Acceptable Cooling Delays for Selected Warm Season Vegetables and Melons

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Abstract

Small-scale vegetable growers often do not have postharvest equipment and may transport products to larger operations for cooling and storage. Delays from harvest to cool may impact quality mainly due to water loss and its consequences, loss of firmness and visual appearance. The impact of delays to cool on marketable quality (visual appearance, gloss, weight loss, color change, decay, defects, and firmness) was evaluated in several tests on warm season vegetables (eggplant, summer squash, peppers) and cantaloupe melons. In most tests, products were harvested early in the morning, placed in perforated plastic bags in coolers for transport to the lab and then exposed for different periods to temperature and humidity conditions that are representative of California conditions for that product. Products were then cooled and evaluated after a postharvest regime of storage and/ or retail display appropriate to each product. In some experiments packed products were held for different periods under field conditions before cooling. Sutured melons with 1.5% weight loss did not have browning, while fruit with 4-5% weight loss had severe suture browning. Delays to cool of 6-8 h at 37°C resulted in increased browning. For non-sutured cantaloupes, delays of 4 hours or longer at 25-30°C resulted in reduced quality when melons were stored for 2 weeks at 2.5°C. Weight loss of mature-green bell peppers during delays at 25 and 37°C was 0.4 and 0.75% per hour, respectively. A weight loss of 2 to 4% reduced pepper firmness, gloss and visual quality. Color change occurred in peppers held for 12 hours at 37°C before cooling. Marketable quality of Japanese eggplants was decreased with a 3% weight loss, achieved with a 3 hour delay at 37°C or 6 h delay at 25°C. Delays to cool at 25°C of 6 hours in yellow crookneck squash resulted in reduced quality and shelf-life.

INTRODUCTION

Temperature management is critical for marketing high quality produce to regional or long distant markets. Previously we summarized our recommendations regarding allowable delays to cool for different commodities (Thompson et al., 2001). Although our general recommendation is “cool as soon as possible”, we estimate that a few hours delay would generally not affect the postharvest quality and shelf-life of most products. However, we lack specific data for different products. Here we summarize several studies that evaluate the impact of water loss and delays to cool on quality attributes of bell peppers, eggplants, summer squash and cantaloupe melons. We also report objective measurements of gloss and firmness, which were highly correlated with subjective scoring of both attributes.

MATERIALS AND METHODS

Peppers were obtained from harvest crews in the field, packed into waxed carton boxes and cooled in high humidity air to 7°C within 1 hour of harvest, placed in perforated plastic bags in coolers and transported to the lab under cool humid conditions (water loss under these conditions was <0.2%). Some fruit were held at 20°C on trays to determine quality attributes in relation to % weight loss. For the delay to cool test, we subjected fruit to different periods at 37°C, 35-38% RH and 25°C, 47-50% RH. Peppers

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were then weighed, hydrocooled for 15 min, and reweighed. Peppers were evaluated for final quality after 7 days storage at 7.5°C. Japanese eggplants were harvested and packed commercially in the field (rinsed, sized) into waxed cartons, cooled in humid air at 7-8°C within 0.5 hours of harvest, and then handled as described for peppers. Some fruit were held at 20°C on trays to determine quality attributes in relation to % weight loss. For the delay to cool test, eggplants were placed in waxed cartons after weighing (2 boxes per delay containing 10 fruit each), and subjected to delays to cool at 25°C, 48-50% RH and at 37°C, 38-40% RH. After delays, fruit were hydrocooled, reweighed, and stored in waxed boxes at 7.5°C. Eggplants were evaluated for final quality after 7 days of storage. For squash and melons similar procedures were used.

Visual quality was scored on a 9 to 1 scale, where 9=excellent, fresh appearance, 7=good, 5=fair (limit of marketability), 3=fair (usable but not salable), 1=unusable. Intermediate numbers are assigned where appropriate. Decay was estimated as area percentages of the tissue affected with any decay, and then scored as follows: 1=no macroscopic decay, 2=slight decay, 1-2% area, but product salable, 3=moderate (2-5%), product usable but not salable, 4=moderately severe (5-10% area affected) and 5=severe (>10% area affected), unusable. Dehydration was scored on a 1 to 5 scale, where 1=none, 2=slight, 3=moderate (would result in price adjustment commercially), 4=moderately severe, 5=severe. Weight loss was determined by weighing product to the nearest 0.01 g. Texture was scored on a 5 to 1 scale, where 5=very firm, 3=moderately firm, and 1=soft or limp. Texture was also determined objectively measuring the force (N) to compress product 5 mm with a 25 mm diameter flat probe on a TAXT texture analyzer or on melon by force to penetrate pulp with a 1 cm probe, unless otherwise specified. Gloss was measured with a portable gloss meter (BYK-Gardner Micro Tri-gloss meter, 60° geometry, calibrated with gloss standard 4520). This meter measures a flat surface about 1×2 cm. Areas on the fruit surface were chosen which were essentially flat for measurement as required by the instrument.

