence averaged 38% in the controls stored at 12°C (Table 1) and averaged 55% in the chilled controls (Table 2); decay in the hot water-treated fruit appeared to correspond to the severity of heat injury. The fruit exposed to 50°C water for 10 or 20 min developed the least decay (≤10%) after either 2 or 12°C storage. Results were similar for 'Florida 47' tomatoes (data not shown).

When 'SunPride' tomatoes were exposed to 50, 52, or 54°C water for 2.5, 5, or 10 min, only the fruit treated at 50°C for 2.5 min were free from heat injury symptoms, whereas tomatoes treated for 5 or 10 min at 50°C or 2.5 min at 52°C developed only slight heat injury (Tables 3 and 4). Those treatments, whether followed by 2 or 12°C storage, also had
Table 1. Quality characteristics of 'Sanibel' tomatoes stored at 12 and 20°C following various hot water treatment schedules.

<table>
<thead>
<tr>
<th>Heat treatment</th>
<th>2 wk @12°C</th>
<th>2 wk @12°C + 4 d @20°C</th>
<th>2 wk @12°C + 10 d @20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HP rating</td>
<td>Decay (%)</td>
<td>HP rating</td>
</tr>
<tr>
<td>24°C/10 min</td>
<td>1.00 a</td>
<td>0 b</td>
<td>1.00 f</td>
</tr>
<tr>
<td>24°C/20 min</td>
<td>1.00 a</td>
<td>30 a</td>
<td>1.00 f</td>
</tr>
<tr>
<td>24°C/30 min</td>
<td>1.00 a</td>
<td>5 b</td>
<td>1.00 f</td>
</tr>
<tr>
<td>50°C/10 min</td>
<td>1.00 a</td>
<td>0 b</td>
<td>2.60 e</td>
</tr>
<tr>
<td>50°C/20 min</td>
<td>1.00 a</td>
<td>0 b</td>
<td>3.60 d</td>
</tr>
<tr>
<td>50°C/30 min</td>
<td>1.00 a</td>
<td>0 b</td>
<td>4.05 c</td>
</tr>
<tr>
<td>52°C/10 min</td>
<td>1.00 a</td>
<td>10 b</td>
<td>4.20 bc</td>
</tr>
<tr>
<td>52°C/20 min</td>
<td>1.00 a</td>
<td>0 b</td>
<td>4.30 ab</td>
</tr>
<tr>
<td>52°C/30 min</td>
<td>1.00 a</td>
<td>0 b</td>
<td>4.40 ab</td>
</tr>
<tr>
<td>54°C/10 min</td>
<td>1.00 a</td>
<td>5 b</td>
<td>4.35 ab</td>
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<td>1.05 a</td>
<td>0 b</td>
<td>4.45 a</td>
</tr>
<tr>
<td>54°C/30 min</td>
<td>1.05 a</td>
<td>0 b</td>
<td>4.50 a</td>
</tr>
</tbody>
</table>

*Heat injury (HI) index: 1 = none, 2 = trace, 3 = slight, 4 = moderate, and 5 = severe.
*Mean separation in columns by Duncan's multiple range test, 5% level.

Table 2. Quality characteristics of 'Sanibel' tomatoes stored at 2 and 20°C following various hot water treatment schedules.

<table>
<thead>
<tr>
<th>Heat treatment</th>
<th>2 wk @2°C</th>
<th>2 wk @2°C + 4 d @20°C</th>
<th>2 wk @2°C + 10 d @20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CI rating</td>
<td>HI rating</td>
<td>Decay (%)</td>
</tr>
<tr>
<td>24°C/10 min</td>
<td>1.05 ab</td>
<td>1.00 a</td>
<td>5 a</td>
</tr>
<tr>
<td>24°C/20 min</td>
<td>1.05 ab</td>
<td>1.00 a</td>
<td>0 b</td>
</tr>
<tr>
<td>24°C/30 min</td>
<td>1.0 a</td>
<td>1.00 a</td>
<td>0 b</td>
</tr>
<tr>
<td>50°C/10 min</td>
<td>1.00 b</td>
<td>1.00 a</td>
<td>0 b</td>
</tr>
<tr>
<td>50°C/20 min</td>
<td>1.00 b</td>
<td>1.00 a</td>
<td>0 b</td>
</tr>
<tr>
<td>50°C/30 min</td>
<td>1.05 ab</td>
<td>1.10 a</td>
<td>0 a</td>
</tr>
<tr>
<td>52°C/10 min</td>
<td>1.00 b</td>
<td>1.10 a</td>
<td>0 a</td>
</tr>
<tr>
<td>52°C/20 min</td>
<td>1.00 b</td>
<td>1.05 a</td>
<td>0 b</td>
</tr>
<tr>
<td>52°C/30 min</td>
<td>1.00 b</td>
<td>1.05 a</td>
<td>0 b</td>
</tr>
<tr>
<td>54°C/10 min</td>
<td>1.00 b</td>
<td>1.10 a</td>
<td>0 b</td>
</tr>
<tr>
<td>54°C/20 min</td>
<td>1.05 ab</td>
<td>1.10 a</td>
<td>0 b</td>
</tr>
<tr>
<td>54°C/30 min</td>
<td>1.05 ab</td>
<td>1.10 a</td>
<td>0 b</td>
</tr>
</tbody>
</table>

