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Keeping Qualities of 'Stayman' and 'Delicious' Apples Treated with Calcium Chloride, Scald Inhibitors, and other Chemicals[1]

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Abstract. **'Stayman' apples (*Malus domestica* Borkh.) dipped in 4% $CaCl_2$ were firmer after 5–6 months storage in air at 0°C and developed less senescent breakdown than untreated fruit. Use of the thickener Keltrol with $CaCl_2$ or vacuum infiltrating (VI) $CaCl_2$ resulted in the firmest fruit after storage and the highest flesh Ca levels. 'Stayman' stored 5 or 6 months in CA at 0°C were 1.5 kg firmer than air-stored fruit. Dipping apples in $CaCl_2$ prior to CA storage provided little additional benefit. Liquid concentrate formulations of diphenylamine (DPA) and ethoxyquin used alone or in combination with 4% $CaCl_2$ gave excellent scald control on 'Stayman' stored 5 or 6 months at 0° + 6 days at 20°. However, the same chemicals gave poor scald control for 'Starkrimson Delicious' picked early to midseason. The antioxidants BHT and BHA evaluated as postharvest dips at 2,000 ppm were less effective than DPA or ethoxyquin in controlling scald on 'Stayman'. 'Delicious' apples were not significantly firmer after 6 months storage in air at 0°C when dipped in 3% $CaCl_2$ alone or with Keltrol, or when $CaCl_2$ was VI. When $CaCl_2$ was contaminated with *Penicillium expansum* spores, VI of the solution greatly increased decay of both 'Delicious' and 'Stayman'.**

Bitter pit of apples has been reduced or controlled in numerous cultivars with $CaCl_2$ dips before storage or transport (3, 6, 7, 18, 20, 22, 24, 25, 27). $CaCl_2$ is also used commercially as dip or drench treatments to reduce storage breakdowns of 'Jonathan', 'Spartan', and 'Cox's Orange Pippin' apples (1, 4, 12, 16, 21), the incidence of breakdown being related to the final Ca concentration in the fruit (6, 17). Uptake of Ca solution by fruit was primarily through lenticels and increased with higher concentration of solution; absorbed Ca moved inward through tissues but remained highest near the surface (2, 8, 11, 12, 14). Use of various surfactants, thickeners such as Keltrol, and lecithin with $CaCl_2$ often has increased effectiveness of the treatment, delayed softening (3, 5–8, 10, 13, 14, 19), or reduced Ca injury (7, 18). For some cultivars both vacuum and pressure infiltration of $CaCl_2$ solution may improve control of breakdown and bitter pit over simple dipping (7, 15, 22, 23, 26).

The objective of our studies was to evaluate the post-storage qualities and Ca content of 'Delicious' and 'Stayman' apples when treated with $CaCl_2$ alone and in combination with scald inhibitors and other chemicals, and when applied by different methods after harvest.

Materials and Methods

'Delicious' apples from 4 orchards in Virginia, Maryland, and Pennsylvania were evaluated during the 1978-79 season, using 75 to 90 apples per treatment per orchard. 'Stayman' apples from 4 orchards also were evaluated during the 1978-79 season, using 90 to 115 apples per treatment per orchard. For another 'Stayman' test, fruit was obtained from 8 orchards, 4 in 1978-79 and 4 in 1979-80. All fruit were composited after picking. Initial fruit firmness averaged 7.1 to 7.3 kg for the 'Delicious' and 6.8 to 8.1 kg for the 'Stayman' fruit.

Laboratory grade USP $CaCl_2$ (76%), made up as 2, 3, or 4% (w/v) solutions, was used in most tests. In 1 test, laboratory grade $CaCl_2$ was compared with a commerical grade $CaCl_2$ (78% Dow flake) on 'Stayman' apple. The food thickener Keltrol (xanthan gum) used at 0.2 or 0.3% (w/v) to aid retention of $CaCl_2$ on apples was prepared in a Waring blender with water. In some tests fruit was stored without rinsing following treatment; in others it was rinsed after 2 weeks in storage in an attempt to reduce chemical injury. Some fruit was vacuum infiltrated (VI) with $CaCl_2$ for 1 or 3 min under 250 mm Hg vacuum and then held in the solution 1 min after vacuum release. Another comparison involved VI with either clean $CaCl_2$ solution or $CaCl_2$ solution contaminated with *Penicillium expansum* spores (ca. 3×10^4 spores/ml), as might occur after several hours of use.