RESULTS AND DISCUSSION

Mature-Green Bell Peppers

A weight loss of 2 to 4% reduced bell pepper firmness, gloss and visual quality (Table 1). Hydrocooling peppers resulted in significant weight gain, which did not benefit pepper quality after storage (data not shown). Average weight loss with cooling delays at 37 and 25°C was 0.13 and 0.06% per hour, respectively (Table 2). Total weight loss during storage at 7.5°C averaged 1.9% over 7 days. The overall visual quality of the peppers after a 7-day storage period was significantly less with a 9-hour delay to cool compared to that of peppers with shorter cooling delay periods (Table 2). Significant increases in decay were observed with a 12-hour delay at 37°C (data not shown), but no increase in decay was noted with up to 18 hours delay to cool at 25°C. Significant decreases in gloss scores (data not shown) and gloss meter values (Table 3) were observed with cooling delays of 9 hours at both 25 and 37°C. Important decreases in firmness scores (data not shown) and firmness values (Table 3) occurred after a 9 hour delay at 37°C, but not until after an 18 hour delay at 25°C. No color change occurred in the peppers held at 25°C for up to 18 hours, but after 12 hours at 37°C, some peppers were beginning to color (data not shown).

Summer Squash (Yellow Crookneck)

The yellow crookneck summer squash plants and fruits in one test had been affected by virus (Table 3). Nevertheless, delays between 6 and 9 hours resulted in reduced visual quality after storage (10 days at 7.5°C) in combination with increased scores for defects, mainly discolored and sunken areas (data now shown). There were no clear quality differences between air-cooled and hydro-cooled squash. At temperatures of 25-30°C, squash in commercial waxed cartons lost about 0.3% weight per hour. Squash absorbed dump tank water, with about 1.8 and 2.2% weight gains after a 15 and 30 min

dip in water at 28°C. Absorption of cold water during hydrocooling averaged 1.2% for 15 min. With delays to cool > 3 hours, weight gain due to water uptake did not compensate for weight loss caused by the delay to cool.

Eggplants

Table 4 shows changes in quality attributes of Japanese eggplants in relation to weight loss. Visual quality scores were significantly decreased with a 3% weight loss, but significant differences in firmness were measurable with a 2% weight loss. Gloss values were not significantly affected until weight loss exceeded 8% (Table 4), although the visual quality scores were very low. Weight gain after hydrocooling averaged 0.8% for a 15-min dip (Table 5). Weight loss during the storage period averaged 3.7%. Visual quality scores were decreased by a 6-hour delay to cool at either 25 or 37°C (Table 5). Decreased visual quality with increased cooling delays was associated with increased dehydration and decay scores and decreases in whole fruit firmness and gloss scores. Firmness and gloss were not affected as rapidly as the visual quality scores by delays to cool. Firmness values decreased significantly after 9 and 12 hours at 37 and 25°C, respectively (Table 5). Gloss values did not decrease significantly until delays of 9 hours at either temperature.

Cantaloupe Melons

Non-sutured western shipping cantaloupes were affected by delays to cool of greater than 4 hours at typical summer field temperatures (25-30°C). The impact of 6 and 12 hour delays to cool on quality are illustrated in Figure 1. In another test, Table 6 shows similar results with cooling delays in morning and afternoon harvested fruit. In sutured melons ('Tuscan'), suture discoloration associated with weight loss affects the visual quality of the melons (Fig. 2). Delays of 8 hours or more were required to decrease quality by increasing suture discoloration (Table 7), but in another test, sutured melons had decreased quality with a 6 hour delay to cool (data not shown).