*Chilling injury (CI) and heat injury (HI) indexes: 1-5 with 1 = none, 2 = trace, 3 = slight, 4 = moderate, and 5 = severe.
*Mean separation in columns by Duncan's multiple range test, 5% level.

The lowest incidence of decay (mostly 5 to 10%; Tables 3 and 4). Fruit from the other hot water treatments (5 and 10 min at 52°C; 2.5, 5, and 10 min at 54°C) developed mostly moderate heat injury. As before, chilling injury, which was moderate in the controls after 2°C storage, was completely eliminated by the hot water treatments (Table 4). Decay incidence in the 5 and 10 min at 52°C and 2.5 and 5 min at 54°C treatments stored at 12°C (mean = 35%) was not significantly different from the control treatments (mean = 28%), while the 10 min at 54°C treatment had higher (60%) decay incidence (Table 3). For the chilled fruit, decay incidence averaged 42% for the controls and was not increased by the hot water treatments that caused moderate heat injury (mean = 25%; Table 4). Results were similar for 'Florida 47' tomatoes (data not shown).

The color values for 'Florida 47' tomatoes from the 2.5, 5, and 10 min at 50°C water treatments were compared to those of control fruit during ripening at 20°C following 2 or 12°C storage in order to find if these hot water treatments affected color development. The fruit from 12°C storage had already begun to ripen as indicated by the L* values (Fig. 1A) and hue angles (Fig. 1B) by the time they were transferred to 20°C. While decay was too severe in the control fruit to allow color measurements beyond 4 d at 20°C, nevertheless, it is apparent that the hot water treatments accelerated color development of fruit stored at 12°C and then ripened at 20°C as both the L* values and hue angles decreased more compared to the control, indicating development of darker, more red color. Color development was also stimulated by longer hot water treatments. Although chroma values were highest in the 2.5-min hot water treatment at transfer from 12°C to 20°C, after 4 d the chroma values were higher in the 5 and 10-min hot water treatments than in the control and 2.5-min hot water treatments (Fig. 1C). This indicates that the fruit from the longer hot water treatments developed purer shades of red as they ripened following 12°C storage.

The fruit stored at 2°C were still light green at the time of transfer to 20°C as indicated by the relatively high L* values (Fig. 1A) and by hue angles of 90-100° (Fig. 1B). There was little difference among the treatments in L* values through 4 d at 20°C (Fig. 1A), but changes in hue and chroma indicated that the control fruit became light orange while the hot water-treated fruit remained somewhat green (Figs. 1A and B). By 7 d after transfer from 2°C to 20°C, the tomatoes from the 10 min at 50°C treatment had developed more red color than the other hot water treatments, but their color was still only roughly equivalent to that of the 12°C-stored fruit at the time they were transferred to 20°C. The pattern of color development in the hot water-treated fruit after 2°C storage, however, was similar to that of the 12°C-stored fruit, and appeared to be normal, i.e. without unevenness or blotchiness indicative of chilling injury.

**Discussion**

Brief, 2.5 to 5-min, immersion of mature-green tomato fruit in water at 50 to 52°C induced tolerance to 2 weeks of chilling exposure at 2°C with no or only minor heat injury. These treatments were at least as effective as an immersion for 60 min in 42°C water reported by McDonald et al. (1996, 1998, 1999) and could more easily be incorporated into current commercial tomato handling operations. Hot water treatments that caused moderate to severe heat injury in our tests included >44°C for >60 min, 52°C for >5 min, and 54°C for >2.5 min. These results are quite different from those of Inaba and Crandall (1988), who reported that 'Sunny' tomatoes could tolerate 45°C water for 166 min and 50°C water for 105 min, and Hakim et al. (1997), who reported tolerance of...
Table 3. Quality characteristics of ‘Sun Pride’ tomatoes stored at 12 and 20°C following various hot water treatment schedules.

