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Effect of Preharvest Calcium Treatments on Sweet Cherry Fruit Quality

Deniz EROGUL

Ege University, Faculty of Agriculture, Department of Horticulture, 35100, İzmir, Turkey; deniz.erogul@ege.edu.tr

Abstract

In this study, the effects of different foliar calcium compounds on fruit cracking and quality of sweet cherry variety '0900 Ziraat' were investigated. Calcium caseinate, calcium chloride, calcium hydroxide and calcium nitrate were used as foliar sprays. Calcium applications reduced the cracking index 38% to 66% compared to cherries that did not receive foliar treatment. The most efficient applications for decreasing cracking were calcium hydroxide and calcium chloride. Calcium chloride and calcium hydroxide were determined to be the most effective compounds, reducing cracking by 62% and 66%, respectively. Calcium caseinate also decreased fruit cracking, by nearly 50% compared to the control. However, the leaves and fruit were covered with white film. This white film can be easily removed, as postharvest processing of cherries uses water, and normally no residue remains. Preharvest foliar calcium treatments significantly decreased fruit cracking, but cracking may not be completely eliminated. None of the calcium compounds affected removal force, average fruit weight, total soluble solids, or titratable acidy. Another potentially important finding was that foliar treatment with calcium chloride significantly increased firmness of sweet cherry fruit. Calcium chloride application increased the firmness of cherries by an average of 12% compared to other compounds.

Keywords: calcium, fruit cracking, fruit quality, preharvest sprays, sweet cherry

Introduction

Turkey has suitable conditions for growing cherry (*Prunus avium* L.) because of its location in the temperate zone and its geographical advantages which include its climatic advantages a great range providing chilling as well as earliness. Thus, it allows a long harvest period and day length. The total sweet cherry production was 2.225.519 tons in the world and Turkey was the leading worldwide sweet cherry producer country in 2012 with 480.748 tons (FAO, 2014).

Cherry production in the Aegean region starts with the harvest of early season varieties in May and continues until mid-August in the inner parts of the region where mid- and late-season cherry varieties are grown. Fruit cracking occurs in years that receive excess rainfall before the harvest period, and presents a significant problem for cherry growers. These rains cause significant economic loss as a result of the cracking, decay, and decrease in fruit quality.

Cracking in sweet cherries caused by rainfall shortly before harvest is one of the major limits to successful production of sweet cherry in many parts of the world (Sekse, 1995). A number of other factors affect cherry cracking, including fruit firmness and maturity stage, crop load, orchard temperature, irrigation status, duration of rainfall, and other environmental conditions (Rupert *et al*., 1997; Simon, 2006). Crack-resistant varieties can reduce cracking rate but are not effective in completely eliminating or controlling the problem (Cline and Trought, 2007). Resistant cultivars and application of plant nutrients are used to help prevent cracking.

Calcium is involved in the construction of cell walls and is the major component contributing to the mechanical properties of plant tissues; calcium is also the most widely studied nutritional factor in relation to fruit cracking (Shear, 1975; Huang *et al*., 2005). It is known that calcium decreases the permeability of cell membranes. Dipping fruits at optimum harvest stage in calcium solutions was reported to decrease water uptake rate and cracking index of fruit by 15% to 30% (Ackley, 1956). Various studies have examined the potential to reduce cracking in cherry fruit by spray application of calcium compounds such as calcium chloride [$CaCl_2$], calcium hydroxide [$Ca(OH)_2$] and calcium nitrate [$Ca(NO_3)_2$] (Callan, 1986; Meheriuk *et al*., 1991; Yamamoto *et al*., 1992; Rupert *et al*., 1997; Marshal and Weaver, 1999). Studies on calcium caseinate are limited, but this compound has been reported to significantly decrease cracking in cherry (Ono *et al*., 1954).

In this study, to examine the prevention or reduction of cracking in cherry, different calcium sprays were applied before the harvest period. Various forms of calcium were combined to perform trials on *Prunus avium* L. '0900 Ziraat', and the effect of these treatments on cherry fruit cracking and quality were determined.

