Fungicidal Effectiveness of Electrolyzed Oxidizing Water on Postharvest Brown Rot of Peach

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Abstract. The fungicidal effectiveness of electrolyzed oxidizing (EO) water on peach [Prunus persica (L.) Batsch.] fruit was studied. Fruit were inoculated with a spore suspension of 5 × 10⁵ conidia/mL of Monilinia fructicola ([G. Wint.] Honey) applied as a drop on wounded and nonwounded fruits, or by a uniform spray-mist on nonwounded fruits. Fruit were immersed in tap water at 26 °C for 5 or 10 minutes (control), or treated with EO water varying in oxidation-reduction potential (ORP), pH, and free available chlorine (FAC). Following treatment, fruit were held at 20 °C and 95% relative humidity for 10 days to simulate retail conditions. Disease incidence was determined as the percentage of fruits showing symptoms of the disease, while severity was expressed as lesion diameter. EO water did not control brown rot in wounded-inoculated fruits, but reduced disease incidence and severity in nonwound-inoculated peach. Symptoms of brown rot were further delayed in fruit inoculated by a uniform-spray mist compared with the nonwounded-drop-inoculated peaches. Fruit treated with EO water held for 8 days at 2 °C, 50% RH, did not develop brown rot, until they were transferred to 20 °C, 95% RH. The lowest disease incidence and severity occurred in fruit immersed in EO water for up to 5 minutes. EO water having pH 4.0, ORP 1,100 mV, FAC 290 mg L⁻¹ delayed the onset of brown rot to 7 days, i.e., about the period peach stays in the market from a packing house to consumer. No chlorine-induced phytotoxicity was observed on the treated fruit. This study revealed that EO water is an effective surface sanitizer, but only delayed disease development.

Brown rot caused by Monilinia fructicola ([G. Wint.] Honey) is one of the most destructive diseases of stone fruits (Prunus sp.) (De Vries-Paterson et al., 1991). The disease appears as blossom blight and progresses into a twig blight and canker, which can provide inoculum for latent infection of the green fruit. From the latent infection, fruit brown rot develops either at the pre- or postharvest stage (Bosch et al., 1992).

The stone fruit industry has had no registered fungicides for control of postharvest brown rot since 1996 (Hong et al., 1998). Hydrocooling of peaches removes field heat from fruit up to 15 times more rapidly than the forced-air method (Boyette et al., 1992), and can provide up to 15 times more rapidly than the forced-air method (Boyette et al., 1992), and can provide 50% RH, did not develop brown rot, until they were transferred to 20 °C, 95% RH. The lowest disease incidence and severity occurred in fruit immersed in EO water for up to 5 minutes. EO water having pH 4.0, ORP 1,100 mV, FAC 290 mg L⁻¹ delayed the onset of brown rot to 7 days, i.e., about the period peach stays in the market from a packing house to consumer. No chlorine-induced phytotoxicity was observed on the treated fruit. This study revealed that EO water is an effective surface sanitizer, but only delayed disease development.

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The stone fruit industry has had no registered fungicides for control of postharvest brown rot since 1996 (Hong et al., 1998). Hydrocooling of peaches removes field heat from fruit up to 15 times more rapidly than the forced-air method (Boyette et al., 1992), and cleans products by removing chemical residues and debris (Nunes et al., 1995). However, hydrocooling with plain water does not reduce brown rot caused by M. fructicola, and tends to disseminate the pathogen (McClure, 1958). To reduce peach decay, the hydrocooling water is being widely used for disinfection purposes in the Japanese hospitals and dental clinics, while EO water is being used for disinfection purposes in the Japanese hospitals and dental clinics, while EO water is being used for disinfection purposes in the Japanese hospitals and dental clinics, while EO water is being used for disinfection purposes in the Japanese hospitals and dental clinics, while EO water is being used for disinfection purposes in the Japanese hospitals and dental clinics. The use of postharvest chlorine dips also has shown potential for reduction of residues of preharvest pesticide on apple fruits (Hendrix, 1991).

