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# Sodium chloride reduces damage to nectarines caused by hot water treatments

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## Abstract

The tolerance of six nectarine (*Prunus persica* L. Batch var. (Ait.) Maxim.) cultivars to hot water treatment was evaluated and the effect of addition of NaCl to the treatment solution tested as a means of reducing treatment damage. Hot water immersion was extremely damaging to all cultivars tested, although differences in tolerance existed. Treatment at 50°C for 25 min, a treatment for fruit fly disinfestation, rendered the fruit of all cultivars unmarketable. Sodium chloride at a concentration of 200 mM reduced the mean injury rating averaged over all six cultivars from 3.9 (severe damage) to 1.9 (slight damage), although the latter was still too severe for the fruit to be marketable. At the less injurious temperature of 46°C, the slight amount of injury caused by hot water treatment was eliminated in the presence of NaCl. Flesh firmness was not altered by NaCl in the treatment solution, but firmness was slightly greater in fruit treated at 50°C as compared with 46°C. Sodium chloride reduced damage by effectively reducing the amount of water entering the fruit during treatment and may be useful in reducing the damage from hot water immersion treatments used for surface disinfestation. © 1997 Elsevier Science B.V.

**Keywords:** Disinfestation; Quarantine; Osmotic potential

## 1. Introduction

Regulatory pressure to ban methyl bromide, and environmental restrictions on the use of chemical fumigants, necessitate the development of non-chemical means of fruit disinfestation. Relatively short treatment times make immersion in hot water an especially attractive alternative to

chemical fumigants. Although hot water has often been evaluated as a means to control decay, it has also been tested as an insecticidal treatment for a number of different commodities (Couey, 1989). While some commodities, such as mangoes, are reasonably tolerant of hot water treatment (Sharp et al., 1989), others, including peaches and nectarines (Kerbel et al., 1985; Sharp, 1990), often show browning, scalding and pitting in response to this treatment.

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Sucrose added to the treatment water at concentrations of 0.5 or 1.0 M has been reported to be effective in substantially reducing the discolouration of peaches and nectarines treated in hot water at 52°C for 10 min (Barkai-Golan and Phillips, 1991). The authors suggested that sucrose might be acting by stabilizing proteins or by slowing the hydration of the fruit. Although the hot water treatment described in their study was for surface decay control, we were interested in whether or not the addition of sucrose or some other solute, such as NaCl, might be useful in lessening the damage from insecticidal hot water treatment of nectarines.

In this study we examined the tolerance of six cultivars of early- and mid-season California nectarines to hot water treatment and tested the effect of addition of NaCl to the water on heat-induced damage.

## 2. Materials and methods

Early and mid-season nectarines (*Prunus persica* L. Batch var. (Ait.) Maxim.) were obtained in the spring and summer of 1996 from packing houses near Dinuba, CA, USA. All of the fruit had been harvested at a maturity stage (California well matured) normally used by the nectarine packing industry for commercial shipping. The fruit were unprocessed and of a similar size (average weight = 144 g/fruit). After transport back to Fresno, the fruit were stored overnight at 24°C. The next day the fruit were separated into five treatments: untreated control; water immersion at 46°C for 25 min with and without 200 mM NaCl; and water immersion at 50°C for 25 min with and without 200 mM NaCl. The 50°C treatment was chosen as a treatment previously shown to be effective against fruit flies that have infested nectarines (Sharp, 1990), and 46°C was selected to demonstrate a treatment of lesser severity than that required for fruit fly disinfestation. An NaCl concentration of 200 mM was chosen as a result of experimentation done to establish an optimal concentration that was most successful in reducing hot water damage (see Section 3). Each treatment was repeated four times for each variety

using 15–20 fruit per replication that had been randomly selected from the same lot of fruit.

Hot water treatments were conducted using a Water Troll system (Gaffney Engineering, Gainesville, FL) with 12 stirred stainless steel baths holding 20 l of liquid. The fruit were held within the tanks using plastic baskets with a widely spaced mesh to allow free circulation of water. Temperatures at the skin and pit surface were monitored with a GETC precision temperature measurement system (Gaffney Engineering, Gainesville, FL) equipped with Type T thermocouples. Fruit were weighed before and after treatment to estimate the amount of water loss or gain due to the treatment.

After storage for 7 days at 1°C, followed by 1 day at 24°C each fruit was visually evaluated for incidence of surface damage, which included discolouration, pitting and loss of pigmentation, and given a rating: 0 = none, 1 = trace, 2 = slight, 3 = moderate, 4 = severe, 5 = very severe damage. Fruit with a slight or greater amount of damage were considered to be unmarketable. All treated fruit (15–20/replication) were examined. The ratings for all of the fruit within the replication were summed and the total divided by the number of fruit within the replication to give a mean rating for that replication. Following damage evaluation, flesh firmness of each fruit was measured using a University of California Firmness Tester with a 7.9 mm diameter plunger.

