Postharvest Application of Chelated and Nonchelated Calcium Dip Treatments to Commercially Grown Honey Dew Melons: Effects on Peel Attributes, Tissue Calcium Concentration, Quality, and Consumer Preference following Storage

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SUMMARY. Commercially grown honey dew fruit [*Cucumis melo* (Inodorus

group)] typically are harvested before abscission because fruit cut unripe have a longer storage life than fully ripe fruit. However, because fully ripe fruit contain higher concentrations of soluble solids (predominantly as sugars), an attribute that increases their preference among consumers, methods are being explored to extend the storage life of fully ripe fruit. In this study, fully abscised honey dew fruit were evaluated for tissue attributes and consumer preference following postharvest dipping in either chelated or nonchelated calcium (Ca) solutions. Calcium sources were an amino acid-chelated Ca, ethylenediamine tetraacetic acid (EDTA)-chelated Ca, or calcium chloride (CaCl_2), with each provided at three different rates. Fruit were evaluated at harvest, and after 14 or 22 days commercial storage. Evaluations were peel surface changes (color and disorders), hypodermal-mesocarp tissue Ca concentration, flesh firmness, soluble solids concentration, and consumer preference of the edible flesh. Peel color became yellowed and lighter during storage for all fruit, with higher Ca rates resulting in more intensely yellowed fruit. Hypodermal-mesocarp tissue Ca concentration was $0.90 \text{ mg} \cdot \text{g}^{-1}$ of fresh weight (900 ppm) at harvest, and declined in all fruit by 22 days storage. Peel disorders (disease and spotting) were none to slight for all fruit by 14 days storage, but by 22 days storage disease incidence ranged from none to severe, depending on the Ca source and rate. Fruit firmness declined in all fruit throughout storage, with the smallest declines measured in fruit treated with the amino acid-chelated Ca. Soluble solids concentration of fully ripe fruit was 12.3% at harvest, and showed either no decline or slight declines with storage among the treatments. Consumer preference was highest for freshly harvested fruit, but fruit were desirable even after 22 days storage across all treatments. Postharvest application of Ca at $\leq 0.16 \text{ M}$ Ca in an amino acid-chelated form, versus EDTA-chelated Ca or CaCl_2 , slowed honey dew melon senescence so that after 22 days of commercial and retail storage the fruit were of high marketable quality, and there was no detrimental effect on consumer preference for the edible flesh.

shown to benefit storage life and other postharvest characteristics (Lester and Grusak, 1999). When applied immediately after harvest, an amino acid-chelated Ca treatment (0.08 M Ca for 20 min) maintains the hypodermal-mesocarp Ca concentration in 10 d postharvest fruit equal to the Ca concentration found in untreated fruit at abscission. Maintaining stored honey dew fruit Ca concentration at levels found in recently abscised fruit extends tissue firmness, plasma membrane integrity, and storage life. Additionally, the application of Ca chloride (a nonchelated source of Ca) to excised tissue disks taken from greenhouse-grown netted muskmelon fruit, also delayed tissue senescence by maintaining cellular osmotic tonicity (Lester, 1996). Although application of Ca to whole fruit or tissue disks of greenhouse-grown melon fruit has been reported, no similar studies have been reported for commercially grown fruit. Therefore, the objective of this study was to assess the benefits of the postharvest application of three Ca sources (two commercial chelated-Ca formulations, and CaCl_2) at three different Ca treatment rates, using commercially grown, harvested, and packed melon fruit. Fruit were evaluated for peel changes (color and disorders), tissue Ca concentration, firmness, soluble solids concentration, and consumer preference following commercial storage for 14 or 22 d.

Materials and methods

PLANT MATERIAL. Fully abscised fruit of 'Honey Brew' honey dew muskmelon, free of defects, were obtained from Starr Produce Co., a commercial melon producer/packer/shipper, located near Rio Grande City, Texas. All fruit were collected from the packing house by 0900 HR, washed in 0.53% (sodium hypochlorite) bleach, rinsed with tap water, then randomized into lots for Ca/storage treatments. All fruit and all solutions were about 23 to 26°C (73 to 79°F).

