Applying Calcium Chloride Postharvest to Improve Highbush Blueberry Firmness

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Abstract. Immature and marketable highbush blueberries often are separated by buoyancy in water tanks. Calcium chloride was added to the water to improve berry firmness or integrity. Berries were immersed in 0% to 4% CaCl₂ and held at 2C for several days. Vertical compression of a column of berries decreased linearly with increased CaCl₂ concentration, a result indicating that CaCl₂ increased the ability of the berries to resist physical damage. Immersion duration (0.5, 2, or 4 minutes) did not affect results. However, rinsing berries in water immediately after immersing them in CaCl₂ negated the effect. Taste panelists associated an objectionable, salty taste with berries immersed in 2% and 4% CaCl₂, but not for those immersed in 1% CaCl₂.

A high frequency of crushed or broken berries reduces the grade [U.S. Dept. of Agriculture (USDA)] of frozen blueberries. Berries may be damaged during harvesting and sorting on the farm, in transport to a freezing facility, and during freezing. This is particularly true for overripe berries or when freezing is delayed. Improving the firmness or integrity of berries before freezing may reduce the number of crushed or broken berries, thus avoiding grade reductions.

Tissue Ca concentrations influence fruit texture, firmness, and ripening rate. Apples

(*Malus domestica* Borkh.) often are treated commercially pre- and postharvest with Ca solutions (Ferguson and Watkins, 1989). Preharvest CaCl₂ sprays increase the firmness of strawberries (*Fragaria × ananassa* Duch.) (Cheour et al., 1990; Eaves and Leefe, 1962) and raspberries (*Rubus idaeus* L.) (Eaves et al., 1972). Calcium may maintain fruit firmness by delaying postharvest ripening (Cheour et al., 1990). The relationship between tissue Ca concentration and blueberry firmness is not known. Reported Ca concentrations in blueberries range from 0.039% to 0.32% of dry matter (Ballinger et al., 1958; Bishop et al., 1971).

Blueberries destined for processing often are immersed in water tanks to separate the less-dense green berries from the mature berries (Wolfe et al., 1975). In Michigan, water sorting is done on the farm, and sometime may elapse before berries are frozen. Quality can decline during this time if berries are overripe

or mishandled in transit to the freezer; therefore, berries may be treated with CaCl₂ in the sorting tank. These studies examined the effects of postharvest CaCl₂ immersion on firmness and quality of highbush blueberries.

Four studies were conducted during 1991 and 1992. In each study, ≈1 kg of mature berries was placed in plastic mesh bags and immersed in treatment solutions. Berries were held for various periods to allow them to soften and to simulate commercial delayed-freezing conditions. Berry firmness was assessed indirectly by evaluating the ability of the berries to resist physical damage. Rigid polyvinylchloride pipe (50 cm long, 4 cm i.d., with an end cap) was filled with berries. The tube was shaken gently to settle the berries, then held vertically and dropped four times on a hard surface from 10 cm high. The column height of berries was measured before and after dropping, and the vertical compression was calculated.

In Study 1, 'Bluecrop' blueberries were immersed in 0%, 0.25%, 1.0%, or 4.0% CaCl₂ for 0.5, 2, or 8 min. Treated berries, still in

Table 1. Effect of CaCl₂ concentration (C) and immersion duration (D) on compression of 'Bluecrop' blueberries determined after berries had been held for 5 days at 2C plus 3 days at 18C (Study 1).

Variable	Compression (cm)
C (%)	
0	9.6
0.25	9.5
1.0	8.7
4.0	8.2
D (min)	
0.5	9.1
2.0	9.0
4.0	8.8
Significance	
C	L**
D	NS
C × D	NS

NS,**Nonsignificant or significant at $P \leq 0.01$ by F test; L = linear.

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mesh bags, were held for 5 days at 2C plus 3 days at 18C and tested for compression. A completely randomized, 4 × 3 factorial design was used, with five replications.

In Study 2, 'Jersey' blueberries were immersed in 0%, 1%, 2%, 3%, or 4% CaCl₂ for 2 min. Treated berries were held for 3 days at 2C plus 3 days at 18C before evaluating compression. After compression, berries were removed from the tube and frozen at -20C. Several weeks later, berries were sorted while frozen, and nondamaged, moderately damaged (dented or deformed), and severely damaged (crushed or broken) berries were counted. A completely randomized design was used, with six replications.

Study 3 determined whether rinsing berries after immersion in CaCl₂ affected their response. 'Jersey' blueberries were immersed in 4% CaCl₂ for 2 min. Samples were washed immediately by briefly immersing the bags twice in water, held at 2C for 2 or 4 days and washed by the same procedure, or not washed. All berries were held for 4 days at 2C plus 3 days at 18C before being tested for compression. A completely randomized design was used, with six replications.

