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Effects of Preharvest and Postharvest Calcium Treatments on Fruit Calcium Content and the Susceptibility of 'Van' Cherry to Impact Damage[1]

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Abstract. **Preharvest sprays or postharvest dips of $CaCl_2$ decreased the incidence of surface pitting of 'Van' cherries (*Prunus avium* L.) resulting from impact damage. Inclusion of a surfactant and thickener in the dip enhanced Ca uptake by cherries in storage. Ca from postharvest dips penetrated the cherry mesocarp rapidly in storage. Maximum Ca uptake by the cherry mesocarp was attained when the pH of the dipping solution was 7. However, postharvest Ca dips were most effective in preventing surface pitting when their pH was 4.**

The application of Ca by preharvest sprays and postharvest dips has increased cherry firmness (6) and decreased cherry susceptibility to impact damage (8). Ca penetration from a postharvest dip was enhanced by the inclusion of a thickener in the dipping solution and by prolonging the contact time between the fruit and dipping solution (6). However, depth of Ca penetration was not determined. Inclusion of thickeners in postharvest Ca dips increase the retention of dipping solution and the eventual Ca uptake by apples (2, 9). The effects of surfactants and thickeners on Ca uptake vary with apple cultivar (5).

Findings of Porritt and Lidster (11) suggest that Ca in apple fruit may be associated with exchange sites and not easily washed from the fruit surface with water. However, Perring (10) found that Ca could be readily removed from apple tissue by an acidic solution. This evidence suggests that fruit Ca can be displaced from exchange sites and mobilized and that Ca penetration from a postharvest $CaCl_2$ dip may be dependent upon solution pH.

Lidster et al. (8) determined that $CaCl_2$ postharvest dips could significantly reduce the incidence of surface disorders in cherries. However, in commercial cherry packing operations, the interval between a possible $CaCl_2$ dip and the rinse prior to packaging may be very short and would be expected to reduce the potential benefits of the $CaCl_2$ dip.

The present study investigated the effects on cherry fruit of: 1) preharvest $CaCl_2$ sprays on impact damage; 2) surfactants, thickeners and pH of the $CaCl_2$ dipping solution on Ca uptake and impact damage; 3) washing before and after impact damage on the efficacy of $CaCl_2$ postharvest dip in preventing surface disorders.

Materials and Methods

Impact damage to fruits. All fruit samples which required uniform impact damage were cooled to $0^{o}C$ within 12 hr of harvest and then placed onto a moving fiber belt from which they dropped 46 cm onto another moving fiber belt. The lower belt moved faster than the upper belt so that fruit-fruit collisions were minimized. Fruits were then placed in 38 μm perforated polyethylene liners and stored at 0^{o}. One hundred fruit per replication were examined for surface disorders immediately upon removal from storage using the classifications of Lidster et al. (8).

Ca determinations. Determination of non-radioactive Ca levels was done using the procedure of Lidster et al. (6). ^{45}Ca levels were determined by the modified procedure of Lidster et al. (4). All determinations of ^{45}Ca were corrected for background quenching and decay, and values were expressed as mg/kg of Ca uptake from a 30 g/liter $CaCl_2$ postharvest dip.

Effects of surfactants and thickeners on Ca uptake from a postharvest dip. 'Van' cherries of No. 6 color maturity (red-mahogany) and of uniform size were dipped in solutions of: 1) 30 g/liter $CaCl_2$; 2) 30 g/liter $CaCl_2$ plus 1 ml/liter non-ionic surfactant; 3) 30 g/liter $CaCl_2$ plus 2.5 g/liter thickener (Keltrol[3]); or 4) 30 g/liter $CaCl_2$ plus 2.5 g/liter thickener plus 1 ml/liter non-ionic surfactant. All solutions contained 0.5 g/liter Benlate (50w)[4] and were labelled with 0.5 uCi/ml ^{45}Ca. Cherries at 21°C were dipped by grasping 3 or 4 separate stems and immersing the fruit in $21^{o}C$ dipping solution for 15 sec. Fruit from each dip was randomly divided into 4 replications, placed in corrugated paperboard boxes lined with 38 μm perforated polyethylene liners and immediately stored at 0^{o}. Ten fruit per replication were removed after 1, 2, 4, 8 and 16 days and washed for 5 sec in deionized water. The stem was removed, the fruit sliced in half along the suture line, the pit removed, and a No. 5 cork borer was pushed from the pit side through the flesh to the epidermis. The tissue plug was then removed from the cork borer by pushing it along the length of the borer to prevent tissue contamination. Tissue plugs from identical treatments were collected from each of 10 cherries, the epidermis removed, the tissue chopped into small pieces and was weighed in 50 ml tared beakers and dried to constant weight in a forced air oven at 65^{o} for 2 days. The tissue was then ashed at 550^{o} for 3 hr and the ash taken up in 3 ml of 0.5 N HCl. The solution was then poured into liquid scintillation vials and an additional 15 ml of PCS[5] liquid scintillation cocktail added. The resulting mixture was analyzed by a Beckman LCS-100 liquid scintillation counter. The data were analyzed by forward stepwise multiple regression using each and all combinations of the potential independent variables: days, log (days), surfactant and thickener.