Electrolyzed oxidizing (EO) water is the product of a new concept developed in Japan. Research has revealed that addition of deionized water containing 0.2% sodium chloride to an electrolysis chamber, where the anode and cathode electrodes are separated by a diaphragm, and subjecting the water to electrolysis, imparted strong bactericidal and virucidal properties to the water collected from the anode (EO water) (Venkitanarayanan et al., 1999a,b). In the process, EO water and electrolyzed reduced (ER) water are produced simultaneously. Chlorine is generated in the anode (acidic or oxidized) water, and H₂ in the cathode (alkaline or reduced) water. The Cl₂ reacts with the water to form HOCI and HCl. At low pH of EO water, HOCI, which is a very weak acid but a very effective sanitizer, undergoes virtually no hydrolysis to the much less effective hypochlorous acid (OCI⁻) (White, 1992). Molecular Cl₂ is in equilibrium with HOCI and HOCl and FAC are probably the major contributors to the sanitizing effect of EO water (White, 1992). A cascade of redox reaction occurs during electrolysis producing many reactive and toxic compounds, such as ozone, and very highly reactive and short-lived radicals such as O·, Cl·, and OH· in the EO water. These compounds contribute to the sanitizing effect of EO water (Shiba and Shiba, 1995). EO water is being widely used for disinfection purposes in the Japanese hospitals and dental clinics, while EO water is being used for disinfection purposes in the Japanese hospitals and dental clinics, while EO water is being used for disinfection purposes in the Japanese hospitals and dental clinics, while EO water is being used for disinfection purposes in the Japanese hospitals and dental clinics, while EO water is being used for disinfection purposes in the Japanese hospitals and dental clinics. The use of postharvest chlorine dips also has shown potential for reduction of residues of preharvest pesticide on apple fruits (Hendrix, 1991).

Materials and Methods

Fruit material. In 1999 and 2000, mature peaches of 75 ± 5 mm diameter were obtained from the Yamashita Prefecture (Japan) and kept in a cold room at 1 °C for up to 2 weeks. Inoculum. A pure culture of M. fructicola was obtained from the Laboratory of Fungicide Chemistry, National Institute of Agro-Environmental Sciences, Tsukuba, Japan, and cultured in petri dishes on potato dextrose agar
was determined by using the DPD-test (EX-20; HORIBA Ltd., Kyoto, Japan). C
were collected in separate containers. These and ER water from their respective outlets and cell electrolyzed the water, producing EO water serve until the machine stabilized. The Sterilox electrolyzed water generator and voltage between 1005). The current passing through the electric engineering Co. Ltd., Tokyo (model IKS 0.1, ORP 1,165 ± 20 mV, and FAC 220 ± 5 mgL⁻¹ of EO water-I and II were pH 3.0 ± 0.1, ORP 1,100 ± 15 mV, FAC 290 ± 15 mgL⁻¹ (EO water-IV), at 26 °C for 2 or 5 min (Table 3). Control fruit were immersed in tap water at 26 °C for 5 min. Following treatment, half of the treated fruit were placed at 20 °C, 95% RH. The other half were held at 2 °C, 50% RH for 8 d, and then were transferred to 20 °C, 95% RH for evaluation of ripening and disease development. The experiment was performed twice with three replicates of 10 fruits per treatment.

Data recording and statistical analysis. Fruits were examined daily for brown rot development. Disease incidence was calculated as the percentage of fruits that became infected on a particular day. Disease severity was based on the lesion diameter of inoculated infected and developed brown rot symptoms. The diameter of brown rot lesions was significantly smaller on fruits treated with EO water-I compared to those treated with EO water-II. About 5% of fruits were naturally infected and developed brown rot symptoms during incubation. Symptoms resulting from natural infections were easily recognized by their distance from the inoculation points and they usually developed more slowly than those resulting from artificial inoculation. No signs of phytotoxicity were evident.

Effect of EO water-I and II on decay of wound-inoculated (WI) peach fruit. ‘Kawanakajima Hakuhou’ peaches were harvested in July 1999. Two wounds (2 mm deep and 1 mm wide) were made near the stem end of each fruit with a sterile dissecting needle. Twenty microliters of the suspension of M. fructicola was applied to each wound of a fruit and treated with two types of EO water for the immersion periods of 1, 5, 10, and 30 min. The properties of EO water-I and II were pH 3.0 ± 0.1, ORP 1,165 ± 20 mV, and FAC 220 ± 5 mgL⁻¹, and pH 6.8 ± 0.1, ORP 940 ± 20 mV, and FAC 180 ± 10 mgL⁻¹, respectively. The control fruit were immersed in tap water at 26 °C (ambient condition) for 10 min. Following treatment, all fruits were held at 20 °C, 95% RH for 6 d. Each treatment had three replicates of 10 fruits. The experiment was performed twice.