FRUIT WEIGHT AND PEEL COLOR DETERMINATIONS. All fruit were weighed before and after storage. At harvest, epidermal (peel) color was measured at three locations around the equator (excluding the side previously in contact with the ground, i.e., the ground spot was not included in any of the analyses due to altered metabolic and developmental factors re-

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The postharvest application of amino acid-chelated Ca to whole, fully ripened, greenhouse-grown honey dew fruit has been

sulting from soil or plastic mulch contact and poor air circulation) with a chromameter (CR-200; Minolta Corp., Ramsey, N.J.) calibrated to a white tile under illuminant condition C and expressed in the L^* (lightness), C^* (chroma), h° (hue angle) measurement mode. Following storage, all fruit were re-measured for color. The three measured values for each parameter were averaged for each fruit.

CALCIUM TREATMENTS. All fruit were submerged (dipped) for 20 min in $24 \pm 2^\circ\text{C}$ ($75 \pm 4^\circ\text{F}$), pH 8.0 to 8.3 solutions adjusted with potassium carbonate containing 0.0 (control), 0.08, 0.16, or 0.24 M Ca of either amino acid-chelated Ca (AC, calcium metalosate; Albion Laboratories, Inc., Clearfield, Utah), CaCl_2 (CC) or EDTA-chelated Ca (EC, Miller Chemical & Fertilizer Corp., Hanover, Pa.). All fruit were allowed to air dry for 20 min before placing in commercial honeydew melon shipping boxes, then stored at $10 \pm 1^\circ\text{C}$ ($50 \pm 2^\circ\text{F}$) and $94\% \pm 2\%$ relative humidity (RH) for 11 d or 19 d (simulating commercial shipping conditions) plus 3 d at $21 \pm 1^\circ\text{C}$ ($70 \pm 2^\circ\text{F}$) and $54\% \pm 2\%$ RH (simulating retail conditions).

CALCIUM DETERMINATIONS. Calcium concentrations were determined on hypodermal-mesocarp tissue taken from the equatorial region of the fruit. The epidermis was removed followed by the hypodermal-mesocarp tissue with a vegetable peeler. The hypodermal-mesocarp tissue was weighed immedi-

ately to determine fresh weight, and then dried at 70°C (158°F) for 48 h. Total Ca concentration per gram (2.2×10^{-3} lb) hypodermal-mesocarp tissue fresh weight was determined using atomic absorption spectroscopy (model 2100, Perkin-Elmer, Norwalk, Conn.) as previously described (Lester and Grusak, 1999).

FRUIT SURFACE DISORDERS. Following storage, all fruit were rated for disease and spotting formation, as described by Carter (1981) and Lester (1989). Data for disease and spotting formation are presented as the percentage of all fruit affected within a treatment.

FRUIT FIRMNESS AND SOLUBLE SOLIDS CONCENTRATION DETERMINATIONS. Firmness of whole-fruit equatorial hypodermal-mesocarp tissue, less the epidermis, was measured using a 1 cm long $\times$ 5.1 mm diameter $\times$ 1 mm wide ($0.4 \times 0.2 \times 0.04$ inches) V-tip gauge (Chatillon force gauge; Lindy Electric, Glen Head, N.Y.) and expressed as mean force Newtons (N) ($4.48 \text{ N} = 1 \text{ lb force}$). Soluble solids concentration was determined on middle-mesocarp sections [1 cm long $\times$ 1 cm diameter] from three different locations along the fruit equatorial circumference (excluding the ground spot). Tissue sections were squeezed using a hand-held garlic press and soluble solids concentration on the expressed juice was determined using a temperature corrected, digital refractometer (Reichert Scientific Instruments, Buffalo, N.Y.).

CONSUMER PREFERENCE DETERMINATIONS. Eating quality for fruit from each of the treatments by storage combinations was determined at individual stations by an untrained 25-member preference panel. Each station displayed 2-cm^3 (0.8-inch^3) melon cubes of middle-mesocarp tissue taken from the equatorial region of the fruit (excluding the ground spot). The panelists were randomly selected from the local USDA-ARS research community. A 9-cm (3.6-inch) line scale was used to rate overall fruit preference as previously described (Lester and Shellie, 1992).