^{45}Ca penetration. For each of 4 replications, 60 fruit were dipped at 20°C in a solution of 30 g/liter $CaCl_2$ containing 2.5 g/liter thickener, 0.5 gm/liter Benlate and 1 ml/liter non-ionic surfactant and placed immediately in 0^{o} storage in 38 μm perforated polyethylene liners. Ten fruit of each replication

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[3]Keltrol is the brand name for food grade xanthan gum produced by Kelco Division of Merck and Co., Inc., San Diego, California.

[4]Benlate is the brand name for benomyl fungicide produced by E.I. DuPont de Nemours & Co., Wilmington, Delaware.

[5]PCS is the brand name for liquid scintillation cocktail produced by Amersham Searle Co., Arlington Heights, Illinois.

were removed at 1, 2, 4, 8, and 16 days, washed for 5 sec in deionized water, cut in half along the suture line; the pit was removed and a tissue plug was taken with a No. 5 cork borer inserted from the pit side. The tissue plug was then peeled and sectioned into 3 tissue discs of about 3 mm thickness each. Tissue discs from 3, 6, and 9 mm depths were collected from each of 10 fruit and a composite sample was dried, ashed and analyzed for ^{45}Ca as above. The data were analyzed by forward stepwise multiple regression using each and all combinations of the potential independent variables: days, log (days) and depth.

Effects of pH of $CaCl_2$ dipping solution on calcium uptake and disorder incidence. 'Van' cherries were harvested from each of 4 trees (replications) and randomly divided into 5 treatments. Four replications of 250 fruits each were dipped in 30 g/liter $CaCl_2$, 1 ml/liter non-ionic surfactant and 0.5 g/liter Benlate (50 w) with 2.5 g/liter thickener added. The pH of the dipping solution was adjusted to 1, 4, 7, 10, or 12 with either HCl or NaOH. Fruit at 21°C was dipped in the appropriate 21°C solution for 15 sec; the excess was allowed to drain off, and the fruit damaged as described previously was placed in paperboard boxes lined with polyethylene and stored at 0°. Fifty fruits from each pH treatment were removed from storage at 1, 4, and 16 days after dipping. These fruits were washed, destemmed, pitted and frozen for calcium analysis. The remaining fruits were removed after 21 days and examined for surface disorders. The data were analyzed by forward stepwise multiple regression using each and all combinations of the potential independent variables: pH, days, pH^2, and $days^2$.

Preharvest calcium sprays, 1977 study. A solution of 3.9 g/liter $CaCl_2$ plus 1 ml/liter non-ionic surfactant was sprayed to whole branches selected at random on each of 5 cherry trees (replications) of similar age and growth habit. Three $CaCl_2$ sprays were applied at 2 week intervals commencing 6 weeks prior to harvest while the single $CaCl_2$ spray was applied 1 week prior to harvest. Fruits of uniform size and maturity were harvested at No. 6 color maturity (red-mahogany). Control fruit were harvested from an unsprayed branch adjacent to these receiving $CaCl_2$. The fruit were impact damaged, stored for 21 days, examined for surface disorders and the data were analyzed as a 3 spray treatments × 5 replication experiment using the Newman Keuls' multiple range test.

1978 study. Branches selected at random in each of 4 trees (replications) were sprayed with a solution of 3.9 g/liter $CaCl_2$ plus 1 ml/liter non-ionic surfactant. Sprays were applied so that 1 branch per tree received spray applications at: 1) 5 weeks prior to harvest, 2) 3 weeks prior to harvest; 3) 1 week prior to harvest; 4) 3 and 1 week prior to harvest; 5) 5, 3, and 1 week prior to harvest; and 6) no spray (control). All fruit was harvested at No. 6 color maturity, impact damaged, stored and examined for surface disorders. The data were analyzed as 6 spray treatment × 4 replication experiment using the Newman Keuls' multiple range test.