Effect of EO water-III on decay of wound-inoculated (WI) and nonwound-inoculated (NWI) peaches. ‘Misaka Hakuhou’ peaches, harvested in June 2000, were divided into two batches. For the first batch, two wounds (2 mm deep and 1 mm wide) were made and inoculated as described above. The second batch of fruit were nonwounded and 20 µL of inoculum was applied on the wounded fruit. After inoculation, fruit were allowed to air-dry for 2 h, followed by treatment with EO water having properties pH 5.8 ± 0.1, ORP 990 ± 5 mV, FAC 270 ± 20 mgL⁻¹ (EO water-III) for 2, 5, and 10 min. Control fruits were immersed in tap water at 26 °C for 10 min. Immediately after treatment, fruits were held at 20 °C, 95% RH for 10 d. The experiment was done twice with three replicates of 10 fruits per treatment.

Effect of EO water-IV on decay of spray-mist-inoculated peaches held at two regimes. ‘Asama Hakutou’ peaches, harvested in July 2000, were wounded but inoculated by a uniform spray-mist of 5 × 10⁴ conidia/mL of M. fructicola spore suspension. After inoculation, fruit were allowed to air-dry at 26 °C. After about 2 h incubation, fruit were treated with EO water of pH 4.0 ± 0.2, ORP 1,100 ± 15 mV, FAC 200 ± 15 mgL⁻¹ (EO water-IV), at 26 °C for 2 or 5 min (Table 3). Control fruit were immersed in tap water at 26 °C for 5 min. Following treatment, half of the treated fruit were placed at 20 °C, 95% RH. The other half were held at 2 °C, 50% RH for 8 d, and then were transferred to 20 °C, 95% RH for evaluation of ripening and disease development. The experiment was performed twice with three replicates of 10 fruits per treatment. Disease incidence/severity and the storage period

Data recording and statistical analysis. Fruits were examined daily for brown rot development. Disease incidence was calculated as the percentage of fruits that became infected on a particular day. Disease severity was based on the lesion diameter of inoculated infected and developed brown rot symptoms. The diameter of brown rot lesions was significantly smaller on fruits treated with EO water-I compared to those treated with EO water-II. About 5% of fruits were naturally infected and developed brown rot symptoms during incubation. Symptoms resulting from natural infections were easily recognized by their distance from the inoculation points and they usually developed more slowly than those resulting from artificial inoculation. No signs of phytotoxicity were evident.

Results

Effect of EO water-I and II on decay of wound-inoculated peaches. The relationship between incidence and immersion period is presented as regression of means (Fig. 1). Incidence was best described by quadratic function in both types of EO water. Disease incidence 6 d after treatment in wounded-control fruit was 100%, whereas for EO water-treated fruit, it ranged from 20% to 80% for EO water-I and 70% to 95% for EO water-II (Fig. 1). Suppression of brown rot was dependent on the immersion period as well as the properties of the EO water. Maximum reduction occurred with a 1-min immersion in EO water-I. A 30-min immersion period was ineffective and therefore excluded from the further experiments.

Disease severity (or lesion diameter) increased during the holding period depending upon properties of EO water and the immersion period. The regression equations for all treatments are shown in Table 1. Brown rot first appeared 1 d after treatment (2 d after inoculation) on control fruit and on those immersed for 30 min in both types of EO water (data not shown). Symptoms were delayed for 3 d by a 1-min immersion. The immersion periods of 5 and 10 min were equally effective up to 2 d after treatment, but thereafter brown rot developed. The diameter of brown rot lesions was significantly smaller on fruits treated with EO water-I compared to those treated with EO water-II. About 5% of fruits were naturally infected and developed brown rot symptoms during incubation. Symptoms resulting from natural infections were easily recognized by their distance from the inoculation points and they usually developed more slowly than those resulting from artificial inoculation. No signs of phytotoxicity were evident.
Effect of EO water-III on decay of WI and NWI peaches. The data taken 5 d after treatment were subjected to regression analysis. Disease development of WI peaches was not affected by treatment with EO water-III but NWI treated were (Fig. 2). Immersion period of 10 min was the most effective in reducing the incidence. Brown rot on ‘Misaka Hakuhou’ peaches appeared 1 and 2 d after treatment in WI and NWI controls, respectively (data not shown). After 3 d of treatment, 100% of the WI-control fruits had brown rot. Whereas NWI-control fruit, 3 d after treatment, had 40% and EO treated had 20% to 30% incidence. They took 5 d to develop 100% incidence (data not shown). Disease development, therefore, was delayed by EO water-III treatment.

