Field Application of Chelated Calcium: Postharvest Effects on Cantaloupe and Honeydew Fruit Quality

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Summary. Commercially grown honeydew fruit (*Cucumis melo* Inodorus group) and netted cantaloupe fruit (*C. melo* Reticulatus group) in low-humidity regions of the U.S. are typically field packed, eliminating the possibility for postharvest chelated-calcium dip treatments to extend fruit shelf life. In this study, calcium treatments were applied to orange-flesh honeydew fruit commercially grown in 2001 and 2002 in Sacramento Valley, Calif. and orange-fleshed netted cantaloupe fruit commercially grown in 2002 in Imperial Valley, Calif., and Rio Grande Valley, Texas. Amino-acid-chelated calcium and mannitol-complexed calcium compounds were applied to field-grown plants at the rate of 2.3 L·ha^{-1} (1 qt/acre) at 0, 1, 2, or 4 total applications during growth of honeydew and cantaloupe fruit. Applications were A) at female flowering, B) within 15 days (cantaloupe) or 20 days (honeydew) after flowering, C) within 30 days (cantaloupe) or 40 days (honeydew) after

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female flowering, and/or D) within 3 to 5 days before abscission. One application equaled (A) or (D), two applications equaled (A + B) or (C + D) and four applications equaled (A + B + C + D). Evaluations of fully abscised fruit were exterior and interior firmness, marketability, calcium concentrations, interior soluble solids concentration (sugars), and consumer preference (taste) following harvest and up to 3 weeks commercial/retail storage. Cantaloupe fruit at both locations did not appear to benefit from preharvest plant applications of calcium when compared to fruit from plants treated with water. Honeydew fruit, however, did and the benefit was observed both years. Honeydew fruit that received four preharvest plant applications of calcium, regardless of source, were generally superior in firmness, marketability, and had a higher calcium concentration than fruit from plants receiving water or one or two applications of calcium. Fruit sugars and taste were not affected by preharvest plant applications of calcium.

Postharvest dipping fully ripened honeydew melons in organic-chelated calcium versus EDTA-chelated calcium or calcium chloride ($CaCl_2$) solutions has been shown to maintain stored honeydew fruit calcium concentration at levels found in recently abscised fruit, thus maintaining fruit tissue firmness, plasma membrane integrity, and extending storage life (Lester and Grusak, 1999, 2001). However, applying calcium to commercially grown melons as a postharvest dip is not suitable for melon growers in the desert southwestern U.S., or other low-humidity melon growing regions of the U.S. These growers box melons for shipment in the field at harvest, making a postharvest dip impractical. Although applications of calcium to melon fruit tissue disks (Lester, 1996), greenhouse-grown melons (Lester and Grusak, 1999), or commercially harvested melons (Lester and Grusak, 2001) has been reported, no studies have been reported for preharvest plant application of organic-chelated calcium sources to commercial fields of either honeydew or netted cantaloupe during fruit production. Therefore, the objective of this study was to assess the benefits of preharvest plant applied applications of two commercial organic-chelated (amino-acid or mannitol) calcium formulations at different times during fruit growth and maturation. Fruit were evaluated for firmness, marketability, calcium concentrations, interior soluble solids concentration (sugars) and consumer preference (taste) following harvest and commercial storage for up to 22 d.

Materials and methods

CALCIUM TREATMENTS. Either amino-acid-chelated calcium [calcium metalosate, 6% actual calcium (Albion Laboratories, Inc., Clearfield, Utah)], or mannitol-complexed calcium [Folical, 10% calcium (Monterey Chemical Co. Fresno, Calif.)] were applied to plants at the manufacturers recommended rate of 2.3 $L \cdot ha^{-1}$ in 75.7 to 113.6 L (20 to 30 gal) of water, sprayed at 345.0 kPa (50 lb/inch^2) in California, or 621.0 kPa (90 lb/inch^2) in Texas. Plants were sprayed by a commercial pesticide applicator 0, 1, 2, or 4 total times during fruit growth to spring cantaloupes and to summer honeydew melons. Applications were A) at female flowering, B) within 15 d (cantaloupe) or 20 d (honeydew) after flowering, C) within 30 d (cantaloupe) or 40 d (honeydew) after female flowering, and/or D) within 3 to 5 d before abscission. Therefore, plants receiving one application = [A (one early)] or [D (one late)], two applications = [A + B (two early)] or [C + D (two late)] and four applications = [A + B + C + D (two early and two late)].

PLANT MATERIAL. Fully abscised fruit of 'Orange Dew' honeydew muskmelon grown in Sacramento Valley, Yolo County, Calif., 'Sol Real' netted cantaloupe muskmelon fruit grown in Imperial Valley, Imperial County, Calif., and 'Primo' grown in Rio Grande Valley, Starr County, Texas, free of defects, were harvested and shipped overnight to Weslaco, Texas. All fruit were washed in 0.53% (sodium hypochlorite) bleach, rinsed with tap water, then, within a treatment application randomized into lots for storage. Although field packing melons does not permit surface sterilizing fruit with a bleach solution, a bleach rinse was used to suppress postharvest disease decay in order to focus on physiological disorders associated with exogenous calcium applications. All fruit were placed in commercial honeydew or cantaloupe melon shipping boxes, then stored at 10 ± 1 °C (50.0 ± 1.8 °F) for honeydew or 4 ± 1 °C (39.2 ± 1.8 °F) for cantaloupe and 94% ± 2% relative humidity (RH) for 4 d or 11 d for cantaloupe, and 11 d and 19 d for honeydew (simulating commercial shipping conditions) plus 3 d at 21 ± 1 °C (69.8 ± 1.8 °F) and 54% ± 2% RH (simulating retail conditions).