STATISTICS. Analysis of variance was used to evaluate Ca treatments and Ca rate differences for the various data sets (SAS Inst., Cary, N.C.). Duncan's multiple range test ($P \leq 0.05$) was used to discern between Ca treatment/rate classifications when F values were significant for main effects. Orthogonal comparisons for linear and quadratic components were determined for rate when F values were significant. Data are the average of eight, single-fruit replications per Ca treatment per Ca rate per storage period.

Results and discussion

PEEL COLOR DETERMINATIONS. Following 14 d of simulated commercial and retail marketing storage there was no difference among the Ca treatments (source), or the Ca concentrations (rate) for fruit peel lightness (L^*) or a change in hue angle (h° , i.e., the

Table 1. Color measurements of 'Honey Brew' honeydew melon peel before treatment (Pre), and after treatment and storage (Post). Abscised (harvested) fruit were treated for 20 min in water, or solutions of amino acid-chelated calcium (AC), calcium chloride (CC), or EDTA-chelated calcium (EC) at 0.08, 0.16, or 0.24 M calcium (Ca) concentration. Treated fruit were stored for 11 or 19 d at 10°C (50°F) plus 3 d at 21°C (70°F) and $95\% \pm 5\%$ relative humidity (total simulated commercial and retail storage duration of 14 or 22 d respectively).

Treatment/ molar Ca concn	Color characteristics ^z											
	Storage (d)											
	0			14			0			22		
	Pre L^*	Pre C^*	Pre h°	Post L^*	Post C^*	Post h°	Pre L^*	Pre C^*	Pre h°	Post L^*	Post C^*	Post h°
Water	81.90	20.08	100.23	81.81	19.38 c ^y	99.74	81.54	20.32	99.73	82.35 b	21.07 c	98.60
AC (0.08)	82.05	20.91	100.18	81.60	20.07 bc	99.19	82.12	20.23	99.87	82.35 b	22.30 bc	99.08
CC (0.08)	81.98	20.14	99.46	82.17	20.06 bc	99.19	81.99	20.56	99.81	82.44 b	21.42 bc	98.82
EC (0.08)	82.12	19.55	99.35	82.28	20.08 bc	98.94	81.77	21.37	99.96	82.21 b	22.55 bc	98.86
AC (0.16)	82.02	20.09	99.24	81.62	20.00 bc	98.92	81.96	19.01	100.89	82.32 b	23.32 ab	99.40
CC (0.16)	81.25	20.72	99.15	81.17	20.59 ab	98.83	81.72	20.16	99.98	82.50 ab	24.17 ab	98.62
EC (0.16)	81.74	20.41	99.77	81.89	20.41 ab	99.26	82.21	21.64	99.96	82.69 ab	23.60 ab	98.62
AC (0.24)	82.37	20.51	99.16	82.08	20.79 a	98.85	81.81	20.75	99.89	82.86 a	25.14 a	98.78
CC (0.24)	81.55	20.08	99.81	81.41	20.85 a	99.22	82.43	20.58	99.59	83.14 a	25.95 a	98.38
EC (0.24)	81.57	18.96	100.18	82.03	20.91 a	99.65	82.59	20.52	99.19	82.81 a	25.11 a	99.54
$P < 0.05$	NS	NS	NS	NS		NS	NS	NS	NS			NS

^zMeans of 10 fruit per treatment. L^* = lightness (+100 = white, -100 = black), C^* = Chroma (intensity), h° = hue angle (0° = red-purple, 90° = yellow, 180° = bluish-green, 270° = blue).

^yMean separation within a column and within days of storage at $P < 0.05$ according to the Duncan's multiple range test.

Table 2. Main effects of simulated commercial and retail storage (14 or 22 d) on color measurements of 'Honey Brew' honey dew melon peel before treatment (Pre), and after treatment and storage (Post). Control plus calcium sources and rate pooled. Treated fruit were stored for 11 or 19 d at 10 °C (50 °F) plus 3 d at 21 °C (70 °F) and 95% ± 5% relative humidity (total simulated commercial and retail storage duration of 14 or 22 d respectively).

Treatment	Storage (d)	Color characteristics ^z		
		L*	C*	h°
Pre	None	81.86 a ^y	20.14 a	99.65 a
Post	14	81.81 a	20.31 b	99.18 b
Pre	None	82.01 a	20.51 a	99.83 a
Post	22	82.57 b	23.46 b	98.87 b

^zMeans of 100 fruit for combined treatments/storage duration. L* = lightness (+100 = white, -100 = black), C* = Chroma (intensity), and h° = hue angle (0° = red-purple, 90° = yellow, 180° = bluish-green, 270° = blue).