Lesion diameter and daily growth rate were also greater in WI fruit compared with NWI fruit. Wounding facilitated fungus penetration into fruit, even in the short incubation period of 2 h, and EO water-III failed to protect WI peaches (Fig. 3). Size of the lesions on NWI fruit was almost half of the size of the WI fruit (Fig. 3). After 10 d of treatment, the minimum lesion diameter was recorded for the 5-min immersion period for NWI fruits (Fig. 3).

Effect of EO water on decay of spray-mist-inoculated peach held at two regimes. Symptoms of brown rot on control fruit of ‘Asama Hakutou’ peaches appeared after 3 d of treatment (Table 2) and the onset of symptoms of brown rot was delayed for 9 and 7 d, for 2- and 5-min immersion periods, respectively (Table 2). A longer immersion period of 5 min enhanced disease development. After 5 d of treatment, incidence was 30% and 0% in the control and EO water treatments, respectively (Table 2). The minimum lesion diameter was recorded for the 2-min immersion period even after 11 d of treatment (Table 2). A nonlinear pattern for disease severity was observed for the ‘Asama Hakutou’ peaches which, after treatment, were held at 20 °C, 95% RH (Fig. 4). The regression models had correlation coefficients of 0.99, 0.97, and 0.98 for the control, 2- and 5-min treatments, respectively.

The second groups of fruit did not develop brown rot at 2 °C, 50% RH for 8 d, but gradually started showing brown rot, when they were shifted to 20 °C, 95% RH. Control fruit showed symptoms of brown rot within 3 d of shifting, while EO water treated fruit (2- and 5-min immersion periods) had delayed rot development for 5 and 7 d, respectively (Fig. 5). Disease incidence for a 5-min immersion was 30% after 7 d compared with 70% for the 2-min immersion, and 90% for the control fruit (Table 2). There were no signs of phytotoxicity on EO water treated peaches. For control fruit a linear pattern was observed for daily brown rot development, whereas for EO water treated fruit nonlinear pattern was recorded (Fig. 5).

Discussion

EO water reduced but did not prevent brown rot. These results concur with previous findings where some other chemical disinfectants, such as sodium- or calcium-hypochlorite, chlo-

Table 1. Linear regression equations for disease severity of ‘Kawanakajima Hahukou’ peaches after treatment with EO water-I (pH 3.0, ORP 1165 ± 20 mV, and FAC 220 mg L⁻¹) and EO water-II (pH 6.8, ORP 940 mV, and FAC 180 mg L⁻¹).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Regression equation</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>EO water-I</td>
<td>Control: ( Y = 11.44 x - 10.307 )</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>1 min: ( Y = 9.7629 x - 15.087 )</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>5 min: ( Y = 11.44 x - 10.307 )</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>10 min: ( Y = 8.6914 x - 11.853 )</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>30 min: ( Y = 10.583 x - 6.9087 )</td>
<td>0.99</td>
</tr>
<tr>
<td>EO water-II</td>
<td>Control: ( Y = 11.44 x - 10.307 )</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>1 min: ( Y = 9.7629 x - 15.087 )</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>5 min: ( Y = 11.44 x - 13.66 )</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>10 min: ( Y = 10.583 x - 6.9087 )</td>
<td>0.99</td>
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</tbody>
</table>

\( Y \) = lesion diameter (mm); \( x \) = holding period (days).

Fig. 2. Regression models for brown rot incidence of ‘Misaka Hakuhou’ peaches 5 d after treatment with EO water-III (pH 5.8, ORP 990 mV, FAC 270 mg L⁻¹) at 26 °C. Wound-inoculated fruit (○) (no significant function), and nonwound-inoculated fruit (●) (\( Y = 53.571 - 3.5714 x \), \( R² = 0.89, P < 0.005 \)).

Fig. 3. Regression models for the severity of brown rot of ‘Misaka Hakuhou’ peaches treated with EO water-III (pH 5.8, ORP 990 mV, FAC 270 mg L⁻¹) for (A) wound-inoculated (○) nonwound-inoculated (●) during the 10 d holding at 20 °C, 95% RH.
The concentration of 5 × 10^5 conidia/mL spore suspension of *M. fructicola*, allowed to air-dry for about 2 h, and treated with EO water-IV at 26 °C.