<table>
<thead>
<tr>
<th>Heat treatment</th>
<th>2 wk @12°C</th>
<th>2 wk @12°C + 4 d @20°C</th>
<th>2 wk @12°C + 7 d @20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H1 rating</td>
<td>Decay (%)</td>
<td>H1 rating</td>
</tr>
<tr>
<td>24°C/2.5 min</td>
<td>1.00 b</td>
<td>0.0 %</td>
<td>1.00 f</td>
</tr>
<tr>
<td>24°C/5 min</td>
<td>1.00 b</td>
<td>0.0 %</td>
<td>1.00 f</td>
</tr>
<tr>
<td>24°C/10 min</td>
<td>1.00 b</td>
<td>0.0 %</td>
<td>1.00 f</td>
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<tr>
<td>50°C/2.5 min</td>
<td>1.00 b</td>
<td>0.0 %</td>
<td>1.00 f</td>
</tr>
<tr>
<td>50°C/5 min</td>
<td>1.00 b</td>
<td>2.65 c</td>
<td>5 ed</td>
</tr>
<tr>
<td>50°C/10 min</td>
<td>1.00 b</td>
<td>3.25 d</td>
<td>5 ed</td>
</tr>
<tr>
<td>52°C/2.5 min</td>
<td>1.00 b</td>
<td>3.15 d</td>
<td>0 e</td>
</tr>
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<td>1.00 b</td>
<td>3.50 c</td>
<td>5 ed</td>
</tr>
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<td>4.50 a</td>
<td>25 bc</td>
</tr>
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<td>1.00 b</td>
<td>4.10 a</td>
<td>30 bc</td>
</tr>
<tr>
<td>54°C/5 min</td>
<td>1.10 b</td>
<td>4.40 a</td>
<td>35 b</td>
</tr>
<tr>
<td>54°C/10 min</td>
<td>2.35 a</td>
<td>4.50 a</td>
<td>60 a</td>
</tr>
</tbody>
</table>

Heat injury (HI) index: 1-5 with 1 = none, 2 = trace, 3 = slight, 4 = moderate, and 5 = severe.

Table 4. Quality characteristics of ‘Sun Pride’ tomatoes stored at 2 and 20°C following various hot water treatment schedules.

<table>
<thead>
<tr>
<th>Heat treatment</th>
<th>2 wk @2°C</th>
<th>2 wk @2°C + 4 d @20°C</th>
<th>2 wk @2°C + 7 d @20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CP rating</td>
<td>HP rating</td>
<td>Decay (%)</td>
</tr>
<tr>
<td>24°C/2.5 min</td>
<td>1.00 a</td>
<td>1.00 a</td>
<td>0 a</td>
</tr>
<tr>
<td>24°C/5 min</td>
<td>1.00 a</td>
<td>1.00 a</td>
<td>0 a</td>
</tr>
<tr>
<td>24°C/10 min</td>
<td>1.00 a</td>
<td>1.00 a</td>
<td>0 a</td>
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<tr>
<td>50°C/2.5 min</td>
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<tr>
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<td>1.00 a</td>
<td>1.00 a</td>
<td>0 a</td>
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<tr>
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<tr>
<td>52°C/10 min</td>
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<td>1.00 a</td>
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<td>54°C/2.5 min</td>
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<td>1.00 a</td>
<td>1.00 a</td>
<td>0 a</td>
</tr>
<tr>
<td>54°C/10 min</td>
<td>1.00 a</td>
<td>1.00 a</td>
<td>0 a</td>
</tr>
</tbody>
</table>

Chilling injury (CI) and heat injury (HI) indexes: 1-5 with 1 = none, 2 = trace, 3 = slight, 4 = moderate, and 5 = severe.

Mean separation in columns by Duncan’s multiple range test, 5% level.
number of green and breaker fruit in the nonheated controls at transfer (data not shown), suggesting that less mature fruit may be more susceptible to heat injury. However, fruit that developed serious heat injury symptoms remained green and failed to ripen, precluding a definitive conclusion as to whether heat injury preferentially affected less mature fruit or simply inhibited the ripening of those fruit it affected.