Two commercial scald inhibitors (Chemley Products Co.) were compared: liquid concentrate "160" DPA used at 2000 ppm and liquid concentrate "260" ethoxyquin (ETOQ) used at 2700 ppm. Two other antioxidants, butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) were evaluated for scald control at 2,000 ppm. Some treatments included the wetting agent Tween-20 (0.1% v/v). Apples were dipped for 30 sec, then drained briefly and packed in fiberboard cartons.

Storage was at 0°C with 90% relative humidity for 4 to 6 months and then fruit were ripened 6 days at 20°. The CA chamber for the 'Stayman' apples was maintained at 3% O_2 and 2% CO_2. Firmness was measured on opposite pared sides of 16 or 20 apples per treatment per orchard with a Magness-Taylor penetrometer. Apples also were examined for decay, scald, other defects and possible injury after storage and after ripening. All fruit were eventually cut for internal examination. For Ca analysis, 10 fruit per treatment from each farm were washed in distilled water and a stem to calyx sector cut to the cord was removed. Peel and

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Table 1. Effects of scald inhibitors, $CaCl_2$ and other postharvest treatments on condition of 'Delicious' apples after 6 months at 0°C plus 6 days at 20°.[z]

Treatment	Firmness (kg)	Total scald (%)	Decay (%)	Calyx injury (%)	Flesh Ca (ppm)
Control, H_2O dip	6.1 a[y]	66 a	4.1 a	0.5 a	242 a
2,000 ppm DPA[x]	6.0 a	41 b	2.2 a	0.5 a	260 ab
2.700 ppm ETOQ[x]	6.0 a	45 bc	1.9 a	1.2 a	259 ab
3% $CaCl_2$ (lab grade)	6.0 a	59 ab	1.8 a	2.2 a	339 bc
3% $CaCl_2$ + 2,000 ppm DPA	5.8 a	36 c	1.5 a	2.2 a	286 abc
3% $CaCl_2$ + 2,700 ppm ETOQ	5.9 a	43 bc	1.7 a	1.8 a	292 abc
3% $CaCl_2$ + 0.2% Keltrol	5.7 a	47 bc	4.0 a	5.1 a	459 d
3% $CaCl_2$ + 0.2% Keltrol, rinse after 2 wks.	5.9 a	51 abc	2.3 a	3.3 a	328 abc
3% $CaCl_2$, VI 1 min, clean soln[w]	6.1 a	45 bc	11.3 b	10.7 b	456 d
3% $CaCl_2$, VI 1 min, contaminated soln	6.1 a	55 abc	38.9 c	11.1 b	374 c
3% $CaCl_2$, VI 1 min, rinse immediately	6.2 a	52 abc	11.8 b	1.1 a	288 abc
3% $CaCl_2$, 45°C, 30 sec, warm fruit	6.0 a	43 bc	2.5 a	1.5 a	341 bc
3% $CaCl_2$, 45°C, 1 min, cold fruit	5.9 a	59 ab	1.4 a	2.6 a	294 abc

[z]Values are means of fruit from 4 orchards, 1978-79 season, 75-90 apples per treatment per orchard. All postharvest chemical treatments are for 30 sec unless stated otherwise. Initial fruit firmness averaged 7.2 kg (15.9 lb.).
[y]Mean separation within columns by Duncan's multiple-range test, 5% level.
[x]Chemley Products Co., liquid conc "160" No Scald DPA and liquid conc. "250" No Scald Ethoxyquin.
[w]VI = vacuum infiltrated 1 min 250 mm Hg vacuum. Contaminated soln contained *Penicillium* spores.

core tissue were discarded. These composited flesh samples then were freeze dried, ground and 0.5 g samples were ashed, dissolved in 5 ml 2 N HCl, filtered and diluted into 100-ml flasks, and analyzed for Ca with a Jarrell-Ash atomic absorption spectrophotometer. All Ca values are reported on a dry-wt basis.