However, disease incidence was relatively high when used after inoculation (Bertrand and Sautie-Carter, 1979). While chlorine quickly destroys microbes suspended in water, it is less effective on pathogens that are embossed in host tissues, appressed to product surfaces, embedded in organic matrices such as clamps of decayed tissues, or suspended in waxes as well as epiphytic bacteria and yeasts (Wilson, 1989).

In the first experiment, the period from incubation to treatment was 24 h, and most of the conidia might have germinated and penetrated into the fruit before treatment. The fruit used in our study resembled fruit inoculated in the orchard prior to harvest. In both inoculation periods, conidia of *M. fructicola* would have time to germinate and penetrate beneath the fruit epidermis (Smith et al., 1972). For additional control of fruit decay, pathogens must be inactivated before they become embossed in fruit (Eckert and Sommer, 1967). Decay control of pears was poor when they were inoculated and dried before chlorine treatment (Phillips and Grendahl, 1973). To reduce peach decay, the hydrocooling water usually contains sodium or calcium hypochlorite at a chlorine concentration of 125–200 mg·L⁻¹ (Cardinell and Barr, 1952). However, chlorine is much less effective on spores of pathogens suspended in water at 1 °C compared with that at >20 °C (Dychdala, 1991). In the tropical countries with temperatures above 30 °C, where hydrocooling is done by dipping in plain water, i.e., without any refrigerating agent (e.g., ice), the use of EO water could be a useful practice. It would not only remove excess field heat but also have a higher germicidal activity.

The pH, as well as immersion period, played a vital role in efficacy of EO water as a disinfectant (Fig. 1, Table 1). Solution pH is important to the efficacy of chlorinated water as a disinfectant (Dychdala, 1991; Hicks and Segall, 1974). At pH 6, nearly 98 % of the hypochlorite added to water is in the form of HOCl, which is extremely active as a disinfectant; while at pH 9.6, nearly 99 % is in the ion form (Dychdala, 1991). The acid form is up to 80 times more bactericidal than the ion form. In other studies, water chlorination did not reduce postharvest decay of the peach probably due to the high pH and low temperatures of the solutions, which restrict activity of the chloroform (Bartz, 1988; Dychdala, 1991). Similarly, water chlorination did not prevent decay development in tomato fruit contaminated with *Erwinia carotovora subsp. carotovora* and then infiltrated with chlorinated water at 26 °C and pH 6.8 to 9.6 (Bartz, 1988). On the con-

**Table 2. Brown rot incidence of ‘Asama Hakutou’ peaches treated with EO water-IV (pH 4.0 ± 0.2, ORP 1100 ± 15 mV, FAC 290 ± 15 mg·L⁻¹).**

<table>
<thead>
<tr>
<th>Group</th>
<th>Immersion period</th>
<th>Incidence (%) on day^a^</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>9</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Control^b^</td>
<td>26.4 (20) a</td>
<td>32.9</td>
<td>45.0</td>
<td>67.5</td>
<td>67.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 min</td>
<td>e (0) b</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>5 min</td>
<td>0.0 (0) c</td>
<td></td>
<td>39.2</td>
<td>50.8</td>
<td>60.5</td>
<td></td>
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<td></td>
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<td>(0) b (0) b (c) (c) (c)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>II</td>
<td>Control^b^</td>
<td>45.0 (50) a</td>
<td>72.1</td>
<td>90.0</td>
<td>90.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 min</td>
<td>0.0 (20) b</td>
<td>26.4</td>
<td>57.1</td>
<td>64.2</td>
<td>76.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 min</td>
<td>0.0 (0) c</td>
<td>33.1</td>
<td>45.0</td>
<td>57.1</td>
<td></td>
<td></td>
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<td></td>
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<td>(0) b (0) c (c) c (c)</td>
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</table>

Days after shifting

- **I**: Following EO water-IV treatment fruit were held at 2 °C, 50% RH for 8 d and thereafter shifted to 20 °C, 95% RH for another 11 d.
- **II**: Following EO water-IV treatment fruit were first held at 2 °C, 50% RH for 8 d and thereafter shifted to 20 °C, 95% RH. Control (❍) (Y = 20.022 – 8.78x^2, R^2 = 0.98). Bars indicate standard error.

- Bar (a) indicates LSD test, *P* 0.05. Data were transformed to arcsin percent before analysis. Figures in parenthesis are nontransformed data.
- Control fruit were immersed in tap water for 10 min.