In Study 4, taste tests were conducted to determine if CaCl₂ immersion resulted in detectable changes in the taste of fresh or frozen and thawed berries that were not rinsed after treatment. 'Bluecrop' blueberries were used for the fresh tests, and 'Jersey' blueberries for the frozen and thawed tests. Berries were dipped in 0%, 1%, 2%, or 4% CaCl₂ for 2 min. Four panelists first tasted berries treated with 0% and 8% CaCl₂ to familiarize themselves with the taste of CaCl₂. Nonsalty fruit received a rating of 0, and berries equivalent to those treated with 8% CaCl₂ received a rating of 10. Panelists then rated unknown samples on the same scale of 0 = no salty taste, 10 = strong salty taste. Berries that were frozen after immersion and thawed several weeks later were given the same test. Four replications were evaluated by each panelist.

Analysis of variance and F tests were used to test for significant treatment effects. The variance was partitioned into the linear component in Studies 1 and 2, and least significant difference values were used to separate means in Studies 3 and 4.

Increasing CaCl₂ concentrations in Studies 1 and 2 resulted in linear reductions in compression levels (Tables 1 and 2), a result indicating that berries immersed in CaCl₂ resisted physical damage to a greater extent than those not immersed. Immersion in CaCl₂ for 0.5, 2, or 8 min each seemed equally effective (Table 1). Increasing CaCl₂ concentrations decreased the percentage of severely damaged fruit and increased the percentage of nondamaged fruit (Table 2).

Although the compression test resulted in excessive damage (29% to 39% crushed or broken berries) by commercial standards, it seemed to be useful in measuring berry sus-

Table 2. Effect of CaCl₂ concentration on compression and degree of damage to blueberries (after the compression test) determined after berries had been held for 3 days at 2C plus 3 days at 18C (Study 2).

CaCl ₂ concn (%)	Compression (cm)	Berry damage (%) ^a		
		N	M	S
0	10.1	19	42	40
1	9.6	21	44	35
2	9.1	21	46	32
3	9.3	23	48	30
4	8.7	29	42	29
Significance	L**	L**	L ^{ns}	L**

^aN = none (no visible damage), M = moderate (dented, deformed), S = severe (crushed, broken).

^{ns}, **Nonsignificant or significant at $P \leq 0.01$, respectively; L = linear.

Table 3. Effect of rinsing 'Jersey' blueberries after immersing them in 4% CaCl₂ for 2 min on their compression after holding them for 4 days at 2C plus 3 days at 18C (Study 3).

Rinsing	Compression (cm)
None	9.2 a ^a
Immediate	10.3 b
After 2 days	8.7 a
After 4 days	8.8 a

^aMeans separated by LSD, $P \leq 0.05$.

ceptibility to physical damage. The percentage of severely damaged fruit and level of compression were strongly correlated ($r = 0.80$, $P \leq 0.01$). USDA Grade A blueberries must have <6% crushed or broken berries, but dented and misshaped berries do not reduce the grade.

The compression of berries washed immediately after CaCl₂ immersion was greater than that of berries washed 2 or 4 days after immersion or not washed at all (Table 3). Residual CaCl₂ remained on the surface of berries during the 6 to 8 days between immersion and compression tests. This residue seems to be necessary for the increased resistance to compression, an observation suggesting that Ca maybe absorbed by berries or affect their integrity gradually. Blueberries have a waxy surface that may limit their permeability to CaCl₂. The water spray that rinses berries as they exit some commercial water tanks may remove residual CaCl₂ from berries and, thus, reduce the benefit of CaCl₂ immersion. Neither immersion nor rinsing led to fruit cracking.

Panelists found a salty taste to be associated with increasing CaCl₂ concentrations when tasting fresh berries on the same day they were treated (Table 4). A salty taste also was detected in berries that were frozen and thawed; it was present in berries treated with 2% or 4% CaCl₂ but not in berries treated with 1% CaCl₂ (Table 4). This result suggests that 1% CaCl₂ can be used without adversely affecting the flavor of frozen berries.

How CaCl₂ immersion affected fruit Ca

Table 4. Effect of CaCl₂ concentration on the taste rating of fresh 'Bluecrop' and frozen and thawed 'Jersey' blueberries (Study 4).

CaCl ₂ concn (%)	Taste rating ^a	
	Fresh	Frozen and thawed
0	2.4 a ^b	3.9 ab
1	5.0 b	2.9 a
2	6.1 b	4.8 b
4	8.5 c	6.5 c

^aRating on a scale of 0 (no salty taste) to 10 (strong salty taste).

^bMeans separated in columns by LSD, $P \leq 0.05$.

concentrations is not known, since no fruit were analyzed. The effect of immersion on berry integrity did not seem to be associated with a Ca deficiency, since berries for these studies were obtained from several commercial plantings.

These studies indicated that adding CaCl₂ to water sorting tanks increases the ability of blueberries to resist physical damage, as long as they are not rinsed as they exit the tanks. However, treatments cannot be recommended commercially, since CaCl₂ concentrations that provided the greatest benefit (2% to 4%) also resulted in an objectionable taste in frozen blueberries. Perhaps applying CaCl₂ preharvest would provide similar benefits without adversely affecting taste. Also, a periodic difficulty with density separation in water tanks is that some ripe berries float and are removed with the immature berries. Adding CaCl₂ will increase the density of the separation medium and may increase the proportion of mature berries removed during the separation process.

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