Effect of washing on effectiveness of postharvest dips. 'Van' cherries were harvested at No. 6 color maturity and randomly divided into 4 replications for each of 4 dipping solutions and 3 washing sequences. The 4 dipping solutions consisted of: 1) water; 2) 2.5 g/liter thickener; 3) 30 g/liter $CaCl_2$; and 4) 30 g/liter $CaCl_2$ plus 2.5 g/liter thickener; each contained 1 ml/liter non-ionic surfactant plus 0.5 g/liter Benlate (50w). The washing schedules consisted of: 1) no wash, 2) washing prior to bruising, or 3) washing after bruising of the fruit.

Fruits were harvested, dipped immediately in 21°C dipping solution and placed in 0° storage until fruit temperature reached 0°. Fruit which required washing prior to bruising were rinsed in cold running water and returned to storage until they reached 0°. All fruit were then impact damaged. Fruit which required washing after bruising were rinsed in cold water. All fruit were placed in paperboard boxes in polyethylene liners and replaced in 0° storage. Fruit was removed after 14 days of storage and examined for surface disorders. The data were analyzed as a 4 dip × 3 wash × 4 replication factorial experiment using the Newman Keuls' multiple range test.

Results and Discussion

Factors affecting Ca uptake. Calcium uptake as determined by radiotracer techniques was modified by the inclusion of surfactants and thickeners in the dipping solution (Fig. 1). Addition of a non-ionic surfactant to the $CaCl_2$ dipping solution decreased Ca uptake from that obtained from a solution not containing a surfactant. The addition of 0.25% thickener to the $CaCl_2$ dipping solution increased Ca uptake by the cherry mesocarp. The addition of a surfactant to the dipping solution containing a thickener increased Ca penetration to exceed the Ca uptake of fruit dipped in a solution with thickener but without surfactant. These results agree with the data of Mason et al. (9) on apples.

Radiotracer studies showed that Ca from a postharvest dip moved readily into cherry fruit mesocarp (Fig. 2). Significant amounts of ^{45}Ca were detected in the 6-9 mm depth of flesh

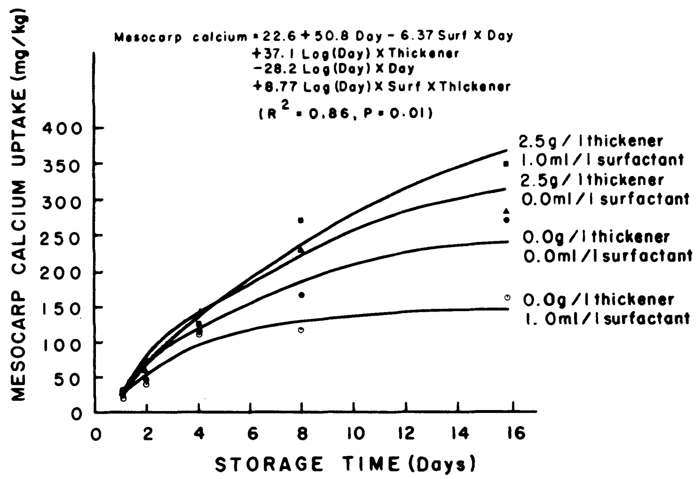

Fig. 1. Mesocarp calcium uptake by 'Van' cherries from a postharvest dip modified by surfactant and thickener (n = 4).

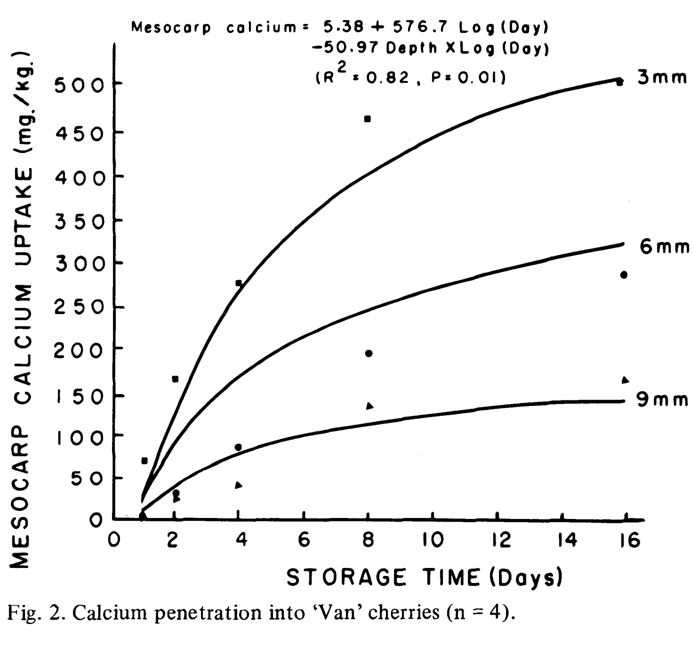

Fig. 2. Calcium penetration into 'Van' cherries (n = 4).