FRUIT FIRMNESS AND SOLUBLE SOLIDS CONCENTRATION DETERMINATIONS. Firmness of whole-fruit equatorial hypodermal-mesocarp tissue, minus the epidermis, and the middle-mesocarp tissue from an equatorially cut fruit, was measured using a V-tip probe [1 cm long (0.4 inch) × 5.08 mm diameter (0.2 inches) × 1 mm wide (0.04 inches)] attached to a force gauge (Mark-10, model MG20; Wagner Instruments, Greenwich, Conn.) and expressed as mean force in Newtons. Soluble solids concentration was determined on middle-mesocarp sections (1 cm long × 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.).

CALCIUM DETERMINATIONS. Calcium concentrations were determined on hypodermal-mesocarp tissue taken from the equatorial region of the fruit and on middle-mesocarp tissue taken from three different locations around the fruit equatorial circumference (excluding the ground spot). The epidermis was removed followed by the hypodermal-mesocarp tissue with a ceramic vegetable peeler. Tissues were weighed immediately to determine fresh weight, and then dried at 70 °C (158.0 °F) for 48 h. Total calcium concentration per gram hypodermal-mesocarp or middle-mesocarp tissue fresh weight was determined, using atomic absorption spectroscopy, by a commercial plant tissue analysis lab.

FRUIT MARKETABILITY. Following storage, all fruit were rated for marketability (Lester and Shellie, 2002; Shellie and Lester, 2002); 0 = 0% of each fruit with disorders, 1 = ≤15% of each fruit with disorders, 2 = ≤50% of each fruit with disorders, 3 = ≤85% of each fruit with disorders, and 4 = ≤100% of each fruit with disorders. The data were arcsine transformed before analysis of variance (Little and Hills, 1978) and presented as percent marketable fruit.

Data for marketability are presented as the percentage of fruit affected within a treatment.

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 (0.12-$inch^3$) 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 (3.5-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 calcium treatments, firmness, marketability, and consumer preferences for the various data sets (SAS Inst., Cary, N.C.). Duncan's multiple range test ($P \leq 0.05$) was used to discern between calcium application classifications when F values were significant for main effects. Data are the average of eight, single-fruit replications per application per storage period.

Table 1. Firmness of 'Orange Dew' orange-flesh honeydew melon exterior with peel removed (exterior) and edible-flesh (interior) at harvest and following commercial storage. Amino-acid-chelated calcium [AA-Ca (calcium metalosate)] or mannitol-complexed calcium [MC-Ca (Foli-cal)] applied during fruit development to summer-grown plants in Sacramento Valley, Calif. Fruit were harvested at abscission in September 2001 and 2002.

		Firmness (N)			
		Exterior		Interior	
Treatment	Application[y]	2001	2002	2001	2002
At harvest					
Water	–	9.1 b[x]	17.4 c	6.2 c	7.7 c
AA-Ca	2 early + 2 late	16.0 a	23.5 a	12.1 a	12.3 a
MC-Ca	2 early + 2 late	16.5 a	20.9 ab	13.0 a	9.3 bc
AA-Ca	1 early	–	18.4 b	–	8.3 bc
AA-Ca	2 early	–	18.4 b	–	8.0 bc
MC-Ca	1 early	–	20.4 bc	–	10.4 ab
MC-Ca	2 early	–	19.2 bc	–	9.8 bc
AA-Ca	1 late	8.7 b	–	13.0 a	–
AA-Ca	2 late	12.5 ab	–	10.7 ab	–
MC-Ca	1 late	12.1 a	–	9.6 b	–
MC-Ca	2 late	11.5 b	–	11.9 ab	–
$P \leq 0.05$					
After 2 weeks storage[w]					
Water	–	8.2 c	15.7 c	4.2 b	7.2 d
AA-Ca	2 early + 2 late	11.5 ab	23.5 a	7.5 a	12.3 a
MC-Ca	2 early + 2 late	14.5 a	20.7 ab	8.6 a	9.6 bc
AA-Ca	1 early	–	19.7 ab	–	10.1 ab
AA-Ca	2 early	–	16.6 bc	–	7.9 cd
MC-Ca	1 early	–	17.9 bc	–	11.4 ab
MC-Ca	2 early	–	19.1 bc	–	9.1 bcd
AA-Ca	1 late	8.5 c	–	3.6 b	–
AA-Ca	2 late	8.2 c	–	4.9 b	–
MC-Ca	1 late	8.5 c	–	3.9 b	–
MC-Ca	2 late	9.7 bc	–	3.0 b	–
$P \leq 0.05$					
After 3 weeks storage[v]					
Water	–	7.2 c	14.3 c	3.3 c	6.9 b
AA-Ca	2 early + 2 late	10.1 ab	20.9 a	5.0 ab	11.7 a
MC-Ca	2 early + 2 late	12.3 a	17.2 bc	6.4 a	9.0 ab
AA-Ca	1 early	–	15.3 bc	–	9.1 ab
AA-Ca	2 early	–	15.6 bc	–	8.9 ab
MC-Ca	1 early	–	19.1 ab	–	11.8 a
MC-Ca	2 early	–	14.3 c	–	6.9 b
AA-Ca	1 late	7.5 c	–	2.9 c	–
AA-Ca	2 late	8.1 b	–	4.0 bc	–
MC-Ca	1 late	8.2 bc	–	3.9 bc	–
MC-Ca	2 late	8.1 bc	–	3.5 c	–
$P \leq 0.05$					

[z]1.0 N = 0.225 lb force.
[y]Applications: 1 early = at female flowering, 2 early = 1 early + 20 d later, 1 late = 3 to 5 d before full-slip, 2 late = 40 d after female flowering + 1 late. (–)No treatment application conducted that year.
[x]Mean separation by Duncan's multiple range test. Any two means within a column and within a storage period followed by the same letter are not significantly different. Values are means (n = 8).
[w]11 d at 10 °C (50.0 °F) and 95% ± 3% relative humidity (RH), plus 3 d at 21 °C (69.8 °F) and 50% ± 3% RH.
[v]21 d at 10 °C and 95% ± 3% RH, plus 3 d at 21 °C and 50% ± 3% RH.