^yMean separation within a column and within days of storage at $P < 0.05$ according to the Duncan's multiple range test.

Table 3. Effect of postharvest application of water, amino acid-chelated calcium (AC), calcium chloride (CC) or EDTA-chelated calcium (EC) at 0.08, 0.16, or 0.24 M calcium (Ca) concentration on concentration of Ca (mg·g⁻¹ fresh weight) in 'Honey Brew' honey dew melon hypodermal-mesocarp. Control fruit were analyzed at harvest. Treated fruit were stored for 11 or 19 d at 10 °C (50 °F) plus 3 d at 21 °C (70 °F) and 95% ± 5% relative humidity (total simulated commercial and retail storage duration of 14 or 22 d respectively).

Treatment	Molar Ca concn	Ca concn ^z (mg·g ⁻¹ fresh wt)	
		14 d storage	22 d storage
Harvest	None	0.90 ± 0.10	
Water	None	0.86 ± 0.04	0.70 ± 0.05
AC	0.08	0.91 ± 0.08	0.67 ± 0.05
	0.16	0.91 ± 0.09	0.58 ± 0.04
	0.24	0.80 ± 0.03	0.62 ± 0.05
CC	0.08	0.83 ± 0.04	0.64 ± 0.05
	0.16	0.77 ± 0.06	0.56 ± 0.04
	0.24	0.82 ± 0.07	0.62 ± 0.05
EC	0.08	0.67 ± 0.04	0.62 ± 0.05
	0.16	0.70 ± 0.04	0.59 ± 0.03
	0.24	0.72 ± 0.04	0.62 ± 0.05

^zValues are means ± SE (n=10); 1.00 mg·g⁻¹ = 1000 ppm.

Table 4. Analyses of variance for evaluation of honey dew 'Honey Brew' fruit dipped in various calcium (Ca) solutions (Treatments) at various rates (Rate) on fruit Ca concentration (Fruit Ca), firmness, soluble solids concentration (SSC) and consumer preference panel evaluation (Taste) after 11 or 19 d at 10 °C (50 °F) plus 3 d at 21 °C (70 °F) and 95% ± 5% relative humidity – total simulated commercial and retail storage duration of 14 or 22 d respectively – (Days).

Source of variance	df	Dependent variables ^z			
		Fruit Ca	Firmness	SSC	Taste
Replication	2	NS	NS	NS	NS
Treatment (T)	2	***	***	NS	***
Rate (R)	2	ns	***	NS	**
Linear	(1)	---	***	---	*
Quadratic	(1)	---	**	---	**
Days (D)	1	***	***	NS	NS
T × R	4	NS	**	NS	***
T × D	2	**	**	NS	NS
Error mean square	18	NS	NS	NS	NS

ns,*,***Nonsignificant or significant at the $P < 0.05$, 0.01, or 0.001 respectively.

predominant color, Table 1). However, chroma (C*, i.e., intensity of color), increased (became more intensely yellow) with increased rates of Ca application. After 22 d of storage, h° was still unaffected by Ca source or rate, but L* and C* values were affected (Table 1). As with 14 d stored fruit, 22 d stored fruit exposed to the higher Ca rates had a lighter, more intense yellow color. The effect of 0.24 M Ca in the dip solutions, regardless of source, indicates that higher rates appear to hasten senescence. This finding is supported by a previous study, whereby netted muskmelon fruit disks incubated in high (>0.16 M) versus low (≤0.08 M) Ca hastened senescence, as measured by a loss in chlorophyll (Lester, 1996). Although h°, the basic background color of the peel, did not change following exposure to increasing Ca rates, L* and C* did. This demonstrates that increased L* and C* values are representative indicators of senescence, as they reflect chlorophyll degradation, the transition of darker chloroplasts to lighter chromoplasts during senescence (Gross, 1991).

For control fruit harvested at abscission, the effect of 14 or 22 d storage on peel color parameters demonstrated that, the longer honey dew fruit are stored the more they will naturally become brighter (increased L*), more intensely colored (increased C*), and more yellow-orange (decreased h°) (Table 2.). These attributes have been shown to appeal to consumers (Lester and Shellie, 1992).