Table 1. Effect of pH of postharvest $CaCl_2$ dip (30 g/liter) on mesocarp Ca content in 'Van' cherries, 1978 crop.

Days from dip	Mesocarp calcium content (mg/kg) pH of dipping solution 1		4		7		10		12	
	Observed	Calculated	Observed	Calculated	Observed	Calculated	Observed	Calculated	Observed	Calculated
1	923	864[z]	999	910	878	920	839	894	803	857
4	965	934	1068	1120	1221	1160	963	1050	900	905
16	1177	1210	1938	1940	2145	2100	1414	1690	1225	1090

[z]Values fitted from regression equation: Mesocarp Ca = 841.2 + 25.2 pH × Days − 1.99 pH^2 × Days (R^2 = 0.82, p = 1%).

2 days after the dip. Calcium uptake at all mesocarp depths increased progressively with increased time in storage. Cherries appear to be much more permeable to Ca penetration than apples (6, 9). Cherries also have a larger surface area/volume ratio than apples so that Ca penetration from the residue remaining on the cherry surface is greater per tissue unit volume than for the larger apple fruit.

A pH of 7.0 in the $CaCl_2$ dipping solution resulted in maximum Ca uptake (Table 1). Basic or acidic dipping solution decreased the efficacy of $CaCl_2$ dips. The non-adjusted pH of a 4% $CaCl_2$ solution with thickener may range from pH 7 to 10 depending on the $CaCl_2$ source. Basic $CaCl_2$ dipping solutions may form insoluble carbonates and result in ionic Ca being unavailable for fruit penetration. On the other hand, acidic solutions have been shown to extract Ca from fruit tissues (10). Highly acidic $CaCl_2$ solution may dislocate fruit Ca bound to exchange sites (11) and make fruit Ca more mobile. A reduced amount of bound Ca on fruit surfaces when removed from the dip may result in decreased Ca flux into the fruit.

Factors affecting the efficacy of $CaCl_2$ applications in preventing surface damage in cherries. Preharvest $CaCl_2$ sprays increased the incidence of bruised fruit in 1977 but had no significant effect on the incidence of bruised fruit in 1978 (Table 2, 3). The increased incidence of bruised fruit with $CaCl_2$ sprays in 1977 may have resulted from a resistance to cell rupture imparted by the Ca sprays. The fruit cells may have distorted in response to impact, to form fruit bruises rather than rupturing to form surface pits. However, $CaCl_2$ sprays significantly reduced the incidence of fruit with surface pitting. In the 1977 study, a single $CaCl_2$ spray just prior to harvest significantly reduced the incidence of surface pitting, whereas fruit required a minimum of 2 late $CaCl_2$ sprays in 1978 to significantly reduce the incidence of surface pitting. Three $CaCl_2$ sprays had no observable toxic effects to the tree or fruit.

The pH of a $CaCl_2$ dipping solution was shown to modify Ca penetration into the cherry mesocarp (Table 1), and to have a significant effect on the incidence of surface disorders due to mechanical damage (Table 4). The incidence of bruised fruit showed a positive correlation with the pH of the dipping solution. However, the incidence of total surface pitting was a minimum when dipped in $CaCl_2$ solution with pH 4. The optimum pH of a $CaCl_2$ dip in preventing surface disorders differs from the pH 7 optimum for maximum Ca uptake. This suggests that factors other than Ca uptake, e.g. water uptake, may also affect fruit susceptibility to surface pitting. The positive correlation of bruised fruit with dipping solution pH is as yet unexplained.

The incidence of surface damage in fruit dipped in water prior to impact damage was not significantly different from non-dipped fruit (Table 5). This suggests that water on the surface of the fruit is ineffective in lubricating the fruit to lessen the degree of damage. Similarly the lubricating effects of a thickener solution on the fruit surface to lessen the magnitude of damage were insignificant. However, allowing the thickener solution to remain on the fruit surface after damage decreased the incidence of pitted fruit. This may be due to the restriction of water loss by the thickener coating to prevent the

Table 2. Effects of preharvest $CaCl_2$ (3.9 g/liter) sprays on the incidence of 'Van' cherry fruit disorders, 1977 crop.

Treatment	Bruised fruit (%)	Fruit with pitting (%)
No spray	34 b[z]	64 a
1 spray	57 a	38 b
3 sprays	51 a	43 b

[z]Mean separation within columns by Newman Keuls' test, 5% level.