Table 2. Calcium concentration of 'Orange Dew' orange-flesh honeydew melon exterior with peel removed and edible-flesh (interior) at harvest and following commercial storage. Amino-acid-chelated calcium [AA-Ca (calcium metalosate)] or mannitol-complexed calcium [MC-Ca (Foli-cal)] applied during fruit development to summer-grown plants in the Sacramento Valley, Calif. Fruit were harvested at abscission in September 2001 and 2002.

		Calcium [$\mu g \cdot g^{-1}$ (ppm)]			
		Exterior		Interior	
Treatment	Application[z]	2001	2002	2001	2002
At harvest					
Water	–	2974 b[y]	3756 c	505 b	417 d
AA-Ca	2 early + 2 late	3748 a	4872 a	654 a	667 a
MC-Ca	2 early + 2 late	3748 a	4443 b	638 a	578 ab
AA-Ca	1 early	–	4431 b	–	470 d
AA-Ca	2 early	–	4374 b	–	507 c
MC-Ca	1 early	–	4482 b	–	572 abc
MC-Ca	2 early	–	4387 b	–	473 cd
AA-Ca	1 late	3377 ab	–	513 b	–
AA-Ca	2 late	3373 ab	–	634 ab	–
MC-Ca	1 late	3298 a	–	521 b	–
MC-Ca	2 late	2721 b	–	618 ab	–
$P \leq 0.05$					
After 2 weeks storage[x]					
Water	–	2677 bc	3175 c	502 b	548 cd
AA-Ca	2 early + 2 late	3342 ab	4429 a	642 a	671 a
MC-Ca	2 early + 2 late	3565 a	4119 ab	620 ab	627 a
AA-Ca	1 early	–	3858 b	–	502 d
AA-Ca	2 early	–	3830 b	–	537 b
MC-Ca	1 early	–	4087 b	–	601 ab
MC-Ca	2 early	–	3991 b	–	560 bc
AA-Ca	1 late	2262 c	_	457 c	–
AA-Ca	2 late	2672 bc	–	620 ab	–
MC-Ca	1 late	3020 abc	–	480 c	–
MC-Ca	2 late	2357 c	–	480 c	–
$P \leq 0.05$					
After 3 weeks storage[w]					
Water	–	2114 c	3078 c	344 c	447 b
AA-Ca	2 early + 2 late	2974 ab	4233 a	530 ab	522 a
MC-Ca	2 early + 2 late	3351 a	3960 a	574 a	505 a
AA-Ca	1 early	–	3380 b	–	472 ab
AA-Ca	2 early	–	3241 bc	–	409 b
MC-Ca	1 early	–	3351 bc	–	465 ab
MC-Ca	2 early	–	3405 b	–	465 ab
AA-Ca	1 late	1515 d	–	355 c	–
AA-Ca	2 late	2138 c	–	485 b	–
MC-Ca	1 late	2748 b	–	400 c	–
MC-Ca	2 late	2357 c	–	334 c	–
$P \leq 0.05$					

[z]Applications: 1 early = at female flowering, 2 early = 1 early plus 20 d later, 1 late = 3 to 5 d before full-slip, 2 late = 40 d after female flowering plus 1 late. (–) = no treatment application conducted that year.
[y]Mean separation by Duncan's multiple range test. Any two means within a column and within a storage period, followed by the same letter are not significantly different. Values are means (n = 8).
[x]11 d at 10 °C (50.0 °F) and 95% ± 3% relative humidity (RH), plus 3 d at 21 °C (69.8 °F) and 50% ± 3% RH.
[w]21 d at 10 °C and 95% ± 3% RH, plus 3 d at 21 °C, 50% ± 3% RH.

Results

Honeydew melons

FIRMNESS. In 2001 and 2002, four applications of amino-acid-chelated calcium (AA-Ca) or mannitol-complexed calcium (MC-Ca), versus control applications of water, resulted in significantly firmer readings of the fruit exterior tissues under the peel at harvest (Table 1). Fruit interior (edible tissue) firmness readings in 2001 from four applications of AA-Ca or MC-Ca, and in 2002 AA-Ca only, versus water, resulted in significantly firmer edible tissue. One or two applications of either calcium compound applied at female flowering, and/or within 20 d after flowering (early applications) or within 40 d after female flowering, and/or within 3 to 5 d before abscission (late applications), were not always significantly better than water in affecting exterior or interior fruit firmness. Following storage of melons for 2 or 3 weeks, exterior and interior firmness was generally significantly firmer with four applications, of either plant applied calcium compound, than those receiving one or two early or late calcium applications or water.

Table 3. Marketability of 'Orange Dew' orange-flesh honeydew melon exterior and edible-flesh (interior) following commercial storage. Amino-acid-chelated calcium [AA-Ca (calcium metalosate)] or mannitol-complexed calcium [MC-Ca (Folical)] applied during fruit development to summer-grown plants in the Sacramento Valley, Calif. Fruit were harvested at abscission in September 2001 and 2002.