CALCIUM CONCENTRATION IN THE FRUIT. The Ca concentration of 'Honey Brew' hypodermal-mesocarp tissue (H-M) at harvest was 0.90 mg·g⁻¹ of fresh weight (Table 3). After 22 d storage, control fruit H-M Ca concentration declined 22%. Source of Ca was critical to enriching 'Honey Brew' H-M Ca concentration (Table 4). The only Ca source that resulted in no decline in H-M Ca concentration, after 14 d storage, was AC at the 0.08 and 0.16 M Ca rates (Table 3). This was in agreement with our previous study (Lester and Grusak, 1999) which showed that AC will migrate through the epidermis and will enrich the H-M tissue in stored fruit. Why the AC 0.24 M Ca rate did not result in higher H-M Ca concentration, compared to the lower rates, remains unexplained. Calcium concentrations of CC-treated fruit were less than those of control

fruit, and EC-treated fruit Ca concentrations were significantly less than control fruit. This suggests that CC and EC sources may not be as efficient in enabling the migration/diffusion of Ca through the epidermis and into the H-M. Maintaining the H-M Ca concentration equal to that found in recently harvested fruit is critical for extending honey dew melon postharvest life (Lester and Grusak, 1999). Following 22 d storage, all fruit showed a decline in H-M Ca concentration. On average, all Ca treated fruit had a decline of 32%, compared to fruit at harvest, versus control fruit which had a 22% decline. The general loss of Ca in H-M in AC-treated fruit following 22 d storage and in CC and EC-treated fruit following 14 d storage is explained by continued migration to the seed cavity (Bernadac et al. 1996; Lester and Grusak, 1999).

FRUIT SURFACE DISORDERS. Disease incidence for all fruit following 14 d storage was essentially none (Table 5). After 22 d storage, control fruit had the greatest number of diseased fruit (50%), versus AC- and CC-treated fruit which ranged from 0% to 25% of the fruit affected. The EC-treated fruit demonstrated a consistent 25% disease incidence at each Ca rate at 22 d storage. This indicated that EC treatment, although better than the control, may not be as effective at controlling disease as are AC and CC. However, regardless of Ca source, the post-harvest application of Ca to honey dew fruit reduced the incidence of disease. These results corroborate similar findings for apples (*Malus domestica*) and potatoes (*Solanum tuberosum*) (Conway et al., 1992).

Severity of disease after 14 d of storage was also essentially none, but by 22 d a treatment effect occurred (Table 5). Both the control and EC treatments had severity of disease greater than that for AC or CC. As EC Ca rate increased, the severity of disease increased from slight (0.08 M Ca) to severe (0.24 M Ca). Although too much exogenous Ca applied to apple fruit can have a phytotoxic effect (Saffner et al., 1998), the severe incidence of disease in EC-treated fruit at 0.24 M Ca may be the result of EC toxicity. Severe EC toxicity was found when using the EC form of Ca to treat apple fruit (Beavers et al., 1994). Blockage of openings in the fruit surface may have restricted gaseous exchange resulting in surface injury (Hewitt and Th-

Table 5. Fruit surface disorders evaluation of 'Honey Brew' honey dew melons. Abscised (harvested) fruit were dipped for 20 min in water, amino acid-chelated calcium (AC), calcium chloride (CC), or EDTA-chelated calcium (EC) at 0.08, 0.16, or 0.24 M calcium (Ca) concentration. Treated fruit were stored for 11 or 19 d at 10 °C (50 °F) plus 3 d at 21 °C (70 °F) and 95% ± 5% relative humidity (total simulated commercial and retail storage duration of 14 or 22 d respectively).