Table 3. Effects of preharvest $CaCl_2$ (3.9 g/liter) sprays on the incidence of 'Van' cherry fruit disorders, 1978 crop.

Time of application prior to harvest 5 wks	3 wks	1 wk	Bruised fruit (%)	Pitted fruit (%)
–	–	–	4 a[z]	80 a
+	–	–	5 a	72 a
–	+	–	4 a	73 a
–	–	+	5 a	67 ab
–	+	+	4 a	58 b
+	+	+	5 a	39 c

[z]Mean separation within columns by Newman Keuls' test, 5% level.

Table 4. Effects of pH of $CaCl_2$ postharvest dip (30 g/liter) on disorder incidence in 'Van' cherry, 1978 crop.

pH of solution	Bruised fruit (%) Calculated	Observed	Pitted fruit (%) Calculated	Observed
1	6[z]	9	28[y]	29
4	10	12	18	18
7	14	15	23	21
10	17	17	35	39
12	19	17	44	42

[z]Values fitted from regression equation: Bruised fruit = 5.8 + 1.11 pH (r^2 = 0.61, p = 1%).

[y]Values fitted from regression equation: Pitted fruit = 35.2 − 8.47 pH + 1.22 pH^2 − 0.0377 pH^3 (r^2 = 0.82, p = 1%).

Table 5. Effects of washing on postharvest dips in preventing damage disorders in 'Van' cherries, 1978 crop.

Dipping solution	Concn (g/liter)	Wash time	Bruised fruit (%)	Pitted fruit (%)
Water		None	5 b	63 a
		Before bruising	5 b	62 a
		After bruising	3 b	63 a
Keltrol	2.5	None	4 b	43 b
		Before bruising	3 b	58 a
		After bruising	10 a	54 a
$CaCl_2$	30	None	3 b	41 b
		Before bruising	2 b	61 a
		After bruising	6 b	60 a
$CaCl_2$ + Keltrol	30 2.5	None	3 b	30 c
		Before bruising	6 b	46 b
		After bruising	5 b	42 b

[z]Mean separation within columns by Newman Keuls' test, 5% level.

formation of sunken pits. $CaCl_2$ applied without thickener and not washed off prior to storage and $CaCl_2$ applied with thickener significantly decreased the incidence of surface pitting. However, dipping fruit in $CaCl_2$ with thickener was most effective in reducing surface pitting when the fruit remained unwashed. Washing the dipping solution from the surface of the fruit might be expected to decrease the surface supply of calcium for penetration and hence reduce the efficiency of a $CaCl_2$ dip. However, substantial reductions in the incidence of surface pitting resulted from $CaCl_2$ plus thickener dips even when washed immediately after dipping. This suggests that dipping fruit may have commercial application in reducing surface disorders. The fruit may be dumped into a $CaCl_2$ plus thickener solution prior to the cluster cutter in a commercial packing line. The $CaCl_2$ plus thickener dip may then be washed off the fruit prior to sorting. This procedure could result in 30% reduction in the incidence of surface pitting.

Increased fruit Ca levels resulting from preharvest $CaCl_2$ sprays (7) and postharvest $CaCl_2$ dips (6) were negatively correlated with the incidence of surface pitting. Infused Ca may function by reacting with free carboxyl groups of polygalacturonic acid molecules to increase the intercellular bond strength (1, 3), thus increasing the tissue resistance to impact damage.

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Minimum Critical Foliar Levels of K, Mg, and B in Rieger Elatior Begonia[1]

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Additional index words. nutrition, foliar analysis, tissue analysis, *Begonia* X *hiemalis*

Abstract. **Analysis of deficiency symptoms and foliar analyses of canopy leaves (youngest leaves 5 cm of wider) of Rieger elatior begonias (*Begonia* X *hiemalis* Fotsch cv. Schwabenland Red) indicated that the minimum critical levels for K, Mg, and B lie in the ranges of 0.93 to 0.95%, 0.22 to 0.25%, and 13.0 to 14.0 ppm, respectively.**

Nutritional requirements of the elatior begonia are modest. The effects of nutrient deficiencies and toxicities, however, are pronounced and unlike other crops such as chrysanthemum, are very persistent. Nutritional monitoring therefore is important.

Visual symptoms for deficiencies of N, P, K, Ca, Mg, Fe, and B have been reported (7). Foliar analysis is of greater value since a problem may be identified before irreversible damage occurs. A sampling procedure has been developed for foliar analysis of elatior begonia requiring analysis of canopy leaves; the youngest leaves 5 cm or wider (6). Nelson et al. (6) have established critical concentrations for 3 nutrients in canopy leaves of 'Schwabenland Red' elatior begonia. The

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