CONCLUSIONS

Delays to cool reduced visual quality, glossiness and firmness, and increased visible symptoms of dehydration for bell peppers, eggplants and squash. For melons, delays to cool affected the same parameters except gloss. Acceptable delays to cool vary depending on the product and the specific ambient conditions. In general for bell peppers, delays to cool should be less than 9 hours at 20-25°C and less than 6 hours at 37°C. For Japanese eggplants, delays to cool should be less than 6 hours at 20-25°C and less than 3 hours at 37°C. Under similar conditions, delays to cool for cantaloupe melons should be less than 6 hours.

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Tables

Table 1. Quality attributes of mature-green bell peppers in relation to weight loss at 20°C. Data are averages from 16 fruits per treatment of induced weight loss.

Weight loss (%)	Visual quality (score)	Dehydration (score)	Firmness (Newton)	Gloss (value)
0.3	8.4	1.1	23.3	6.7
2.0	7.2	2.3	16.2	5.8
2.8	5.9	2.8	12.5	4.7
3.9	4.8	3.1	7.1	3.4
LSD.05	0.4	0.4	2.8	1.0

[1] Visual quality scored 9 to 1; 9=excellent, fresh appearance, 7=good, 5=fair (limit of salability), 3=poor (usable but not salable), 1=unusable. A score of 6 is considered the minimum for salability.
[2] Dehydration scored 1 to 5 scale; 1=none, 2=slight, 3=moderate (would result in price adjustment), 4=moderately severe, 5=severe.
[3] Firmness measured as force in Newton to compress the fruit at the equator with a 25 mm diam. flat probe to a depth of 5 mm. 1 Newton= 9.81 kg-force or 4.45 pounds-force.
[4] Gloss was measured with a BYK-Gardner gloss meter; the higher the value, the glossier the surface.

Table 2. Mature-green bell pepper weight loss and quality in relation to delays to cool at 25 or 37°C. After delay periods, fruit were hydrocooled and stored at 7.5°C in waxed cartons and evaluated after 7 days. Data averages of 24 peppers per treatment. See Table 1 for descriptions of analyses.

Temp. and hours delay	Weight loss after delay (%)	Weight gain after cooling (%)	Weight loss during storage (%)	Final weight loss (%)	Visual quality	Dehydra-tion	Firmness (Newton)	Gloss meter value
at 37°C								
0	0	1.09	2.06	0.97	8.5	1.2	19.7	6.1
3	0.25	0.68	1.62	1.19	8.6	1.2	20.9	6.3
6	0.60	1.16	1.66	1.11	8.3	1.5	19.9	5.4
9	1.33	0.69	1.67	2.30	7.5	2.3	16.6	4.9
12	1.80	1.39	2.10	2.52	6.0	2.8	14.2	4.5
18	3.25	1.82	1.64	3.10	3.6	3.4	10.7	4.0
at 25°C								
0	0	1.09	2.06	1.00	8.5	1.2	19.7	6.1
3	0.15	0.67	1.91	1.41	8.1	1.2	21.0	5.4
6	0.36	0.75	1.87	1.49	8.1	1.5	22.5	5.4
9	0.52	1.59	1.55	1.91	7.3	2.4	21.5	4.1
12	0.69	1.82	2.93	1.86	7.2	3.0	19.3	4.4
18	1.04	0.57	1.61	2.08	7.5	3.0	17.4	4.9
LSD.05	0.07	0.31	0.42	0.13	0.6	0.4	2.5	1.1

Table 3. Weight loss and quality attributes of yellow crookneck squash packed in waxed 5-kg cartons with delays before cooling in humid air (Humifresh; weight loss <0.4%). See Table 1 for descriptions of analyses.

Delay to cool (h)	Time of day	Pulp temp. after delay (°C)	% wt. loss after delay and cooling	Visual quality 10 d 7.5°C	Discoloration 10 d 7.5°C	Sunken areas 10 d 7.5°C
1.5	11:45 am	28	0.6	4.6	3.2	2.7
4.5	2:45 pm	31	1.5	4.7	3.1	2.6
7.5	5:45 pm	32	2.3	4.5	3.1	2.9
10.5	8:45 pm	25	3.2	4.5	3.3	3.3
24.0	11:45 am	25	6.2	3.5	3.8	3.8
LSD.05			0.4	0.4	0.3	0.3

Table 4. Quality attributes of Japanese eggplants in relation to weight loss at 20°C. Data are averages of 24 fruits per treatment. See Table 1 for descriptions of analyses.