Data were tested with an analysis of variance (completely randomized design) and by means separation (Fisher's Protected Least Significant Difference, Duncan New Multiple Range) using SuperANOVA (Abacus Concepts, Berkeley, CA).

## 3. Results and discussion

Thermocouple readings were taken of the skin and pit surface temperatures to provide a more precise idea of the degree of heating of the interior of the nectarine over the 25 min hot-water treatment (Fig. 1). The peak pit surface temperature reached by fruit treated at 46°C averaged 41°C, whereas a temperature of 45°C was achieved in the 50°C treatment. As fruit size is a prime deter-

minant of the amount of heating of the flesh, it is important that interior temperatures be provided for quarantine treatments in order to ensure that treatments are sufficient but not excessive.

Initial experiments investigating the effect of solutes on hot water injury used solutions of 0.5 and 1.0 M sucrose in an attempt to repeat the experiments of Barkai-Golan and Phillips (1991). Quite early it was discovered that NaCl and other salts and sugars that were tried all appeared to be as protective as sucrose (data not shown). This indicates that the benefit of adding sucrose or NaCl to a hot-water treatment solution is likely not due to any specific property of each compound, but more to the resulting decrease in osmotic potential of the water. Such a decrease would have the effect of lessening the entry of potentially injurious hot water into the fruit.

As NaCl is less expensive and easier to work with than sucrose, it was used instead of sucrose for the remainder of the experiments. To establish an optimal NaCl concentration, the effect of a range of NaCl concentrations from 25–400 mM was tested on the cultivar ‘Mayglo’ by determining both water gain/loss as estimated by weight change and by evaluating the amount of injury following treatment (Fig. 2). Water entry into the fruit declined steadily as the concentration of NaCl was increased from 25 to 100 mM, where the gain of water by the fruit apparently stopped. Further increases in concentration resulted in loss of water. Damage due to hot water treatment was

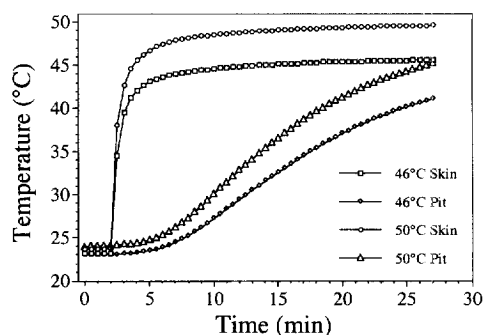


Fig. 1. Temperatures of the skin and pit surface during hot water treatment. Each data point was derived from a mean of three separate runs using different fruit.

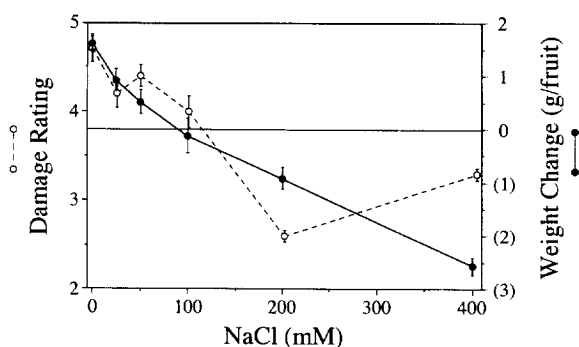


Fig. 2. Damage rating and weight change of nectarines (cv. ‘Mayglo’) following a 25 min immersion in 50°C water containing different concentrations of NaCl. Ten fruit were used per concentration (treatment) and each treatment was repeated three times with different batches of fruit. Numbers in parentheses are negative. Bars are standard errors.

most often noted by a loss of red pigment, pitting, and browning of the skin. The incidence of damage was markedly reduced with increasing NaCl concentration from an initial rating of 4.7 for no NaCl to a low of 2.6 for fruit treated in 200 mM NaCl. With 400 mM NaCl the amount of damage appeared to be somewhat increased over that observed at 200 mM NaCl. Based upon these results NaCl was used at a concentration of 200 mM for all further experiments.

Hot water treatment was very damaging to all nectarine cultivars tested, although sizeable differences existed in tolerance at both 46 and 50°C (Table 1). In this test the cultivar ‘Summer Grand’ was the most resistant, while ‘Mayglo’ and ‘Spring Bright’ were the most susceptible to injury. Cultivar differences in susceptibility are likely and the study of such differences could greatly contribute to our understanding of the causes of hot water injury, suggesting possible solutions to prevent the injury from occurring. The variation in fruit that exists due to maturity, growth conditions, and grower practices, however, means that our results only suggest such differences and that a much larger study would be needed to gain more definitive results.