Results and Discussion

'Delicious' apples. In earlier experiments with 'Delicious', a 4% $CaCl_2$ treatment, with or without 0.3% Keltrol, reduced senescent breakdown and bitter pit (6). Neither disorder was encountered in the tests reported here. A 30-sec dip in 3% $CaCl_2$ alone or with 0.2% Keltrol increased flesh Ca levels but not flesh firmness after 6 months of storage (Table 1). Increasing the dip temperature to 45°C did not result in further increases in flesh Ca. The greatest flesh Ca concentrations were obtained when Keltrol or VI were used with $CaCl_2$, so long as the apples were not subsequently rinsed. However, the VI fruit developed more decay and calyx burn, and were no firmer or otherwise in better condition than fruit dipped in $CaCl_2$. Rinsing fruit in water immediately after VI prevented calyx injury but reduced Ca uptake during storage.

'Delicious' apples that were VI with $CaCl_2$ contaminated with *Penicillium* spores developed almost 40% decay after 6 months of storage plus 6 days at 20°C (Table 1). This problem will have to be overcome if VI becomes a commercial practice.

The 'Delicious' fruit, which were picked early to midseason, developed extensive storage scald even though they were treated with liquid concentrate formulations of DPA or ethoxyquin. Three of the 4 lots were 'Starkrimson', which has been reported to be more susceptible to scale than other strains if the apples are harvested early (R. M. Smock, Cornell Fruit Handling and Storage Newsletter. July 1979). 'Starkrimson' also usually develops less water core than other 'Delicious' strains at harvest (9), so early picking should be avoided. Dip treatments of 3% $CaCl_2$ with either DPA or ethoxyquin also failed to control scald but caused no significant increases in skin injury. In an earlier study (6), 4% $CaCl_2$ + 0.3% Keltrol + ethoxyquin caused severe skin injury to both 'Delicious' and 'Golden Delicious'.

'Stayman' apple. In 5 seasons of testing this cultivar usually has responded favorably to $CaCl_2$ treatment (5, 6). A postharvest dip in 4% $CaCl_2$ retarded softening of 'Stayman' stored 4 months at 0°C (Table 2). Softening was also retarded after only 2 months of storage when laboratory grade $CaCl_2$ was used. After 4 months of storage the apples treated with laboratory grade $CaCl_2$ were more firm and had less breakdown than apples treated with com-

Table 2. Effects of commercial and laboratory grade $CaCl_2$, with and without the adjuvant Keltrol, on the condition of 'Stayman' apples stored 2 and 4 months at 0°C.[z]

Treatment[y]	Firmness (kg)		Flesh Ca (ppm)		Breakdown (%)
	2 mo.	4 mo.	2 mo.	4 mo.	4 mo.
Control, H_2O dip	5.6 a[x]	4.6 a	200 a	230 a	20.0 a
4% $CaCl_2$, comm. grade	5.8 ab	4.9 b	285 ab	275 a	8.3 b
4% $CaCl_2$, lab grade	6.1 bc	5.1 c	304 ab	274 a	4.9 c
4% $CaCl_2$, comm. grade + 0.3% Keltrol	6.0 bc	5.4 d	482 c	612 b	0.8 d
4% $CaCl_2$, lab grade + 0.3% Keltrol	6.3 c	5.5 d	384 bc	563 b	0.8 d

[z]Values are means for fruit from 4 orchards. Initial fruit firmness 6.8 kg (15.0 lbs).
[y]Postharvest 30-sec dips. Commercial grade $CaCl_2$ was 78% Dow flake; lab grade $CaCl_2$ was 76% Fisher USP. Breakdown recorded after 4 months 0°C + 6 days 20°.
[x]Mean separation within columns by Duncan's multiple-range test, 5% level.