^a^Each fruit was inoculated with a uniform spray-mist of 5 × 10^5 conidia/mL spore suspension of *M. fructicola*, allowed to air-dry for about 2 h, and treated with EO water-IV at 26 °C.

^b^Means separation by LSD test, *P* 0.05. Data were transformed to arcsin percent before analysis. Figures in parenthesis are nontransformed data.

^c^Control fruit were immersed in tap water for 10 min.

^d^Group I: Following EO water-IV treatment fruit were held at 2 °C, 95% RH for 11 d.

^e^Group II: Following EO water-IV treatment fruit were first held at 2 °C, 50% RH for 8 d and thereafter shifted to 20 °C, 95% RH for another 11 d.

Fig. 4. Regression models for the severity of brown rot of ‘Asama Hakutou’ peaches after treatment with EO water-IV (pH 4.0 ± 0.2, ORP 1100 ± 15 mV, FAC 290 ± 15 mg·L⁻¹) and held throughout for 11 d at 20 °C, 95% RH. Control (❍) (Y = 22.892 – 6.6x + 0.8982x^2, R^2 = 0.99), EO water-2 min immersion (▲) (Y = 20.022 – 8.78x + 0.8452x^2, R^2 = 0.97), and 5-min immersion (▲) (Y = 2.8389 – 2.885x + 0.5661x^2, R^2 = 0.98). Bars indicate standard error.

The hydrocooling water at 0–4 °C, containing free chlorine, has reduced fungicidal activity (Phillips and Grendahl, 1973). To reduce peach decay, the hydrocooling water usually contains sodium or calcium hypochlorite at a chlorine concentration of 125–200 mg·L⁻¹ (Cardinell and Barr, 1952). However, chlorine is much less effective on spores of pathogens suspended in water at 1 °C compared with that at >20 °C (Dychdala, 1991). At pH 6, nearly 98% is in the ion form, while at pH 9.6, nearly 99% is in the ion form (Dychdala, 1991). The acid form is up to 80 times more bactericidal than the ion form. In other studies, water chlorination did not reduce postharvest decay of the peach probably due to the high pH and low temperatures of the solutions, which restrict activity of the chloroform (Bartz, 1988; Dychdala, 1991). Similarly, water chlorination did not prevent decay development in tomato fruit contaminated with *Erwinia carotovora* subsp. *carotovora* and then infiltrated with chlorinated water at 26 °C and pH 6.8 to 9.6 (Bartz, 1988). On the con-

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orally, in tests with strawberries, a chlorine concentration of 120 mg·L⁻¹ at pH 6.5 protected bruised fruit from inoculum suspended in the hydrocooling water (Ferreira et al., 1996).

The ORP of a solution is an indicator of the ability of the solution to oxidize or reduce, with positive and higher ORP values correlated with greater oxidizing strength (Jay, 1996). Aerobic microorganisms for growth require an optimum ORP of +200 to +800 mV, whereas an optimum range of –200 to –400 mV is favored for growth of anaerobic microorganisms (Jay, 1996). EO water-1 (pH 3.0 and ORP +1165 mV) proved more effective in bacteria control (Phillips, D.J. and J. Grendahl. 1973. The effect of ph and ORP in bacteria control of apples and pears after immersion damping. Plant Dis. 64:1095–97.) and first held at 2 °C, 50% RH for 8 d and then shifted to 20 °C. 95% RH for another 11 d. Control (0) (Y = –9.61 + 7.11 x, R² = 0.99), EO water 2 min (▲) (Y = –2.6386 – 0.73 x + 0.4286 x², R² = 0.99), and 5 min (□) (Y = –15.456 + 4.15 x + 0.0464 x², R² = 0.93). Bars indicate standard error.

Peach fruit usually stays in retail shops for a week, about the time that EO water delays disease onset. Therefore, it could be a practicable method in the packinghouse operations, especially for nonwounded fruits.

These studies indicate that sanitation with EO water prevents fruit decay and could become an important alternative to liquid sterilants such as sodium hypochlorite. However, the mechanism by which EO water affects living organisms is not known (Bonde et al., 1999). The extremely high ORP of EO water obviously is a factor in sterilization. ORP rather than pH was a factor in EO water stimulation of T. indica telosporia germination (Bonde et al., 1999). More research is needed on the EO water properties to determine required properties for decay control.

Literature Cited


