

tion of a carbonate treatment include the risk of injury to fruit the treatment could pose, particularly for navel orange cultivars. Most of these cultivars were introduced since the original carbonate research was published (2,17,21,23), and managers state these are very susceptible to cosmetic defects of the rind that develop after harvest, such as pitting. Another concern is the influence of carbonate treatment on the effectiveness of subsequent fungicide or biological control treatments.

Objectives in the present work were to (i) compare the fungitoxicity and disease control effectiveness of SC, potassium carbonate, SBC, potassium bicarbonate, and ammonium bicarbonate; (ii) determine the influence of water rinse volume applied after SC treatment on the effectiveness of the treatment to control green mold; (iii) investigate the influence of high-pressure water washing on SC effectiveness; (iv) determine if fruit are susceptible to injury by SC treatment, particularly early season oranges; and (v) determine the influence of prior SC treatment on the effectiveness of subsequent imazalil or biological control treatments.

MATERIALS AND METHODS

Inoculum preparation. *P. digitatum* (Pers.:Fr.) Sacc. isolate M6R (obtained from J. W. Eckert, University of California, Riverside) was cultured for 1 to 2 weeks on potato dextrose agar. Spores were harvested by adding 5 ml of water containing 0.05% Triton X-100 to the Petri dish, rubbing the surface with a sterile glass rod, and passing the suspension through two layers of cheese cloth. The suspension was diluted with water to an absorbance of 0.1 at 425 nm determined with a spectrophotometer; this density contains approximately 10^6 spores/ml (9).

In vitro inhibition of spores of *P. digitatum* by bicarbonate and carbonate solutions. Potato dextrose broth containing 0, 2.5, 5.0, 10.0, 25.0, and 50.0 mM of SC (Na_2CO_3), potassium carbonate (K_2CO_3), SBC (NaHCO_3), ammonium bicarbonate (NH_4HCO_3), or potassium bicarbonate (KHCO_3) was prepared in 4-ml volumes from anhydrous salts (Sigma Chemical Co., St. Louis). Three replicates of each were prepared, and 10,000 spores of *P. digitatum* were added to each replicate. In the first test, the pH of each solution was not controlled and increased with increase in salt concentration. After 18 h at 22°C ($\pm 1^\circ\text{C}$), 100 μl of acid fuchsin solution (0.2% wt/vol acid fuchsin in a solution containing one part acetic acid and one part 95% ethanol) was added to each well to stop further germination and the percentage of germinated spores determined by observation of 100 to 150 spores within each replicate with an inverted compound microscope (200 \times). No acid fuchsin was added to a fourth replicate well of each solution; the spores were withdrawn from

this well with a Pasteur pipette, suspended in sterile distilled water followed by low-speed centrifugation, and re-suspended in potato dextrose broth for an additional 18 h. In a second test, the bicarbonate salts alone were tested at similar pH; 50 mM phosphate buffer was included and the final pH of the solutions was 7.3 (± 2). After 18 h at 22°C ($\pm 1^\circ\text{C}$), acid fuchsin was added to each well to stop further germination and the percentage of germinated spores determined as previously described. The experiments were conducted twice.

Fruit inoculation. Lemons (*Citrus limon* (L.) Burm.) or oranges (*C. sinensis* (L.) Osbeck) that had been commercially harvested no more than 2 days prior to use were randomized and inoculated with *P. digitatum* 24 (± 2) h before treatments were applied. This inoculation method simulates infections that occur under commercial conditions and has been recommended for determining the effectiveness of fungicides (9). Fruit were inoculated by immersing a stainless steel rod with a probe tip 1 mm wide and 2 mm in length into the spore suspension and wounding each fruit once. The temperature of the fruit at the time of inoculation and subsequent storage until treatment was 20°C ($\pm 1^\circ\text{C}$). After all treatments were applied, the fruit were placed into plastic cavity trays that prevented contact infections. In every test, controls included fruit that were inoculated and treated with water and fruit that were inoculated and not treated.