Treatment	molar Ca concn	Storage (d)	Diseased areas		Surface spotting	
			Fruit affected ^z (%)	Severity ^y	Fruit affected (%)	Severity
Water	(none)	14	0		0	
AC	(0.08)	14	0		0	
	(0.16)	14	0		0	
	(0.24)	14	0		13	Slight
	(0.08)	14	0		13	Slight
CC	(0.16)	14	13	Slight	25	Slight
	(0.24)	14	0		13	Slight
	(0.08)	14	0		0	
	(0.16)	14	0		0	
EC	(0.24)	14	0		13	Slight
	(none)	22	50	Moderate	50	Moderate
	(0.08)	22	0		25	Slight
	(0.16)	22	0		0	
CC	(0.24)	22	25	Slight	75	Moderate
	(0.08)	22	25	Slight	25	Slight
	(0.16)	22	0		25	Moderate
	(0.24)	22	0		40	Moderate
EC	(0.08)	22	25	Slight	25	Slight
	(0.16)	22	25	Moderate	50	Moderate
	(0.24)	22	25	Severe	25	Moderate

^zn = 10.

^ySeverity was rated on a scale of percent area of fruit affected with: slight = 1 to 33%, moderate = 34 to 66%, severe = 66 to 100%.

Table 6. Flesh firmness and soluble solids concentration (SSC) of 'Honey Brew' honey dew melons. Abscised (harvested) fruit were dipped for 20 min in water, amino acid-chelated calcium (AC), calcium chloride (CC), or EDTA-chelated calcium (EC) at 0.08, 0.16, or 0.24 M calcium (Ca) concentration. Control fruit were analyzed at harvest. Treated fruit were stored for 11 or 19 d at 10 °C (50 °F) plus 3 d at 21 °C (70 °F) and 95% ± 5% relative humidity (total simulated commercial and retail storage duration of 14 or 22 d respectively).

Treatment	Molar Ca concn	Fruit quality determinations ^z			
		Firmness (N) ^y		SSC (%)	
Harvest	None	39 ± 3		12.3 ± 0.4	
		14 d storage		22 d storage	
		Firmness (N)	SSC (%)	Firmness (N)	SSC (%)
Water	None	32 ± 3	11.3 ± 0.3	31 ± 5	11.1 ± 0.4
AC	0.08	36 ± 2	12.1 ± 0.3	31 ± 3	11.4 ± 0.4
	0.16	34 ± 2	12.0 ± 0.2	31 ± 4	11.3 ± 0.4
	0.24	32 ± 3	11.6 ± 0.2	31 ± 5	11.7 ± 0.4
	0.08	31 ± 2	12.1 ± 0.3	29 ± 3	11.3 ± 0.3
CC	0.16	29 ± 4	11.6 ± 0.3	25 ± 5	11.8 ± 0.4
	0.24	28 ± 2	11.4 ± 0.3	22 ± 3	11.6 ± 0.4
	0.08	32 ± 3	11.9 ± 0.2	27 ± 3	11.4 ± 0.4
	0.16	29 ± 3	11.7 ± 0.3	23 ± 5	11.4 ± 0.4
EC	0.24	29 ± 3	11.6 ± 0.3	28 ± 6	11.4 ± 0.3

^zValues are means ± SE (n = 10); 4.5 N = 1.0 lb force.

Table 7. Consumer preference evaluations of 'Honey Brew' honey dew melons. Abscised (harvested) fruit were dipped for 20 min in water, amino acid-chelated calcium (AC), calcium chloride (CC), or EDTA-chelated calcium (EC) at 0.08, 0.16, or 0.24 M calcium (Ca) concentration. Control fruit were analyzed at harvest. Treated fruit were stored for 11 or 19 d at 10 °C (50 °F) plus 3 d at 21 °C (70 °F) and 95% ± 5% relative humidity (total simulated commercial and retail storage duration of 14 or 22 d respectively).

Treatment	Molar Ca concn	Consumer preference evaluation ^z	
		14 d storage	22 d storage
Harvest	None	7.6 ± 0.5	
Water	None	6.6 ± 0.8	6.0 ± 1.0
	0.08	6.5 ± 0.5	6.0 ± 1.0
	0.16	6.0 ± 0.6	5.6 ± 0.7
AC	0.24	5.8 ± 0.5	5.8 ± 0.5
	0.08	7.6 ± 0.6	7.6 ± 0.8
	0.16	6.4 ± 0.5	6.8 ± 0.6
CC	0.24	5.3 ± 0.5	6.1 ± 0.5
	0.08	6.2 ± 0.5	6.6 ± 0.5
	0.16	6.1 ± 0.6	6.0 ± 0.4
EC	0.24	5.0 ± 0.5	5.8 ± 0.5

^zPreference rating based on a scale means of 1 to 10 when 1 to 4 = dislike extremely, 4.1 to 7 = neither dislike or like extremely, 7.1 to 10 = like extremely. Values are means ± SE (n = 25).

ompson, 1992). Calcium concentration of the H-M of AC-, CC- and EC-treated fruit were similar at 22 d storage (Table 3), but EC-treated fruit had the greatest severity of disease, indicating that the cause may be EDTA or CaEDTA toxicity and not Ca toxicity per se.