To enable a clearer comparison of treatments, the damage rating, flesh firmness and weight increase values were averaged across variety (Fig. 3). Sodium chloride was very effective in reducing

Table 1  
Damage from hot water treatments of different cultivars of nectarine

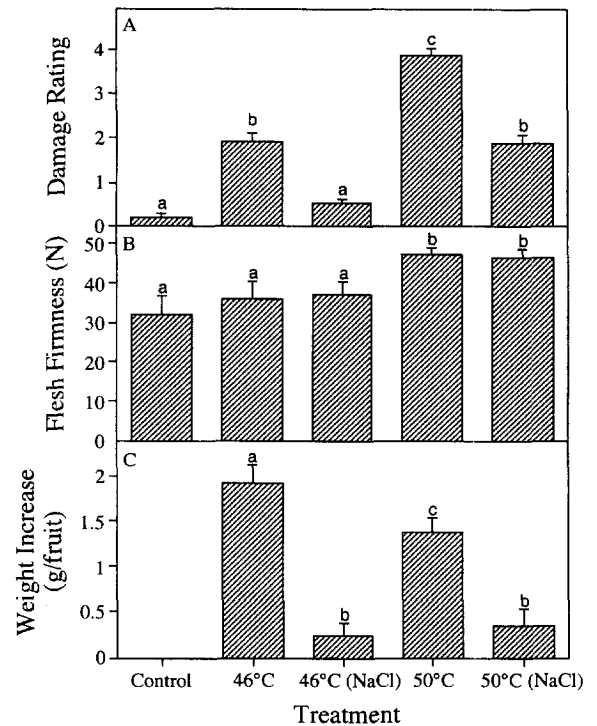
Cultivar	Harvest Date	Damage Rating				
		Control	46°C	46°C (salt <sup>a</sup> )	50°C	50°C (salt <sup>a</sup> )
'Mayglo'	May 17	0.21	2.31	—	4.75	2.80
'Rose Diamond'	May 31	0.16	1.97	0.58	4.24	2.25
'May Grand'	June 5	0.70	2.40	0.95	3.36	1.48
'Red Diamond'	June 25	0.03	1.19	0.16	3.68	1.88
'Spring Bright'	June 25	0.00	2.73	0.56	4.59	2.67
'Summer Grand'	July 3	0.03	1.13	0.21	3.41	1.08
LSD <sub>0.05</sub>		0.16	0.40	0.26	0.37	0.54

<sup>a</sup> 200 mM NaCl.

the damage due to hot water treatment (Fig. 3A). At the lower temperature of 46°C the addition of salt in the treatment water lowered the rating from 1.9 (slight injury) to 0.5 (very slight to no injury). The amount of injury observed in the 46°C (with NaCl) treatment was not significantly different from the untreated control, indicating almost total protection by NaCl. The beneficial effect of NaCl was also substantial at 50°C, a temperature recommended to kill fruit fly (Sharp, 1990). In this case NaCl lowered the damage rating from 3.9 (severe) to 1.9 (slight). Flesh firmness was not significantly influenced by NaCl, although fruit treated at 50°C were definitely firmer than those treated at 46°C (Fig. 3B). Heat has been previously shown to slow the softening of nectarines (Anthony et al., 1989) and a number of other commodities (Paull, 1990). By including NaCl in the treatment bath, the amount of water entering the fruit (as estimated by measuring weight increase) during treatment was reduced by 89% at 46°C and 76% at 50°C (Fig. 3C). This effect of NaCl in slowing the hydration of the fruit is probably the key to its ability to alleviate damage during hot water treatment. Entry of hot water into fruit tissues is quite likely to result in greater damage to the fruit than if the fruit were heated in air.

Even though NaCl was highly effective in reducing the damage of hot water treatment to nectarines, the amount of injury sustained after the fruit fly disinfestation treatment of 50°C for 25 min was still too extensive for market accep-

tance. It must also be recognized that although 50°C for 25 min was reported to be effective in disinfesting nectarines of fruit fly (Sharp, 1990), in



• Fig. 3. The effect of 200 mM NaCl on damage rating (A), flesh firmness (B), and weight increase (C) following hot water treatment of nectarines at either 46° or 50°C. Values are means averaged over the five cultivars tested ('Mayglo' excluded). Bars are standard errors. Treatments with different letters are statistically different from each other at the 5% level of significance by Duncan New Multiple Range Test.

our experiment the interior temperature near the pit only reached 45°C by the end of the treatment, a treatment that might allow larvae near the seed surface to survive. Higher centre temperatures, such as 47.2°C (Armstrong et al., 1989), are normally required for quarantine treatments, and would require a longer and potentially more damaging hot water treatment. Hot water treatments of a lesser severity, as demonstrated in this experiment by the 46°C treatment may, however, be made more feasible by the use of NaCl and could aid in surface decay or insect control. Use of NaCl to enhance the practicality of hot water treatment for commodities other than nectarines should also be possible.

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