		Marketability (%)			
		Exterior		Interior	
Treatments	Applications[z]	2001	2002	2001	2002
After 2 weeks storage[y]					
Water	–	22c[x]	49 c	69 c	86 b
AA-Ca	2 early + 2 late	93 a	77 b	100 a	100 a
MC-Ca	2 early + 2 late	100 a	95 a	100 a	100 a
AA-Ca	1 early	–	75 b	–	100 a
AA-Ca	2 early	–	73 b	–	100 a
MC-Ca	1 early	–	49 c	–	100 a
MC-Ca	2 early	–	32 d	–	100 a
AA-Ca	1 late	48 b	–	69 c	–
AA-Ca	2 late	54 b	–	96 b	–
MC-Ca	1 late	43 b	–	69 c	–
MC-Ca	2 late	69 b	–	99 a	–
$P \leq 0.05$					
After 3 weeks storage[w]					
Water	–	18 c	0 b	62 c	76 b
AA-Ca	2 early + 2 late	80 a	37 a	96 a	100 a
MC-Ca	2 early + 2 late	78 a	36 a	100 a	82 ab
AA-ca	1 early	–	27 a	–	100 a
AA-Ca	2 early	–	0 b	–	100 a
MC-Ca	1 early	–	0 b	–	100 a
MC-Ca	2 early	–	0 b	–	100 a
AA-Ca	1 late	42 b	–	63 c	–
AA-Ca	2 late	42 b	–	96 a	–
MC-Ca	1 late	47 b	–	90 b	–
MC-Ca	2 late	47 b	–	93 ab	–
$P \leq 0.05$					

[z]Applications: 1 early = at female flowering, 2 early = 1 early plus 20 d later, 1 late = 3 to 5 d before full-slip, 2 late = 40 d after female flowering plus 1 late. (–) = no treatment application conducted that year.
[y]11 d at 10 °C (50.0 °F) and 95% ± 3% relative humidity (RH), plus 3 d at 21 °C (69.8 °F) and 50% ± 3% RH.
[x]Mean separation by Duncan's multiple range test. Any two means within a column and within a storage period, followed by the same letter are not significantly different. Values are means (n = 8).
[w]21 d at 10 °C and 95% ± 3% RH, plus 3 d at 21 °C and 50% ± 3% RH.

CALCIUM. In 2001 and 2002, four applications of AA-Ca or MC-Ca, versus water, resulted in significantly higher calcium concentrations in fruit exterior and interior tissues at harvest (Table 2). One or two, early or late, applications of either calcium compound were not always significantly higher in calcium than water. In both years, fruit from four applications of calcium stored for 2 weeks had higher exterior and interior calcium concentrations than water. After 3 weeks, for both years, fruit from four applications of calcium were significantly higher in tissue (exterior and interior) calcium concentrations than those treated with water.

MARKETABILITY. Following 2 or 3 weeks of storage, exterior and interior percent marketability of fruit from plants receiving four applications of AA-Ca or MC-Ca, versus water, for most comparisons, were significantly greater (Table 3). Also, one or two applications of calcium applied early or late compared to water, for most comparisons, were significantly greater in exterior and interior marketability.

SUGARS AND TASTE. Percent soluble solids concentration, within each production year, for all fruit was similar, regardless of calcium source or number of applications (Table 4). Sugars were lower by about 2.8% in 2002 than in 2001.

With few exceptions, consumer preference for all fruit ranged from like to like extremely (Table 4). Consumers usually gave fruit from water-treated plants the best taste ratings, but fruit from the water treatment were generally not significantly better than fruit from plants receiving calcium treatments; only a few of the calcium treatments resulted in fruit with significantly lower ratings, relative to water-treated controls.

Cantaloupe melons

FIRMNESS. At harvest, whether grown in California or Texas, or having received preharvest plant applied calcium treatments or water, exterior or interior firmness readings were not consistently significantly different (Table 5). Following 1 or 2 weeks storage, fruit exterior or interior tissues from plants receiving applications of calcium were usually not significantly firmer than those from the water treatment.

CALCIUM. At harvest, whether grown in California or Texas, calcium concentration was usually numerically the highest in both exterior and interior fruit tissues from plants having received four applications of AA-Ca, but the concentrations were not significantly higher than in fruit from the water treatment (Table 6). Following 1 or 2 weeks storage, fruit exterior and interior tissues from plants having received four applications of AA-

Table 4. Soluble solids concentration and consumer preference of 'Orange Dew', orange-flesh honeydew melon edible-flesh at harvest and following commercial storage. Amino-acid-chelated calcium [AA-Ca (calcium metalosate)] or mannitol-complexed calcium [MC-Ca (Foli-cal)] applied during fruit development to summer-grown plants to the Sacramento Valley, Calif. Fruit were harvested at abscission in September 2001 and 2002.