Weight loss (%)	Visual quality	Dehydration score, calyx	Dehydration score, fruit	Firmness (N)	Gloss value
0.7	8.2	1.6	1.4	30.8	7.1
2.1	7.5	1.1	1.5	24.2	6.2
3.4	6.8	1.3	1.2	25.0	6.0
6.8	5.0	3.7	3.6	21.0	6.4
8.4	2.9	4.0	4.2	21.9	5.4
LSD.05	0.7	0.6	0.5	3.1	1.2

Table 5. Weight loss and quality attributes of Japanese eggplant in relation to delays to cool at 25 or 37°C. After delays, fruits were hydrocooled and stored at 7.5°C (45°F) in waxed cartons. Quality was evaluated after 7 days. Data from 20 fruit per treatment. See Table 1.

Temp. and hour delay	% wt. loss after delay	% weight gain after hydrocool	% weight loss after storage	Final weight loss (%)	Visual quality	Dehydration score	Firmness (N)	Gloss value
at 37°C								
0	0	0.77	3.16	2.41	7.8	1.8	29.0	7.6
3	0.81	0.83	3.51	3.49	7.2	1.8	26.7	7.6
6	2.74	0.78	3.88	5.78	5.8	2.4	25.3	7.0
9	3.78	0.65	3.66	6.69	4.6	2.6	24.9	4.8
12	4.98	1.36	3.89	7.42	3.2	3.5	23.8	3.6
18	6.18	0.37	3.31	8.95	2.2	4.2	21.6	3.4
at 25°C								
0	0	0.77	3.16	2.41	7.8	1.8	29.0	7.6
3	0.46	0.71	3.71	3.47	7.4	1.8	30.0	7.7
6	0.70	0.76	3.94	3.88	6.4	2.0	27.8	6.3
9	1.24	0.71	4.18	4.69	5.8	2.2	25.0	5.5
12	1.94	1.24	4.45	5.13	4.4	2.5	23.1	4.6
18	2.73	0.41	3.50	5.75	3.7	3.6	21.1	4.1
LSD.05	0.24	0.09	0.26	0.30	0.6	0.5	3.6	1.8

Table 6. Effect of delays to cool on initial and final quality of commercially packed cantaloupe melons. Fruit were stored for 10 days at 5°C. Initial melon pulp temperatures at AM harvest were 18°C; Initial melon temperature of PM harvest was 36°C. Boxed melons were cooled in a commercial forced air cooler. See Table 1 for descriptions of analyses.

Hours delay to cool	Visual quality		% soluble solids		% weight loss		Pulp firmness (N)	
	0d	10d	0d	10d	0d	10d	0d	10d
				AM harvest				
0	8.4	7.6	11.0	10.7	1.6	4.4	2.7	2.0
3	8.0	7.3	10.4	10.8	1.8	4.0	2.4	2.0
6	8.2	6.9	10.6	9.4	1.8	4.2	2.0	1.6
9	8.1	7.1	10.1	10.1	1.4	3.9	1.8	1.4
12	8.0	6.6	9.8	9.2	1.6	4.0	1.9	1.6
				PM harvest				
0	8.1	7.4	9.8	9.7	1.7	4.2	2.0	1.6
3	7.6	7.5	9.0	9.6	1.1	3.4	1.9	1.6
6	8.0	6.8	9.6	9.3	1.5	4.0	1.8	1.6
9	7.9	6.8	9.5	9.2	1.2	3.3	1.8	1.4
12	8.1	6.7	9.7	9.4	1.3	4.5	1.6	1.4
LSD.05	0.3		0.4		0.5		0.1	

Table 7. Quality attributes of sutured 'Tuscan' melons held for different periods at 37°C before cooling and storage (10 days storage at 5°C) and simulated shelf-life (plus 4 days at 20°C). Data average of 6 melons. See Table 1 for descriptions of analyses.

Delay to cool hours	% weight loss before cooling	% weight loss 10D 5°C	% weight loss 4D 20°C	Total weight loss (%)	External visual quality	Decay stem-end	Decay surface	Suture browning
0	0.00	2.14	0.97	3.08	7.1	1.4	1.9	1.2
4	0.38	1.95	0.96	3.25	5.8	2.7	2.6	1.3
8	0.85	1.85	0.78	3.45	6.3	2.3	2.6	1.3
12	1.19	1.62	0.79	3.56	5.0	2.4	3.5	1.4
16	1.50	1.32	0.85	3.63	5.0	1.4	2.8	2.8
20	2.06	1.47	0.68	4.15	4.0	3.6	3.0	4.0
24	2.80	1.41	0.71	4.85	2.0	3.9	3.8	4.2
LSD.05	0.21	0.42	ns	0.60	1.5	1.4	1.1	1.1