Materials and methods

Plant material

The experiment was carried out in 2012 on 8 year old

'0900 Ziraat' sweet cherry trees (*Prunus avium* L.) grafted onto '*Prunus mahaleb*' rootstock in Kemalpaşa, İzmir Province, Turkey. Variety '0900 Ziraat' is commonly cultivated in most cherry-growing regions. In the experimental orchard, 'Stella' variety was used as a pollinizer and drip irrigation was provided. Standard methods were used for pruning, cultivating, nutrition, and pest management.

Pre-harvest treatments

Four different calcium compounds were used as preharvest foliar sprays and were applied 30, 20, and 10 days before harvest. The treatments included the following: control (water with surfactant), 0.5% calcium nitrate [$Ca(NO_3)_2$], 0.5% calcium chloride [$CaCl_2$ $2H_2O$], 0.5% calcium caseinate and 0.2 M calcium hydroxide [$Ca(OH)_2$]. The experiment was a randomized block design with 3 replications, each of which comprised one tree. A surfactant was added as 0.04% including the control treatment. Cherries were harvested on June 1, 2012, when they reached commercial harvest ripeness. Fruit were picked from 1.5 to 2 m above the ground and around the canopy for each replicate. Harvest was made from the outer parts of the trees to be representative of an actual harvest from mature trees. Approximately 4 kg cherries were harvested from each tree and brought to the laboratory immediately after collection.

Cracking index

Cracking indexes of cherries were previously calculated (Bilgener *et al*., 1999). Forty cherries were randomly selected from each replicate and immersed in 2 L plastic containers filled with water (20 ± 1 °C) for 6 h. Cherries were then removed from the water; cracked fruit were counted and separated and uncracked fruit were quickly immersed again in the water. This process was repeated 3 times for each treatment. Cracking indexes were calculated according to the following formula:

Cracking index = $(5a + 3b + c) \times 100/200$

Where *a, b,* and *c* represent the number of cracked fruit after 2, 4, and 6 h, respectively. Total number of fruits immersed = 40; maximum cracking, $40 \times 5 = 200$.

Quality assessment

Cherries were weighted (XB-320M,Presica Instruments Ltd., Switzerland) after harvest and average fruit weight was calculated. Fruit firmness was determined on the peel of 25 cherries using a penetrometer (FT 011, Effegi, Japon) with a 4-mm diameter tip and the results were expressed in Newtons (N). Fruit removal force was measured with a penetrometer on 25 cherries selected randomly from each replicate. The total soluble solid (TSS) content of the juice was determined with a digital refractometer (PR-1, Atago, Japon) and expressed as a percentage. Titratable acidity was measured by titration with 0.1 N NaOH to pH 8.1, and the results were expressed as g malic acid/100 mL fruit juice.

Statistical analysis

All data were subjected to Analyses of Variance (ANOVA). Significant differences among groups were determined using Duncan's multiple range tests at $p<0.05$ All computation and statistical analyses were done using IBM SPSS Statistics 19 statistical software (IBM, NY, USA).

Results and discussion

Fruit Cracking

The different preharvest calcium compounds significantly ($p \leq 0.01$) decreased the cracking ratio of cherries relative to the control (Fig. 1). Calcium nitrate was the least effective application for reducing cracking; cracking index was reduced by 38% in cherries that received foliar calcium nitrate compared to those without any application. Treatment of *Napoleon* cherry with 0.5% calcium nitrate was reported to significantly decrease cracking without leaving any residue (Yamamoto *et al*., 1992). Calcium caseinate treatment significantly decreased cracking compared to the control treatment; the cracking ratio of calcium caseinate treated cherries was half that of control cherries. A white film layer was observed on fruit and leaves after calcium caseinate applications. Although this might be considered a problem for marketing, the white film on harvested cherries can be easily washed off. It is also thought that these white films will disappear during the precooling and postharvest treatments, which use water. It was reported that preharvest spray application of calcium caseinate did not leave residue on fruit and significantly