		Soluble solids concn (%)		Consumer preference[y] (taste)	
Treatments	Applications[z]	2001	2002	2001	2002
At harvest					
Water	–	11.5 a[x]	9.9 a	6.3 a	7.8 a
AA-Ca	2 early + 2 late	12.2 a	8.5 ab	6.6 a	6.9 ab
MC-Ca	2 early + 2 late	11.9 a	8.5 ab	6.0 a	6.4 ab
AA-Ca	1 early	–	9.6 ab	–	6.4 ab
AA-Ca	2 early	–	8.4 ab	–	5.4 b
MC-Ca	1 early	–	7.9 b	–	6.1 ab
MC-Ca	2 early	–	9.6 ab	–	5.9 b
AA-Ca	1 late	10.5 a	–	5.7 a	–
AA-Ca	2 late	11.0 a	–	3.9 b	–
MC-Ca	1 late	10.6 a	–	6.2 a	–
MC-Ca	2 late	11.3 a	–	5.9 a	–
$P \leq 0.05$					
After 2 weeks storage[w]					
Water	–	11.7 abc	8.5 a	7.0 a	7.0 a
AA-Ca	2 early & 2 late	12.0 a	7.7 a	5.4 ab	6.8 a
MC-Ca	2 early & 2 late	11.8 ab	7.7 a	4.3 c	6.6 a
AA-Ca	1 early	–	8.4 a	–	6.1 a
AA-Ca	2 early	–	8.2 a	–	7.0 a
MC-Ca	1 early	–	7.2 a	–	7.7 a
MC-Ca	2 early	–	7.8 a	–	6.4 a
AA-Ca	1 late	10.5 bc	–	5.3 ab	–
AA-Ca	2 late	11.9 ab	–	4.7 b	–
MC-Ca	1 late	10.3 c	–	6.7 a	–
MC-Ca	2 late	11.3 abc	–	6.1 ab	–
$P \leq 0.05$					
After 3 weeks storage[v]					
Water	–	10.3 b	8.1 a	4.2 c	7.3 a
AA-Ca	2 early + 2 late	12.2 a	7.3 a	5.4 ab	7.4 a
MC-Ca	2 early + 2 late	13.1 a	8.3 a	5.6 ab	5.0 bc
AA-Ca	1 early	–	8.3 a	–	6.8 a
AA-Ca	2 early	–	7.9 a	–	5.8 ab
MC-Ca	1 early	–	7.4 a	–	3.7 c
MC-Ca	2 early	–	7.8 a	–	6.1 ab
AA-Ca	1 late	12.5 a	–	4.5 c	–
AA-Ca	2 late	11.5 ab	–	5.6 ab	–
MC-Ca	1 late	10.8 b	–	5.7 a	–
MC-Ca	2 late	13.1 a	–	5.2 b	–
$P < 0.05$					

[z]Applications: 1 early = at female flowering, 2 early = 1 early plus 20 d later, 1 late = 3 to 5 d before full-slip, 2 late = 40 d after female flowering plus 1 late. (–) = no treatment application conducted that year.
[y]Preference rating based on a scale means of 1 to 10 when 1 to 4 = dislike extremely, 4.1 to 7 = like, 7.1 to 10 = like extremely. Values are (n = 25).
[x]Mean separation by Duncan's multiple range test. Any two means within a column and within a storage period, followed by the same letter are not significantly different. Values are means (n = 8).
[w]11 d at 10 °C (50.0 °F) and 95% ± 3% relative humidity (RH), plus 3 d at 21 °C (69.8 °F) and 50% ± 3% RH.
[v]21 d at 10 °C and 95% ± 3% RH, plus 3 d at 21 °C and 50% ± 3% RH.

Ca remained numerically the highest in calcium, and were generally significantly higher than water. However, all other calcium treatments were usually not significantly higher than water.

MARKETABILITY. Following 1 week of storage, exterior and interior percent marketability of fruit from plants receiving calcium versus water were not significantly different (Table 7). Following 2 weeks storage, Texas grown fruit exterior and interior marketability from plants receiving calcium applications were significantly better than water. But in California-grown fruit, calcium treatments versus water were not statistically different for either exterior or interior percent marketability.

SUGARS AND TASTE. Percent soluble solids concentration, within each growing location, for all fruit was similar. Between locations, the concentration of sugars was lower in Texas than California-grown fruit.

With few exceptions, consumer preference for all fruit, regardless of location, ranged from like to like extremely (Table 8). Statistically significant differences were observed between certain treatments, but across

Table 5. Firmness of 'Sol Real' (Calif.) and 'Primo' (Texas) orange-fleshed netted cantaloupe, with peel removed (exterior) and edible-flesh (interior) at harvest and following commercial storage. Amino-acid-chelated calcium [AA-Ca (calcium metalosate)] or mannitol-complexed calcium [MC-Ca (Foli-cal)] applied during fruit development to spring-grown plants harvested in June 2002 in the Imperial Valley, Calif., and May 2002 in the Rio Grande Valley, Texas.

		Firmness (N)[z]			
		Exterior		Interior	
Treatment	Application[y]	Calif.	Texas	Calif.	Texas
At harvest					
Water	–	56.9 a[x]	35.2 ab	15. 9 a	11.8 ab
AA-Ca	2 early + 2 late	49.9 ab	38.9 ab	14.0 a	12.3 ab
MC-Ca	2 early + 2 late	51.1 ab	42.1 a	16.4 a	13.4 a
AA-Ca	1 early	56.0 a	30.9 b	15.2 a	10.8 b
AA-Ca	2 early	58.2 a	36.5 ab	16.4 a	11.8 ab
MC-Ca	1 early	51.9 ab	34.9 ab	16.3 a	11.4 abc
MC-Ca	2 early	55.9 a	33.7 ab	16.5 a	13.1 a
AA-Ca	1 late	39.0 b	34.4 ab	13.9 a	10.6 bc
AA-Ca	2 late	41.6 ab	36.5 ab	16.2 a	11.5 abc
MC-Ca	1 late	38.6 b	31.2 b	14.0 a	10.7 bc
MC-Ca	2 late	38.6 b	31.2 b	15.7 a	9.7 c
$P \leq 0.05$					
After 1 week storage[w]					
Water	–	21.8 b	26.8 abc	10.2 a	8.4 bc
AA-Ca	2 early + 2 late	28.1 a	27.7 ab	10.2 a	9.7 b
MC-Ca	2 early + 2 late	25.6 ab	28.3 a	8.3 b	11.5 a
AA-Ca	1 early	20.5 bcd	23.0 d	8.0 b	8.7 bc
AA-Ca	2 early	26.5 ab	24.8 abcd	10.2 a	7.5 c
MC-Ca	1 early	14.9 d	23.9 bcd	7.3 b	9.7 b
MC-Ca	2 early	20.5 bc	25.8 abcd	8.3 b	8.9 bc
AA-Ca	1 late	18.5 cd	24.7 bcd	8.4 b	7.8 c
AA-Ca	2 late	22.9 abc	23.6 cd	9.0 ab	8.4 bc
MC-Ca	1 late	18.5 cd	26.8 abc	7.6 b	8.5 bc
MC-Ca	2 late	23.6 bc	25.5 abcd	8.5 b	9.0 bc
$P \leq 0.05$					
After 2 weeks storage[v]					
Water	–	18.6 cd	22.4 b	9.9 ab	7.9 b
AA-Ca	2 early + 2 late	24.1 a	25.1 ab	10.1 a	9.0 ab
MC-Ca	2 early + 2 late	22.7 ab	27.9 a	7.1 c	11.0 a
AA-Ca	1 early	17 .4 cd	23.4 b	8.6 bc	8.1 b
AA-Ca	2 early	18.6 cd	23.9 ab	8.5 bc	8.7 b
MC-Ca	1 early	19.4 bc	22.9 b	8.9 abc	9.2 ab
MC-Ca	2 early	21.2 abc	22.9 b	8.1 c	8.8 b
AA-Ca	1 late	17.2 cd	22.5 b	7.7 c	7.5 b
AA-Ca	2 late	21.3 abc	23.1 b	8.5 bc	7.7 b
MC-Ca	1 late	15.8 d	20.7 b	7.2 c	8.5 b
MC-Ca	2 late	20.7 abc	20.9 b	7.4 c	8.7 b
$P \leq 0.05$					

