

Keeping Qualities of 'Stayman' and 'Delicious' Apples Treated with Calcium Chloride, Scald Inhibitors, and other Chemicals¹

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Abstract. 'Stayman' apples (*Malus domestica* Borkh.) dipped in 4% CaCl₂ 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 CaCl₂ or vacuum infiltrating (VI) CaCl₂ 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 CaCl₂ prior to CA storage provided little additional benefit. Liquid concentrate formulations of diphenylamine (DPA) and ethoxyquin used alone or in combination with 4% CaCl₂ 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% CaCl₂ alone or with Keltrol, or when CaCl₂ was VI. When CaCl₂ 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 CaCl₂ dips before storage or transport (3, 6, 7, 18, 20, 22, 24, 25, 27). CaCl₂ 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 CaCl₂ 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 CaCl₂ 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 CaCl₂ 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 CaCl₂ (76%), made up as 2, 3, or 4% (w/v) solutions, was used in most tests. In 1 test, laboratory grade CaCl₂ was compared with a commercial grade CaCl₂ (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 CaCl₂ 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 CaCl₂ 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 CaCl₂ solution or CaCl₂ solution contaminated with *Penicillium expansum* spores (ca. 3 × 10⁴ 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% O₂ and 2% CO₂. Firmness was measured on opposite pored 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, CaCl₂ 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 ₂ O 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

^zValues 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.).

^yMean separation within columns by Duncan's multiple-range test, 5% level.

^xChemley Products Co., liquid conc "160" No Scald DPA and liquid conc. "250" No Scald Ethoxyquin.

^wVI = 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% CaCl₂ 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% CaCl₂ 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 CaCl₂, 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 CaCl₂. Rinsing fruit in water immediately after VI prevented calyx injury but reduced Ca uptake during storage.

'Delicious' apples that were VI with CaCl₂ 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 scald 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% CaCl₂ with either DPA or ethoxyquin also failed to control scald but caused no significant increases in skin injury. In an earlier study (6), 4% CaCl₂ + 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 CaCl₂ treatment (5, 6). A postharvest dip in 4% CaCl₂ 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 CaCl₂ was used. After 4 months of storage the apples treated with laboratory grade CaCl₂ were more firm and had less breakdown than apples treated with com-

Table 2. Effects of commercial and laboratory grade CaCl₂, 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 ₂ O 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

^zValues are means for fruit from 4 orchards. Initial fruit firmness 6.8 kg (15.0 lbs).

^yPostharvest 30-sec dips. Commercial grade CaCl₂ was 78% Dow flake; lab grade CaCl₂ was 76% Fisher USP. Breakdown recorded after 4 months 0°C + 6 days 20°.

^xMean separation within columns by Duncan's multiple-range test, 5% level.

Table 3. Effects of scald inhibitors and CaCl₂ 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		Scald (%)	Flesh Ca (ppm)	Calyx injury (%)
	1st exam	2nd exam			
Air storage:					
Control, H ₂ O 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 ^y
CA storage:					
Control, H ₂ O 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

^zAvg. 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.).

^yPostharvest 30-sec dips with laboratory grade CaCl₂ and/or DPA and ethoxyquin liquid concentrates from Chemley Products Co.

^xFirst exam after storage, second exam after holding at 20°C.

^wMean separation within columns by Duncan's multiple range test, 5% level.

^vBHA (butylated hydroxyanisole) caused chemical burn on 37% of the fruit in 1979.

mercial grade CaCl₂. 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% CaCl₂ + Keltrol. Breakdown also was reduced by a CaCl₂ dip without Keltrol.

In another series of 8 tests, 'Stayman' dipped in CaCl₂ + Tween and CaCl₂ + 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.

CaCl₂ 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 CaCl₂ 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 ₂ O 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 ₂ O 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

^zAverages for 4 orchards in each season.

^yPostharvest 30-sec dips unless stated otherwise. VI = vacuum infiltrated at 250 mm Hg vacuum. Tween-20 used with all CaCl₂ treatments in 1979-80 test.

^xMean separation within columns and within seasons by Duncan's multiple-range test, 5% level.

^wSolution contaminated with *Penicillium* spores (ca. 3 × 10⁴ spores/ml).

Liquid concentrate formulations of DPA and ethoxyquin used alone or in combination with 4% CaCl₂ gave excellent scald control on 'Stayman' (Table 3). A CaCl₂ 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 CaCl₂ before CA increased flesh Ca but did not significantly affect flesh firmness. Significant effects of CaCl₂ on 'Stayman' in CA, including a reduction in senescent breakdown, were noted previously (6).

Additional tests with CaCl₂ for 'Stayman' are summarized in Table 4. Rinsing fruit 2 weeks after dipping in CaCl₂ + 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 CaCl₂ resulted in firmness values similar to those produced by CaCl₂ + Keltrol. VI with CaCl₂ soln contaminated with *Penicillium* spores resulted in excessive decay (20%).

In the 1979-80 season, a 4% CaCl₂ + Tween dip did not increase flesh firmness. However, flesh firmness was significantly increased by 4% CaCl₂ + Keltrol and by VI of 2 or 4% CaCl₂ 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% CaCl₂ 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% CaCl₂ on 'Staymans' usually gave firmer fruit and greatly reduced senescent breakdown after storage. Uptake of Ca and firmness were highest when CaCl₂ was VI or applied with Keltrol. Liquid concentrate formulations of DPA and ethoxyquin used alone or combined with CaCl₂ provided excellent scald control for 'Stayman' apples.

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