Surface spotting, defined as uniform brown spots of less than 1 mm in diameter, after 14 d storage, ranged from 0 for control, to 13% at 0.24 M Ca for AC, CC and EC, and 25% at 0.16 M Ca for CC (Table 5). Severity of spotting incidence for all affected fruit was slight. Following 22d storage, spotting affected all treated fruit except AC at the 0.16 M Ca. Otherwise, spotting ranged from 25% to 75% of the fruit affected. Those fruit receiving 0.24 M Ca generally had the highest number of spotted fruit. Severity of incidence ranged from slight at the 0.08 M Ca rate to moderate at the higher rates. Surface spotting, like surface disease, may be regulated by Ca rate, with reduced incidence and severity at <0.16 M Ca, to greater severity due to possible toxicity at the higher rates (≥0.16 M Ca).

FRUIT HYPODERMAL-MESOCARP FIRMNESS AND FLESH SOLUBLE SOLIDS CONCENTRATION. Firmness of the H-M was affected by Ca source, rate and days of storage (Table 4) and was highest in the nonstored, harvested 'Honey Brew' fruit, then declined for all fruit with days in storage (Table 6). Fruit firmness, following 14 d storage

was highest for AC-treated fruit at 0.08 and 0.16 M Ca rates, versus control, CC-, or EC-treated fruit. The high firmness readings for AC-treated fruit coincided with the highest H-M Ca concentrations (Table 3), and this was a significant interaction (Table 4).

Soluble solids concentration although not affected by Ca source, rate or days of storage (Table 4) was highest in nonstored harvested fruit and declined for all fruit, particularly after 22 d in storage (Table 6). Soluble solids concentration of the middle mesocarp at 14 d storage was highest in those fruit with the highest H-M Ca concentration (Table 3) and those which were the most firm. By 22 d storage, as H-M Ca concentration diminished (Table 3), so did fruit firmness and soluble solids concentration. Although soluble solids concentration appeared to be correlated with fruit Ca concentration and firmness, a valid comparison cannot be made since soluble solids concentration (middle-mesocarp) was determined on a different tissue than that of Ca concentration or firmness (H-M).

CONSUMER PREFERENCE EVALUATIONS. Eating quality of commercially grown, fully ripened 'Honey Brew' fruit was perceived by a consumer preference panel to be extremely good (Table 7) and was affected by Ca source and Ca rate (Table 4). Following 14 d commercial and retail storage,

eating quality diminished, but all fruit were considered to be of good eating quality. Calcium source had more of an influence on eating quality than Ca rate. After 14 and 22 d storage, CC treatment at the 0.08 M Ca rate resulted in fruit comparable in taste to those freshly harvested, and of all the Ca source and Ca rate combinations this combination resulted in fruit most preferred by preference panelists. However, as CC rate increased above 0.08 M Ca, preference declined. Eating quality with increased Ca rate also tended to decline for AC- and EC-treated fruit. Higher preference ratings for CC-treated versus AC- or EC-treated fruit is likely due to the CC salt enhancing the perception of melon flavor (Luna-Guzman and Barrett, 2000). These results indicate that the source of Ca had a significant effect on fruit taste, and that high rates (>0.16 M Ca) were significantly linked to reduced eating quality.

Conclusions

Currently, most commercial honey dew melon producers grow melons from hybrid seed which have the capacity for abscising when fully ripe (K. Cosby, personal communication). However, commercial harvesting of hybrid fruit is not performed at abscission, as is done with netted muskmelon; rather, it is cut unripe from the vine when fruit meet minimal marketing order standards of 9% soluble solids concentration (USDA, 1981). The main reason honey dew producers cut their fruit early, versus harvesting at abscission, is that the early harvested fruit have a longer storage life (about 21 d), relative to that of fully ripe fruit (about 10 d) (Kays, 1991). Unfortunately, consumers find that cut honey dew melons can be disappointing to eat (Ryall and Lipton, 1979).