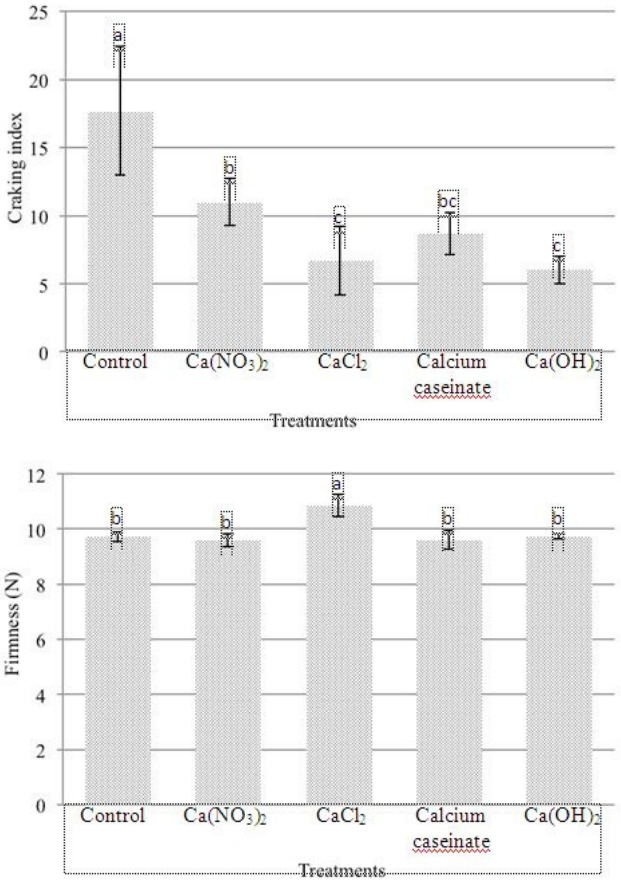

Fig. 1. Effect of pre-harvest different calcium form applications on cherry fruit cracking. Index and fruit firmness. Vertical bars indicate the standard deviation calculated from means of replicates

decreased cracking (Ono *et al*., 1954). Calcium chloride and calcium hydroxide treatments decreased cracking of cherries (Meheriuk *et al*., 1991). Our results revealed that the most efficient treatments for decreasing cracking were calcium chloride and calcium hydroxide. Preharvest calcium chloride spray, applied to prevent rain-induced cracking, protected cherries and significantly reduced cracking (Marshal and Weaver, 1999; Long, 2013). In this study, the cracking ratio in trees treated with calcium chloride was 6.7%, compared to 17% in the control. Cherry cracking was reported to decrease to 11% versus 33% with calcium chloride treatments (Fernandez and Flore, 1998). In locations with better climate conditions, spray application of mineral solutions (e.g., calcium chloride) at harvest time can effectively reduce the ratio of cracked fruit (Simon, 2006). It was stated that automated cyclical overtree sprinkler applications of dilute calcium chloride solutions decreased cracking ratio (Lang *et al*., 1998). The lowest cracking ratio in this study was obtained by 6% calcium hydroxide treatment. Another study using calcium hydroxide and calcium chloride determined that calcium hydroxide treatment was more effective than calcium chloride treatment in preventing cracking (Callan, 1986).

Fruit quality traits

The various calcium treatments had no marked effects on average cherry weight, which varied from 8.62 to 9.71 g (Tab. 1). Preharvest foliar Ca treatments did not affect fruit weight in kiwi (Koutinas *et al*., 2010) or apple (*Brown et al*., 1996; Domagała-Świątkiewicz and Błaszczyk, 2009). Fruit firmness is the most significant quality criteria in cherries and it is used in the evaluation of the fruit (Esti *et al*., 2002; Crisosto *et al*., 2003).