Figures

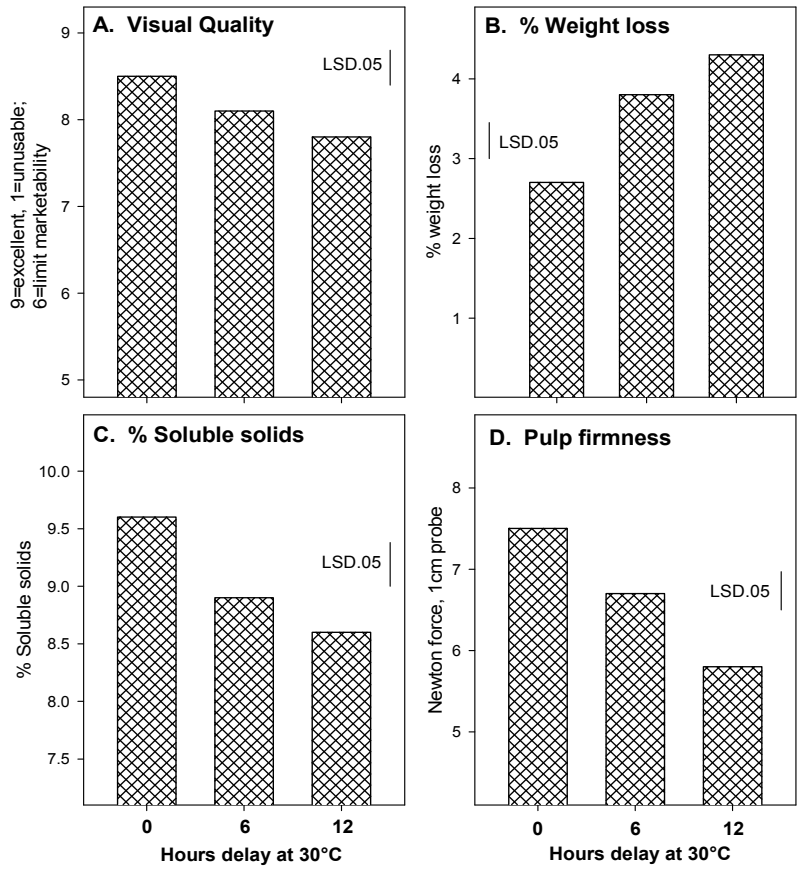

Fig. 1. Quality of cantaloupe melons ('Durango') after 14 days at 2.5°C. Melons were harvested and forced-air cooled after 0, 6 or 12 hour delays at 30°C, 40% RH. Data are averages of 3 replicates of 8 melons each. Vertical bars indicate LSD.05.

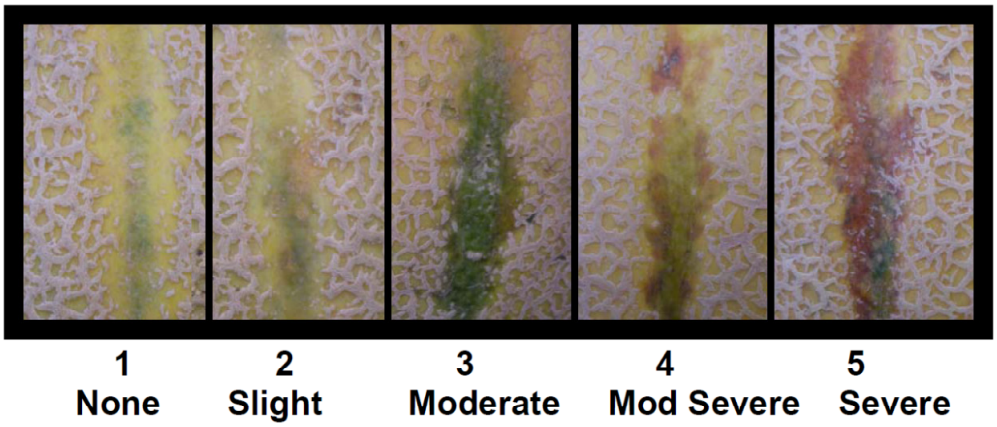

Fig. 2. Scoring system used to evaluate suture discoloration in ‘Tuscan’ melons.