Reduction of Transit Injury-Associated Black Discoloration of Fresh Peaches with EDTA Treatments

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ABSTRACT

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Black marks on the surfaces of peaches were associated with truck transportation of fruit in field bins from orchards to packing sheds. Treatment of discolored fruit with 0.01 M disodium ethylenediaminetetraacetic acid (EDTA) (pH 3.9) or 0.01 M calcium EDTA (pH 3.5) reduced or eliminated the black color, leaving light brown discolored areas associated with rub or abrasion injuries on the fruit surface. Treatment of peach fruit with disodium or calcium EDTA after transit reduced the development of black discoloration, but EDTA treatments applied before transit did not effectively prevent the development of black discoloration. EDTA may prevent a chemical that is associated with the injury from combining with the anthocyanin pigments in the fruit and therefore prevent development of the black discoloration.

Additional key words: chelation, inking, iron

Blotches or spots that develop on the skin of peaches after harvest have been associated with factors such as metal cations in water used to wash the fruit (3,4,7–10,15,17), rubbing or transit injury (11,12,16,18), preharvest application of the fungicide captan (2), ammonia leaks from refrigeration equipment (13), and other injurious physical or chemical factors found in the postharvest environment (1,6). Observations on peach fruit from 1981 to 1985 led us to conclude that, in the San Joaquin Valley of California, skin discoloration developed on areas injured when fruit were transported in bins from the orchard to the packinghouse. The transportation injury was difficult to see immediately after transport but was obvious after the fruit had been held several days in cold storage and was characterized as blotchy, irregular brown to black areas on the fruit surface.

In some fruit the discoloration was not confined to injured areas that were clearly the result of abrasion or rub injury. In its worst form, the injury on the fruit appeared similar to the discoloration reported to be caused by metal cations (3,4,9,15,17) that enter fruit with water through injured areas on the fruit surface (3,4). Aluminum, copper, iron, zinc, and other metallic cations may combine with an anthocyanin pigment and change the color of the pigment (4,14). Although browning of fruit associated with rub or abrasion injury may be due to the oxidation of phenolic substances in the fruit (11,12,18), cations may also be involved in a nonenzymatic reaction. In this report, I verify that black discoloration of peaches results from injuries

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incurred when fruit are transported in bins from the orchard, and I report the effects of treating this transit injury with EDTA.

MATERIALS AND METHODS

Transportation tests. A flatbed truck was used to transport bins of fruit from 10 widely separated orchards; cultivars included Gemfree, Elegant Lady, and O'Henry. These cultivars had been reported to have a high incidence of black discoloration. Fruit from each location were transported a standard distance of 40 km under similar road conditions on the same truck. A 25-fruit sample was taken from the bin (63 cm high × 120 cm wide × 120 cm deep) before and after transit, transported to our laboratory by automobile, held at 1 C for 3 days, and rated for discoloration.

Tests with discolored fruit. Washed and waxed fruit, culled because of discoloration, were collected from commercial fruit packinghouses. Fruit (10 fruits per treatment) were soaked 5 min in 0.28 M ascorbic acid or 20 min in 0.01 M CaEDTA (made up from Hampene 3% calcium chelate solution, W. R. Grace & Co., Nashua, NH; pH adjusted to 3.5), 0.01 M CaEDTA (pH 6.0), 0.01 M NaEDTA (pH 3.9), or tap water (pH 6.5–6.8). One test was done with the peach cultivar Flavorcrest, one with Elegant Lady, and three with O'Henry.

Tests with sound fruit. Fruit were treated (50 fruits per treatment) before or after they were transported 40 km on a flatbed truck. All test fruit were located within the top 30 cm of a field bin during transport. Fruit treated with test solutions before transport were marked and returned to the top of the bin. Treatments before or after transit were as follows: no treatment, 20 min soak in tap water (pH 6.5–6.8), 0.01 M CaEDTA (pH adjusted to 3.5), and 0.01 M NaEDTA (pH 3.9). Control fruit (50 fruits per test) that were not transported in bins were placed in fruit boxes fitted with plastic fruit trays and transported to the laboratory by automobile. One test was done with each of the cultivars Elegant Lady, Fire Red, and Parade, and two were done with O'Henry.