Firmness of cherries affects shelf life and consumer acceptance (Brown *et al*., 1988). The effects of foliar treatments on fruit firmness were significant. Except for calcium chloride, the treatments had no significant effect on fruit firmness (Fig. 1). Other researchers reported that preharvest calcium chloride application had no effect on the firmness of cherries (Meheriuk *et al*., 1991; Rupert *et al*., 1997) or strawberries (Chéour *et al*., 1990), while preharvest calcium chloride application increased fruit firmness in the present study (Fig. 1). It was also reported that calcium chloride application ($p \leq 0.05$) increased the firmness of apple fruit (Malakouti *et al*., 1999). However, preharvest calcium nitrate, calcium caseinate, and calcium hydroxide sprays did not affect fruit firmness. The firmness of cherries from the calcium hydroxide treatment did not differ from that of the control. Similarly, it was stated that preharvest calcium hydroxide treatment did not affect fruit firmness in cherries (Meheriuk *et al*., 1991; Brown *et al*., 1996). In contrast, it was reported that $Ca(OH)_2$ treatment increased fruit firmness (Demirsoy and Bilgener, 1998).

Fruit removal force was best protected in cherries treated with calcium hydroxide and calcium nitrate and the weakest resistance was observed in the control (Tab. 1). However, the effect of foliar treatments on the removal force of fruit was not significant.

One of the most significant parameters determining consumer preference in cherries is the ratio of TSS and TA (Crisosto *et al*., 2003). In this study, it was determined that the effects of preharvest calcium sprays on TSS and TA in cherry were not significant (Tab. 1). The TSS value of control plants was 15.63%, while it varied between 12.90% and 14.97% in plants that received calcium treatments. Acidity was 0.75% in the control while it varied between 0.65% and 0.74% in calcium-treated cherries (Tab. 1). TSS and TA content depend on the variety; TSS ranges between 11–25%, while TA ranges between 0.4–1.5% (Esti *et al*., 2002; Bernalte *et al*., 2003). In parallel with the results of this study, other researchers found that preharvest calcium treatments did not change fruit quality parameters such as total soluble solids and total titratable acidity in cherry and peach (Brown *et al*., 1996; Crisosto *et al*., 2000; Manganaris *et al*., 2005). In another study, preharvest calcium treatments increased soluble solids in cherries but did not affect acidity (Meheriuk *et al*., 1991; Vangdal *et al*., 2008).

Conclusions

Cracking, especially rain-induced, of sweet cherries is one a major problem for cherry producers in almost all producing countries due to significant amount of unmarketable yields. The results of this study have shown that preharvest calcium nitrate, calcium chloride, calcium caseinate, and calcium hydroxide applications decreased the cracked fruit ratio, significantly. Calcium applications reduced the cracking index of cherries by 38% to 66.0% compared to those that received no foliar Ca applications. The most effective preharvest foliar calcium treatments were calcium chloride and calcium hydroxide, which reduced cracking by 62% and 66%, respectively. Calcium

Tab. 1. Effect of pre-harvest different calcium form applications on cherry fruit removal force, average fruit weight, TSS and TA content

Treatments	Fruit removal force (N)	Average fruit weight (g)	TSS (%)	TA (g malic acid/100 ml)
Control	2.79	8.62	15.63	0.75
$CaNO_3$	3.27	9.71	14.70	0.74
$CaCl_2$	3.09	9.29	14.97	0.69
Calcium caseinate	2.84	8.75	12.90	0.65
$Ca(OH)_2$	3.37	9.24	14.63	0.69
Significance	NS	NS	NS	NS

NS - nonsignificant

caseinate even if reduced cracking by 50 % left a white covering over leaves and fruit that could easily be further removed during hydro-cooling and/or washing process. Preharvest calcium sprays had no negative effect on other major fruit quality parameters. Foliar treatment with calcium chloride exerted created an additional effect by increasing firmness, significantly (12 %). On the basis of these data, we can recommend use of tested preharvest calcium foliar treatments to reduce cracking without guaranteeing complete elimination.

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