Comparison of bicarbonate and carbonate solutions for the control of green mold on lemons. To determine if other bicarbonates or carbonates could effectively control green mold, inoculated lemons were immersed for 1.5 or 2 min in 22-liter volumes of water, SC, SBC, potassium carbonate, ammonium bicarbonate, or potassium bicarbonate. Each solution was applied at 27 or 40°C ($\pm 1^\circ\text{C}$). The temperature of the solutions did not change more than 0.5°C during treatment. After treatment, the fruit were rinsed with 10 ml of deionized water per fruit at low pressure (200 kPa) in a spray 30 cm above the fruit over a period of 5 s, stored for 2 or 3 weeks at 13 or 20°C ($\pm 1^\circ\text{C}$), and the incidence of green mold-infected fruit was determined. The solutions contained equimolar or equal-weight quantities of bicarbonates or carbonates. Each treatment was applied to four or five replicates of 25 fruit each. The test was repeated three times, although not all bicarbonate and carbonate treatments were included in every test.

Comparison of SC and SBC for the control of green mold. SC and SBC solutions were compared on an equal-weight basis on lemons and oranges. Inoculated lemons (*C. limon*) cv. Eureka or oranges (*C. sinensis*) cv. Valencia were immersed for 2 min in 22 liters of water or in equal-weight quantities of SC or SBC at 2 or 3%

(wt/vol) at 40 or 45°C ($\pm 1^\circ\text{C}$), rinsed with 10 ml of water per fruit applied as previously described, stored for 2 or 3 weeks at 13 or 20°C ($\pm 1^\circ\text{C}$), and the incidence of green mold infected fruit was determined. Each treatment was applied to four replicates of 25 fruit each. The test was repeated, with minor differences in procedure, three times with Eureka lemons and twice with Valencia oranges.

Influence of chlorination on SBC effectiveness. Solutions containing 0, 0.25, 0.5, 1, and 3% (wt/vol) SBC were prepared, and an identical series of solutions was prepared with the addition of 200 $\mu\text{g/ml}$ of sodium hypochlorite. All were adjusted to pH 7.5 with concentrated HCl. Total chlorine content was periodically measured by combining a diluted sample of the hypochlorite-containing solutions with concentrated HCl and orthotolidine, and the absorbance at 500 nm was compared to a standard curve. The pH was measured repeatedly during the test and did not change. Inoculated lemons were immersed for 2 min in 22 liters of the SBC solutions at 25°C, rinsed with 10 ml of water per fruit applied at low pressure as previously described, and stored 2 weeks at 18°C ($\pm 1^\circ\text{C}$). Each treatment was applied four times to replicates of 25 fruit each. The test was done once.

Influence of post-treatment water rinse volume on SC effectiveness. In a laboratory test, lemons inoculated 24 h earlier were immersed for 1.5 min in 3% (wt/vol) SC solution at 40.6°C ($\pm 1^\circ\text{C}$). After treatment, the fruit were not rinsed or rinsed with 2, 10, or 50 ml of deionized water per fruit applied at 200 kPa in a spray 30 cm above the fruit over a period of 3 to 10 s. Each treatment was applied to four replicates of 25 fruit each. The test was done once. In tests with commercial packing line equipment, fruit inoculated 24 h previously were placed for 60 s into a 2,400-liter-capacity tank containing 3% (wt/vol) SC at 38°C ($\pm 1^\circ\text{C}$). After treatment in the tank, the fruit were immediately rinsed with water (16 to 18°C) from three nozzles placed 20 cm apart and 33 cm above rotating brushes on a 60-cm-wide bed. The 80° solid-cone nozzles were changed to vary water volumes and operated at a water pressure of 300 kPa. Fruit were not rinsed or rinsed after SC treatment with 2, 10, or 50 ml per fruit applied during the approximately 1-s residence period of the fruit under the rinse water nozzles. After rinsing, the fruit were dried for 15 to 20 s through a drier at 32.2°C, a high solids content resin finishing wax (Sealbrite 504, EcoScience Corp., Orlando, CA) was applied, and the fruit were dried again for 15 to 20 s through a drier at 32.2°C. The fruit were placed in fiber board cartons. All fruit were stored for 3 weeks at 10°C before the decayed fruit were counted. Within the test, each treatment was applied to four replicates of 60 to