Evaluation of treated fruit. In each test, the transported fruit and control fruit were placed in boxes fitted with plastic fruit trays, taken to the laboratory, held at 1 C for 3 days, and rated for discoloration. Surface injury of each fruit was rated at the highest level achieved in the following scale: 0 = no marks, 1 = questionable mark, 2 = one brown or black mark, 3 = 2–9 brown marks, 4 = 2–9 black marks, 5 = 10 or more brown marks, and 6 = 10 or more black marks. Data were analyzed using analysis of variance (ratings) or confidence intervals tables for a binomial distribution (black discoloration frequencies) (5).

RESULTS

Transportation tests. Transportation of fruit in bins increased the injury ratings in all 10 tests (Table 1). The discoloration that occurred after transportation was identical to much of the postharvest skin discoloration of peaches observed on fruit culled at packinghouses. Black discoloration was found on fruit in seven samples that had been transported and in three that had not been transported. Transportation increased the average incidence of black discoloration 18.5 percentage points (Table 1).

Tests with discolored fruit. As expected, the injury rating for untreated cull fruit was high. Treatment with CaEDTA (pH 3.5) and NaEDTA (pH 3.8) significantly lowered the injury rating, but the rating remained high because of brown marks associated with abrasion or bruising of the fruit (Table 2). Although significant differences occurred between tests, the CaEDTA (pH 3.5) and NaEDTA (pH 3.8) treatments consistently lowered the overall injury ratings in tests. Treatments affected ratings primarily by reducing the incidence of black marks on fruit. Most of the black discoloration disappeared from fruit immediately after treatment with the ascorbic acid, CaEDTA (pH 2.4), and NaEDTA (pH 3.8). However, when rated 3 days later, black marks reappeared on fruit treated with ascorbic acid but not on fruit treated with CaEDTA (pH 3.5) or NaEDTA (pH 3.8) (Table 2).

Tests with sound fruit. Transportation of fruit in bins increased the injury rating in the controls from 0.7 to 4.2 and the percentage of fruit with black discoloration from 1.8 to 46 (Table 3). Data from fruit that were not transported in bins were not included in the statistical analysis with the transported fruit. Treatment of the fruit before transportation did not reduce the injury rating, but CaEDTA (pH 3.5) and NaEDTA (pH 3.8) reduced the proportion of fruit with black discoloration (Table 3). Treatment of fruit after transportation with CaEDTA (pH 3.5) and NaEDTA (pH 3.8) significantly reduced the injury rating and the proportion of fruit with black discolorations. Black discoloration also was reduced slightly by tap water treatment after transport.

DISCUSSION

Physiologically active cations, such as iron, can be removed from some systems by chelation with EDTA. At a pH of 6.0, CaEDTA was ineffective in removing discoloration from peach fruit in our tests as also seems to have been the case in an earlier test (16). By using NaEDTA (pH 3.8) or CaEDTA (pH adjusted to 3.5), the black discoloration of peaches was removed or was prevented from develop-

Table 1. Discoloration of peach fruit taken from full field bins before or after transit by truck[a]

Picking date	Peach cultivar	Rating[b]		Fruit with two or more black marks (%)	
		Before transit	After transit	Before transit	After transit
22 May	Gemfree	0.8	4.6	4	20
22 May	Gemfree	0.8	4.6	0	0
28 May	Gemfree	0.6	4.5	0	0
28 May	Gemfree	1.1	4.9	0	0
8 Jul.	Elegant Lady	0.3	4.6	0	32
7 Jul.	Elegant Lady	0.3	3.2	0	31
11 Jul.	Elegant Lady	0.9	5.3	0	28
11 Jul.	Elegant Lady	0.2	3.8	0	24
28 Jul.	O'Henry	1.4	5.3	8	54
29 Jul.	O'Henry	2.6	5.4	32	40
Av.		0.9	4.6	4.4	22.9

[a] Fruit from separate orchards were transported 40 km in bins under similar road conditions on the same flatbed truck. After transit, the fruit were held for 2–3 days at 1 C before being rated (25 fruits per sample).

[b] Rating: 0 = no marks, 1 = questionable mark, 2 = one brown or black mark, 3 = 2–9 brown marks, 4 = 2–9 black marks, 5 = 10 or more brown marks, and 6 = 10 or more black marks.