Table 3. Effects of scald inhibitors and $CaCl_2$ postharvest dips on condition of 'Stayman' apples after storage in air and CA at 0°C plus 6 days at 20°C[z]

Type storage and treatment[y]	Firmness (kg)[x] 1st exam	Firmness (kg)[x] 2nd exam	Scald (%)	Flesh Ca (ppm)	Calyx injury (%)
Air storage:					
Control, H_2O dip	5.3 ab[w]	4.8 a	72 a	304 a	3.4 abc
2,000 ppm DPA	5.2 a	4.8 a	4 e	290 a	2.0 ab
2,700 ppm ETOQ	5.1 a	4.8 a	3 e	295 a	2.2 ab
4% $CaCl_2$ + 0.1% Tween	5.4 bc	5.0 b	53 b	357 b	4.7 abc
4% $CaCl_2$ + DPA	5.3 ab	4.9 ab	3 e	365 b	6.0 c
4% $CaCl_2$ + ETOQ	5.3 ab	4.9 ab	3 e	330 ab	5.1 bc
4% $CaCl_2$ + 0.2% Keltrol	5.5 bc	5.3 c	51 b	505 c	8.9 d
4% $CaCl_2$ + 0.2% Keltrol + DPA	5.6 c	5.2 c	2 e	490 c	11.9 e
4% $CaCl_2$ + 0.2% Keltrol + ETOQ	5.5 bc	5.2 c	3 e	513 c	10.0 de
2,000 ppm BHT + Tween	5.3 ab	4.8 a	21 cd	----	1.7 a
2,000 ppm BHA + Tween	5.3 ab	4.8 a	32 c	----	2.7 ab[v]
CA storage:					
Control, H_2O dip	6.8 d	6.0 d	17 de	316 a	1.5 a
4% $CaCl_2$ + 0.1% Tween	6.9 d	6.1 d	12 de	368 b	2.9 abc

[z]Avg. values for 4 orchards in 1978 and 4 orchards in 1979, with 6 and 5 months of storage, respectively. Mean initial fruit firmness 8.1 kg (17.8 lb.).
[y]Postharvest 30-sec dips with laboratory grade $CaCl_2$ and/or DPA and ethoxyquin liquid concentrates from Chemley Products Co.
[x]First exam after storage, second exam after holding at 20°C.
[w]Mean separation within columns by Duncan's multiple range test, 5% level.
[v]BHA (butylated hydroxyanisole) caused chemical burn on 37% of the fruit in 1979.

mercial grade $CaCl_2$. Keltrol increased flesh Ca and flesh firmness after 4 months of storage, as reported for 'Spartan' apples by Mason et al. (14). Senescent breakdown was reduced from 20% in control fruit stored 4 months + 6 days at 20°, to less than 1% in fruit that was dipped in 4% $CaCl_2$ + Keltrol. Breakdown also was reduced by a $CaCl_2$ dip without Keltrol.

In another series of 8 tests, 'Stayman' dipped in $CaCl_2$ + Tween and $CaCl_2$ + Keltrol were somewhat firmer than control fruit after storage plus 6 days at 20°C (Table 3). The increased flesh firmness appeared to be directly related to the Ca in the flesh.

$CaCl_2$ appeared to be compatible with DPA or ethoxyquin for use on 'Stayman' apples. There was no skin injury from the combined treatment other than slight calyx darkening on a few apples. Calyx injury, although not a serious market defect, was more extensive when Keltrol was used.

Table 4. Effects of postharvest $CaCl_2$ treatments on the condition of 'Stayman' apples stored at 0°C plus 6 days at 20°C[z].