[z] 1.0 N = 0.225 lb force.
[y] Applications: 1 early = at female flowering, 2 early = 1 early plus 15 d later, 1 late = 3 to 5 d before full-slip, 2 late = 30 d after female flowering plus 1 late.
[x] Mean separation by Duncan's multiple range test. Any two means within a column and within a storage period, followed by the same letter are not significantly different. Values are means (n = 8).
[w] 4 d at 4 °C (39.2 °F) and 95% ± 3% relative humidity (RH), plus 3 d at 21 °C (69.8 °F) and 50% ± 3% RH.
[v] 11 d at 4 °C and 95% ± 3% RH, plus 3 d at 21 °C and 50% ± 3% RH.

locations or storage times, no treatments were consistently different. Consumers usually gave fruit from calcium treated plants the best taste rating, but it was never always significantly better than fruit from plants receiving water (Table 8).

Discussion

Preharvest application of chelated calcium, especially four applications of either chelate source, consistently resulted in elevated mesocarp calcium concentrations, elevated fruit firmness, and enhanced marketability in honeydew fruit (relative to water-treated controls), but not in cantaloupe fruit (Tables 1–3 and 5–7). For cantaloupe, four preharvest calcium-chelate applications significantly enhanced calcium concentration of fruit interior and exterior tissues, but this effect was found inconsistently across locations, and only among some of the 1- or 2-week stored fruit (relative to water-treated controls; Table 6). No effect of preharvest calcium-chelate application, with either melon type, was found on soluble solids concentration or consumer preference (Tables 4, 8).

Table 6. Calcium concentration of 'Sol Real' (Calif.) and 'Primo' (Texas) orange-fleshed netted cantaloupe, with peel removed (exterior) and edible-flesh (interior) at harvest and following commercial storage. Amino-acid-chelated calcium [AA-Ca (calcium metalosate)] or mannitol-complexed calcium [MC-Ca (Foli-cal)] applied during fruit development to spring-grown plants harvested in June 2002 in the Imperial Valley, Calif., and May 2002 in the Rio Grande Valley, Texas.

		Calcium [$\mu g \cdot g^{-1}$ (ppm)]			
		Exterior		Interior	
Treatments	Applications[z]	Calif.	Texas	Calif.	Texas
At harvest					
Water	–	7743 ab[y]	9076 abc	628 abc	1501 abc
AA-Ca	2 early + 2 late	8172 a	9846 a	747 a	1750 a
MC-Ca	2 early + 2 late	7109 bc	9706 ab	735 ab	1635 a
AA-Ca	1 early	6475 cd	9143 ab	559 c	1319 bcd
AA-Ca	2 early	6912 bc	9636 ab	629 abc	1482 abc
MC-Ca	1 early	5808 d	8663 ab	630 abc	1276 bcd
MC-Ca	2 early	6148 cd	8908 abc	718 a	1291 bcd
AA-Ca	1 late	6407 cd	9287 abc	671 abc	1059 d
AA-Ca	2 late	6971 bc	9308 abc	679 ab	1130 d
MC-Ca	1 late	6871 bc	8267 bc	665 abc	1232 cd
MC-Ca	2 late	6254 c	8310 bc	725 ab	1299 bcd
$P \leq 0.05$					
After 1 week storage[x]					
Water	–	5724 c	8888 ab	625 b	1323 a
AA-Ca	2 early + 2 late	7573 a	9511 ab	882 a	1557 a
MC-Ca	2 early + 2 late	5949 bc	9580 a	814 a	1424 a
AA-Ca	1 early	5542 c	8719 ab	617 b	1375 a
AA-Ca	2 early	5623 c	8748 ab	713 ab	1299 a
MC-Ca	1 early	5803 bc	8552 ab	752 ab	1209 a
MC-Ca	2 early	7508 a	8452 ab	847 a	1289 a
AA-Ca	1 late	6448 abc	9206 ab	742 ab	1396 a
AA-Ca	2 late	7001 ab	8467 ab	716 ab	1207 a
MC-Ca	1 late	5703 c	8722 ab	770 ab	1323 a
MC-Ca	2 late	5966 bc	8285 b	614 b	1262 a
$P \leq 0.05$					
After 2 weeks storage[w]					
Water	–	5284 c	6685 b	689 a	1268 c
AA-Ca	2 early + 2 late	6769 a	8817 a	764 a	1775 a
MC-Ca	2 early + 2 late	5099 c	8818 a	655 a	1363 bc
AA-Ca	1 early	5088c	8697 a	664 a	1663 ab
AA-Ca	2 early	5644 bc	8747 a	667 a	1276 c
MC-Ca	1 early	4580 cd	7714 ab	600 a	1622 ab
MC-Ca	2 early	4485 cd	7913 ab	632 a	1373 bc
AA-Ca	1 late	4965 c	7310 b	641 a	1502 abc
AA-Ca	2 late	6415 ab	8553 a	631 a	1407 bc
MC-Ca	1 late	3717 d	7693 ab	611 a	1400 bc
MC-Ca	2 late	4078 d	6883 b	634 a	1363 bc
$P \leq 0.05$					