Table 2. Rating of discolored cull fruit taken from a peach packing line after soaking in several test solutions and being held for 3 days at 2 C

Treatment	Injury rating[y]	Fruit with two or more black marks (%)
Control	5.6 a[z]	63 a
5% Ascorbic acid (5 min)	5.0 ab	60 a
CaEDTA, pH 6 (20 min)	5.2 a	47 a
CaEDTA, pH 3.5 (20 min)	4.2 bc	10 b
NaEDTA, pH 3.8 (20 min)	3.8 c	8 b

[y] Rating: 0 = no marks, 1 = questionable mark, 2 = one brown or black mark, 3 = 2–9 brown marks, 4 = 2–9 black marks, 5 = 10 or more brown marks, and 6 = 10 or more black marks.

[z] Means within a column not followed by the same letter differ at $P = 0.05$.

Table 3. Discoloration of peach fruit treated with several test solutions before or after transit by truck[x]

Treatment	Injury rating[y]	Fruit with two or more black marks (%)
No transport	0.7	1.8
Fruit treated before transportation		
No treatment	4.2 a[z]	46.4 a
Tap water (20 min)	4.4 a	37.6 ab
CaEDTA, pH 3.5 (20 min)	4.0 a	29.4 b
NaEDTA, pH 3.8 (20 min)	4.5 a	32.8 b
Fruit treated after transportation		
No treatment	4.1 a	45.2 a
Tap water (20 min)	3.9 a	29.8 b
CaEDTA, pH 3.5 (20 min)	3.1 b	7.2 c
NaEDTA, pH 3.8 (20 min)	3.1 b	5.4 c

[x] Fruit from separate orchards were transported 40 km in bins under similar road conditions on the same flatbed truck. After transit, the fruit were held for 3 days at 2 C before being evaluated.

[y] Rating: 0 = no marks, 1 = questionable mark, 2 = one brown or black mark, 3 = 2–9 brown marks, 4 = 2–9 black marks, 5 = 10 or more brown marks, and 6 = 10 or more black marks.

[z] Means within a column not followed by the same letter differ at $P = 0.05$.

ing on transit-injured peaches. The treatment of peaches after transportation with NaEDTA (pH 3.8), CaEDTA (pH adjusted to 3.5), or tap water was more effective than treatment before transportation. If the EDTA or water removed a cation that causes discoloration in peaches, the ion seems to have been absent or could not come in contact with EDTA until the fruit was injured by transportation. The injury may allow the EDTA to penetrate the fruit, or the injury may cause the release of a cation that is a prerequisite for development of the black discoloration. The EDTA could prevent the ion from functioning as a cofactor in an enzymatic reaction responsible for discoloration, or the EDTA may prevent the ion from combining with the pigments found in the peach skin (3,4,7,8). The colors of the anthocyanin pigments are affected by pH and by metallic ion concentration (3). At pH 3–4, EDTA seems to remove and hold cations that have combined with a fruit pigment and thus can prevent the return of the black color to the fruit skin.

Transportation of fruit caused an increase in the injury rating, but in three of four transportation tests of the cultivar Gemfree, black discoloration was absent. These results confirm earlier observations that factors other than transportation influence the occurrence of the black discoloration of fruit. To date, we have not been able to identify genetic and environmental factors of fruit that contribute to this variation. Further study of the ions affected by the EDTA may provide an understanding of the discoloration and lead to a means of selecting less susceptible new cultivars or predicting or avoiding the conditions that predispose the fruit to the black discoloration associated with transit injury.

Low temperatures may reduce transit injury of fruit (15). However, controlling the injury of fruit coming from the orchard by temperature management is difficult, because the injury happens before the fruit reaches refrigerated installations. Reducing vibration and rubbing of fruit during transport from the orchard will reduce transit injury (11). In addition, a chelating agent, such as EDTA, applied to fruit after it has arrived at the packinghouse may provide control of some symptoms. The discoloration remaining on the fruit after treatment with EDTA may not be objectionable to fruit buyers. Thus, EDTA or chelation treatment of fruit may offer a new approach to the control of peach fruit discoloration and may lead to a commercially acceptable treatment. However, the effects of a chelator, such as EDTA, on rot control and other factors of fruit quality need more evaluation before it can be used commercially.

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