Season and treatment[y]	Firmness (kg)	Decay (%)	Flesh Ca (ppm)	Calyx injury (%)
1978-79 (6 months of storage):				
Control, H_2O dip	4.8 a[x]	3.0 a	335 a	2.1 a
4% $CaCl_2$ (lab grade)	5.0 b	0.7 a	414 ab	7.6 ab
4% $CaCl_2$ + 0.2% Keltrol	5.2 c	1.0 a	543 c	8.1 ab
4% $CaCl_2$ + 0.2% Keltrol, rinse after 2 wks	5.1 bc	0.7 a	441 b	3.3 ab
4% $CaCl_2$ VI 1 min, clean soln	5.2 c	1.9 a	444 b	11.7 ab
4% $CaCl_2$ VI 1 min, contaminated[w]	5.2 c	20.4 b	----	12.6 b
1979-80 (5 months of storage):				
Control, H_2O dip	4.8 a	0.7 a	274 a	4.8 ab
4% $CaCl_2$ (lab grade)	5.0 ab	0.7 a	301 a	4.6 ab
4% $CaCl_2$ + 0.2% Keltrol	5.3 c	2.7 a	467 b	9.9 c
4% $CaCl_2$ VI 1 min, clean	5.4 c	0.9 a	341 a	9.9 c
4% $CaCl_2$ VI 3 min, clean	5.3 c	0.7 a	317 a	8.7 bc
2% $CaCl_2$ VI 1 min, clean	5.1 bc	0.9 a	291 a	5.8 abc
2% $CaCl_2$ VI 3 min, clean	5.2 bc	1.6 a	271 a	4.1 a

[z]Averages for 4 orchards in each season.
[y]Postharvest 30-sec dips unless stated otherwise. VI = vacuum infiltrated at 250 mm Hg vacuum. Tween-20 used with all $CaCl_2$ treatments in 1979-80 test.
[x]Mean separation within columns and within seasons by Duncan's multiple-range test, 5% level.
[w]Solution contaminated with *Penicillium* spores (ca. 3×10^4 spores/ml).

Liquid concentrate formulations of DPA and ethoxyquin used alone or in combination with 4% $CaCl_2$ gave excellent scald control on 'Stayman' (Table 3). A $CaCl_2$ dip alone reduce scald significantly in these tests but did not provide adequate control. Both BHT and BHA, possible substitutes for DPA and ethoxyquin, reduced scald significantly, but DPA and ethoxyquin were much more effective. Also, BHA caused severe skin burn (37% damaged) in 1980.

'Stayman' apples stored in CA averaged 1.5 kg firmer than comparable air-stored fruit (Table 3). Dipping fruit in $CaCl_2$ before CA increased flesh Ca but did not significantly affect flesh firmness. Significant effects of $CaCl_2$ on 'Stayman' in CA, including a reduction in senescent breakdown, were noted previously (6).

Additional tests with $CaCl_2$ for 'Stayman' are summarized in Table 4. Rinsing fruit 2 weeks after dipping in $CaCl_2$ + Keltrol did not significantly reduce the calyx burn found after 6 months of storage. Flesh Ca after storage was ca 100 ppm lower in rinsed than in non-rinsed apples but the rinsed fruit was not significantly softer. One-minute VI with $CaCl_2$ resulted in firmness values similar to those produced by $CaCl_2$ + Keltrol. VI with $CaCl_2$ soln contaminated with *Penicillium* spores resulted in excessive decay (20%).

In the 1979-80 season, a 4% $CaCl_2$ + Tween dip did not increase flesh firmness. However, flesh firmness was significantly increased by 4% $CaCl_2$ + Keltrol and by VI of 2 or 4% $CaCl_2$ for 1 or 3 min. An advantage of VI over dip treatment is that apples can be rinsed immediately after treatment, reducing the possibility of fruit injury and corrosion of equipment (23).

In conclusion, there was no advantage of dips or VI with 3% $CaCl_2$ for 'Delicious' when bitter pit or storage breakdown were not problems. Scald of some strains of 'Delicious' was not controlled with either DPA or ethoxyquin when fruit was picked early to midseason some years. A dip of 4% $CaCl_2$ on 'Staymans' usually gave firmer fruit and greatly reduced senescent breakdown after storage. Uptake of Ca and firmness were highest when $CaCl_2$ was VI or applied with Keltrol. Liquid concentrate formulations of DPA and ethoxyquin used alone or combined with $CaCl_2$ provided excellent scald control for 'Stayman' apples.

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