[z]Applications: 1 early = at female flowering, 2 early = 1 early plus 15 d later, 1 late = 3 to 5 d before full-slip, 2 late = 30 d after female flowering plus 1 late.
[y]Mean separation by Duncan's multiple range test. Any two means within a column and within a storage period, followed by the same letter are not significantly different. Values are means (n = 8).
[x]4 d at 4 °C (39.2 °F) and 95% ± 3% relative humidity (RH), plus 3 d at 21 °C (69.8 °F) and 50% ± 3% RH.
[w]11 d at 4 °C and 95% ± 3% RH, plus 3 d at 21 °C and 50% ± 3% RH.

These results are consistent with those previously found following postharvest application of chelated calcium to fruit of honeydew or cantaloupe melons (Lester and Grusak, 1999). In that study, the calcium chelate permeated the netted epidermis of cantaloupe very poorly, and thus no increase was observed in the calcium concentration of the hypodermal mesocarp. Similarly, in the current study, it appears that the netted melons were unable to absorb calcium in sufficient amounts to have an influence on fruit quality traits (especially marketability). For the honeydew melons, on the other hand, it appears that with four treatments, enough calcium chelate was applied to the fruit, and enough of this calcium penetrated the non-netted epidermis to have an impact on the quality of the harvested fruit.

Interestingly, these results imply that the extra calcium which moved into honeydew fruit came from chelated calcium that was sprayed directly on the fruit, as is the case with preharvest calcium spraying of pear (*Pyrus communis*) trees (Rease and Drake, 1995). Although field spraying primarily covered the leaves with calcium chelate, some of the spray also would have reached the fruit, either as

Table 7. Marketability of 'Sol Real'(Calif.) and 'Primo' (Texas) orange-fleshed netted cantaloupe, with peel removed (exterior) and edible-flesh (interior) at harvest and following commercial storage. Amino-acid-chelated calcium [AA-Ca (calcium metalosate)] or mannitol-complexed calcium [MC-Ca (Foli-cal)] applied during fruit development to spring-grown plants harvested in June 2002 in the Imperial Valley, Calif., and May 2002 in the Rio Grande Valley, Texas.

		Marketability (%)			
		Exterior		Interior	
Treatments	Applications[z]	Calif.	Texas	Calif.	Texas
After 1 week storage[y]					
Water	–	88 a[x]	100 a	84 b	100 a
AA-Ca	2 early + 2 late	87 a	100 a	100 a	100 a
MC-Ca	2 early + 2 late	87 a	100 a	100 a	100 a
AA-Ca	1 early	71 bc	100 a	100 a	100 a
AA-Ca	2 early	76 b	100 a	100 a	100 a
MC-Ca	1 early	79 ab	100 a	100 a	100 a
MC-Ca	2 early	77 b	100 a	97 a	100 a
AA-Ca	1 late	62 c	100 a		100 a
100 a					
AA-Ca	2 late	79 ab	100 a	100 a	100 a
MC-Ca	1 late	72 bc	100 a	100 a	100 a
MC-Ca	2 late	79 ab	100 a	100 a	100 a
$P \leq 0.05$					
After 2 weeks storage[w]					
Water	–	59 a	20 c	100 a	85 b
AA-Ca	2 early + 2 late	55 a	85 a	100 a	100 a
MC-Ca	2 early + 2 late	56 a	85 a	88 a	100 a
AA-Ca	1 early	36 cd	85 a	94 a	100 a
AA-Ca	2 early	43 bc	85 a	100 a	100 a
MC-Ca	1 early	36 cd	50 b	100 a	100 a
MC-Ca	2 early	50 ab	50 b	100 a	100 a
AA-Ca	1 late	30 d	85 a	100 a	100 a
AA-Ca	2 late	30 d	85 a	100 a	100 a
MC-Ca	1 late	45 ab	85 a	94 a	100 a
MC-Ca	2 late	36 cd	85 a	97 a	100 a
$P \leq 0.05$					

[z]Applications: 1 early = at female flowering, 2 early = 1 early plus 25 d later, 1 late = 3 to 5 d before full-slip, 2 late = 30 d after female flowering plus 1 late.
[y]4 d at 4 °C (39.2 °F) and 95% ± 3% relative humidity (RH), plus 3 d at 21 °C (69.8 °F) and 50% ± 3% RH.
[x]Mean separation by Duncan's multiple range test. Any two means within a column and within a storage period, followed by the same letter are not significantly different. Values are means (n = 8).
[w]11 d at 4 °C and 95% ± 3% RH, plus 3 d at 21 °C and 50% ± 3% RH

foliar run-off, or as direct application to exposed melons on the ground. Secondary movement of calcium from leaves to fruit (i.e., potentially via the phloem transport pathway) appears not to have occurred, because both cantaloupe and honeydew melons should have responded positively to the treatments. This was not the case, and there is no reason to expect a difference in the way that leaves of the two melon types (which are both the same species) would have performed with respect to the foliar absorption of the calcium chelate, or to its subsequent partitioning. Furthermore, calcium is generally believed to move very poorly, if at all, in the phloem pathway (Clarkson, 1984). Thus, with direct application presumed to be the source of the supplemental calcium for honeydew melons, it is clear that plants should be sprayed in a way that will maximize coverage of the fruit themselves. Although four applications of chelated calcium proved the most beneficial to postharvest quality, further studies are needed to assess whether fewer sprayings with more concentrated calcium-chelate solution may also be effective.