The narrow range of times and temperatures that we found would minimize both chilling injury and heat injury is somewhat problematic when considering the likelihood of the hot water treatments reported here being adopted by commercial tomato handlers. However, our observation that less mature fruit might be more susceptible to heat injury led us to speculate that exposure to ethylene following treatment with hot water might reduce or eliminate heat injury. Ethylene treatment following heated water exposure is the sequence used in commercial mature-green tomato handling, in which the fruit are dumped from field bins or gondolas into a heated water (typically 40-45°C) dump tank, elevated to the packing line after <3 min, sorted, packed, then treated with ethylene in gassing rooms at 21°C for 1 or more days until >90% of the fruit have reached the breaker stage of ripeness. In a preliminary test with ‘Florida47’ tomatoes (unpublished), we found that treatment with 100 μl l⁻¹ ethylene for 2 d following 50°C hot water treatment resulted in complete elimination of both chilling injury and heat injury symptoms after 2 weeks at 2°C. McDonald et al. (1998) had previously reported that a 1-d ethylene treatment, either before or after heat treatment (42°C water for 60 min or 38°C air for 2 d), had no effect on fruit quality of ‘Sunbeam’ tomatoes following storage for 2 weeks at 2°C.

**Literature Cited**


**Figure 1.** Changes in L⁺ values (A), hue angles (B), and chroma values (C) of hot water-treated ‘Florida47’ tomatoes at 20°C following storage at 2 or 12°C. Heated fruit were exposed to 50°C water for the times indicated. Control (CK) fruit were exposed to 24°C water for 10 min. Vertical bars represent standard deviations of the data (n = 20).

**Figure 1**.

---

![Graph A](image1)

**Graph A:**

- CK/12°C
- CK/2°C
- 2.5min/12°C
- 2.5min/2°C
- 5min/12°C
- 5min/2°C
- 10min/12°C
- 10min/2°C

![Graph B](image2)

**Graph B:**

- Hue angle

![Graph C](image3)

**Graph C:**

- Chroma value

---

**Literature Cited**

THE POTENTIAL FOR BELL PEPPER HARVEST PRIOR TO FULL COLOR DEVELOPMENT

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Additional index words. Capsicum annuum, postharvest, quality, ethylene, ripening, storage.

Abstract. 'Triple 4' (red cultivar) and 'Kelvin' (yellow cultivar) bell peppers (Capsicum annuum L.) were greenhouse-grown and harvested during two distinct seasons. Harvest 1 (February, 1999) occurred during short photoperiods and cooler daytime temperatures, and Harvest 2 (May) during longer photoperiods and warmer days. Peppers were picked with 10 to 30% color (Stage 3) and 100% color (fully ripe). Fruits of each variety at Stage 3 were also tagged and left to ripen on the plants. Harvested peppers were stored at 20°C and 90% relative humidity (RH) +/- continuous exposure to ethylene gas (100 ppm) using a flow-through system. Both cultivars of peppers ripened off the plant had similar appearance and compositional quality to those ripened on the plant. Red peppers harvested at the onset of color change developed full color faster in storage (4.7 to 5.2 days) than yellow bell peppers left on the plant (10.7 days). Constant exposure to ethylene and harvest season had no effect on ripening for either variety. At full-ripe stage red and yellow peppers averaged 29.9 and 87.5 °Brix, respectively. Red and yellow peppers had similar flesh firmness with respect to harvest season and harvest maturity (26.6 to 31.8 N for red and 22.6 to 28.3 for yellow). Red and yellow pepper varieties could be harvested commercially at the onset of color change and ripened at 20°C and 90% RH while maintaining high quality.

With 19,000 acres of land planted during the 1996-97 season, bell pepper is one of the most important vegetable crops in Florida (Anonymous, 1998). Bell peppers ripen to various colors depending on the cultivar. Most are harvested and commercialized at immature stage or green color, after the fruit pericarp walls have thickened. Being a hollow fruit, the walls are quite sensitive to bruising and must be handled carefully (Brecht and Sargent, 1995).

Sales of fully ripened fruits have increased in recent years. Several factors have stimulated the market in this direction, notably, fruit quality characteristics (thicker and firmer wall, higher nutritional value and sweeter flavor) and higher prices. Sugar contents have been associated with flavor for a number of fruits and vegetables. Total sugar contents of 1/3 and 50% higher, respectively, than those for mature-green peppers (J. K. Brecht, unpublished data). Ascorbic acid contents for raw green and red peppers were reported to be 128 and 190 mg/100 g fresh wt., respectively (USDA, 1984). Other flavor and aroma compounds may also play a part in the flavor differences noted between green and fully ripe bell peppers.

The majority of ripe-harvested peppers are greenhouse grown and imported from Europe, although U.S., Canadian and Mexican production is increasing, and a number of Florida field growers pack ripe peppers on a small scale. Field-grown bell peppers in Florida may have higher returns when harvested green, since the extra time required to develop full color increases production costs due to additional decay and insect damage. A single application of ethephon at 1.12 kg/ha resulted in an almost three-fold increase in ripe 'Yolo Wonder' peppers at harvest (Locascio and Smith, 1977). Care must be