Our study showed that abscised 'Honey Brew' fruit have ≥12% soluble solids concentration and have high consumer preference at harvest. Exogenous application of Ca at ≤0.16 M Ca in an amino acid-chelated form, versus EDTA-chelated Ca or CC, slowed 'Honey Brew' melon senescence so that after 22 d of commercial and retail storage, the fruit were of high marketable quality. Furthermore, the post-harvest application of Ca resulted in no detrimental effect on consumer preference for the edible flesh.

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The Influence of Paper Wraps on the Quality of 'd'Anjou' Pears after Controlled Atmosphere Storage

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ADDITIONAL INDEX WORDS. physiological disorders, black speck, scald, oil infused paper

SUMMARY. Pears (*Pyrus communis* 'd'Anjou') were packed in six commercial paper wraps (dry; 3% oil; 3% oil with copper and ethoxyquin; 6% oil; 6% oil with ethoxyquin; 9% oil). After packing, the pears were placed in three different controlled atmosphere (CA) storage conditions in commercial CA rooms: 1) 1.5% oxygen (O₂) and 1% carbon dioxide (CO₂); 2) 1.5% O₂ and 3% CO₂; 3) 1.5% O₂ and 1% CO₂ for 60 days, 4% O₂ for 60 more days and finally 6% O₂ for an additional 90 days. Pears were stored in CA for 120 and 210 days, with or without an additional 30 days in regular atmosphere (RA) storage to simulate shipping and handling. Objective quality evaluations were conducted after each storage period and sensory evaluations after 210 days of storage. Paper type influenced both the peel and flesh color of pears before and after ripening, but did not influence firmness, soluble solids or acid content. Subjective ratings of appearance and disorder incidence were unacceptable for pears stored in a variable atmosphere wrapped in dry or paper containing 3% oil. The

disorder black speck was present only in pears wrapped in paper with 6% oil and stored in an atmosphere of 1.5% O₂ and 1% CO₂. Pears stored in an atmosphere of 1.5% O₂ and 3% CO₂ received acceptable subjective scores regardless of paper type.

Atmospheres of 2% to 2.5% O₂ and <1% CO₂ are normally used for controlled atmosphere storage of 'd'Anjou' pears (Hansen and Mellenthin, 1979; Hardenburg et al., 1986). Using 2% or less O₂ for long term storage reduced losses of firmness, acidity, greenness and reduced scald severity (Chen et al., 1981; Mellenthin et al., 1980). Elevated levels of CO₂ (up to 3%) have been used for long-term pear storage (Allen and Claypool, 1948; Drake, 1994; Hansen, 1957), but the quality following storage has been inconsistent.

The standard atmosphere for the CA storage of 'd'Anjou' pears in the State of Washington contains 1.5% to 2% O₂ and <1% CO₂ held at -1 °C (30-31 °F) (Meheriuk, 1993). The CA storage law in Washington state requires that winter pears must be stored at <5% O₂ for a minimum of 90 d before they can be certified as CA stored pears (Washington Dept. of Agriculture, 1990).

Speckled skin or black speck is a superficial disorder that occurs in 'd'Anjou' pears following CA storage (Kupferman, 1988). Black speck is not caused by chemicals or pathogens, but is associated with low oxygen (<2%) in storage (Chen and Varga, 1989). Lee et al. (1990) postulated that black speck was associated with preharvest environmental stresses. Regardless of the cause, black speck is a frequently observed problem of late CA-stored 'd'Anjou' pears in Washington State.

For decades, pears have been individually wrapped in paper impregnated with low-viscosity petroleum oils, fungicides and/or antioxidants to help control various disorders and reduce postharvest decay problems. Paper wraps have been used in the Washington State fruit industry since the early 1900s. Initially paper wraps were used to cushion the fruit when in transit and to isolate decay. Use of oil (15%) impregnated paper to reduce scald was suggested by Brooks et al. (1919). Cooley and Crenshaw (1931) later suggested that copper sulfate (CuSO₄) be incorporated in the paper wrap to prevent the spread of rot. The oil in paper wraps has

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