The pertinent goal for melon growers is to have a highly marketable product of good nutritional quality. Although some improvements in the application techniques may yet arise following further investigations, our study has shown that preharvest calcium chelate application can improve postharvest fruit quality traits in honeydew melons, and that the use of this technology is a viable option for regions where melons are boxed in the field (or where postharvest applications of calcium chelate is impractical—in the packing shed—before boxing).

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Table 8. Soluble solids concentration and consumer preference of 'Sol Real'(Calif.) and 'Primo' (Texas) orange-fleshed netted cantaloupe, with peel removed (exterior) and edible-flesh (interior) at harvest and following commercial storage. Amino-acid-chelated calcium [AA-Ca (calcium metalosate)] or mannitol-complexed calcium [MC-Ca (Foli-cal)] applied during fruit development to spring-grown plants harvested in June 2002 in the Imperial Valley, Calif., and May 2002 in the Rio Grande Valley, Texas.

		Soluble solids concn (%)		Consumer preference[z] (taste)	
Treatment	Application[y]	Calif.	Texas	Calif.	Texas
At harvest					
Water	–	10.9 ab[x]	8.3 ab	5.9 a	6.6 a
AA-Ca	2 early + 2 late	10.6 ab	8.2 ab	6.9 a	6.3 ab
MC-Ca	2 early + 2 late	10.8 ab	7.6 bc	5.5 a	5.3 abc
AA-Ca	1 early	12.0 a	8.0 abc	6.3 a	4.6 bc
AA-Ca	2 early	11.3 a	8.3 ab	5.7 a	5.3 abc
MC-Ca	1 early	11.1 a	7.8 bc	6.6 a	6.2 ab
MC-Ca	2 early	11.7 a	7.5 bc	5.5 a	5.3 abc
AA-Ca	1 late	10.5 ab	8.4 ab	5.5 a	5.6 abc
AA-Ca	2 late	11.6 a	9.2 a	6.2 a	6.1 abc
MC-Ca	1 late	9.5 b	6.6 c	6.2 a	4.2 c
MC-Ca	2 late	10.8 ab	7.4 bc	6.4 a	4.9 abc
$P \leq 0.05$					
After 1 week storage[w]					
Water	–	10.5 c	8.3 ab	6.9 ab	5.9 a
AA-Ca	2 early + 2 late	11.6 ab	7.7 ab	7.5 ab	5.6 a
MC-Ca	2 early + 2 late	11.2 bc	8.8 ab	7.3 ab	4.8 a
AA-Ca	1 early	11.1 bc	7.6 b	7.0 ab	6.2 a
AA-Ca	2 early	12.5 ab	8.4 ab	6.2 ab	6.3 a
MC-Ca	1 early	11.7 ab	8.4 ab	7.8 a	4.7 a
MC-Ca	2 early	12.6 a	8.1 ab	7.1 ab	6.3 a
AA-Ca	1 late	11.6 ab	8.4 ab	6.0 c	5.7 a
AA-Ca	2 late	12.4 ab	9.2 a	5.7 c	5.9 a
MC-Ca	1 late	11.9 ab	7.9 ab	7.3 ab	5.9 a
MC-Ca	2 late	11.2 bc	8.9 ab	6.4 bc	6.2 a
$P \leq 0.05$					
After 2 weeks storage[v]					
Water	–	10.1 b	8.0 ab	6.0 ab	6.3 a
AA-Ca	2 early + 2 late	11.1 a	7.9 ab	7.2 a	5.3 ab
MC-Ca	2 early + 2 late	10.4 ab	11.0 a	6.6 a	3.4 c
AA-Ca	1 early	10.6 a	7.9 b	7.4 a	5.3 ab
AA-Ca	2 early	11.3 a	8.4 b	7.4 a	5.4 ab
MC-Ca	1 early	10.4 ab	9.2 ab	7.2 a	3.8 c
MC-Ca	2 early	10.9 a	8.8 b	5.6 b	3.2 c
AA-Ca	1 late	10.0 b	8.3 b	7.0 a	5.8 a
AA-Ca	2 late	10.8 a	8.6 b	6.4 a	5.3 ab
MC-Ca	1 late	11.4 a	8.5 b	6.8 a	4.6 b
MC-Ca	2 late	9.7 b	8.7 b	6.6 a	4.6 b
$P \leq 0.05$					

[z]Preference rating based on a scale means of 1 to 10 when 1 to 4 = dislike extremely, 4.1 to 7 = like, 7.1 to 10 = like extremely. Values are (n = 25).
[y]Applications: 1 early = at female flowering, 2 early = 1 early plus 20 d later, 1 late = 3 to 5 d before full-slip, 2 late = 40 d after female flowering plus 1 late.
[x]Mean separation by Duncan's multiple range test. Any two means within a column and within a storage period, followed by the same letter are not significantly different. Values are (n = 8).
[w]4 d at 4 °C (39.2 °F) and 95% ± 3% relative humidity (RH), plus 3 d at 21 °C (69.8 °F) and 50% ± 3% RH.
[v]11 d at 4 °C and 95% ± 3% RH, plus 3 d at 21 °C and 50% ± 3% RH.

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