

other workers have shown that sodium, potassium, and ammonium bicarbonates have similar inhibitory activity against spores (Fig. 1; 29,30), and they were equal to or superior to SBC for the control of other diseases (18,29). Ammonium bicarbonate in particular would be anticipated to be effective, because ammonia and ammonium salts have been used to control green mold (39).

This work offers partial solutions for the disposal of the process water from packinghouses, where the discharge to ponds or sewers of various solutions used to treat citrus, namely borax-boric acid, sodium ortho-phenyl phenate, and SC, is under regulatory control. An equivalent-weight solution of SBC has a lower pH and less sodium than a similar solution of SC. Equimolar amounts of SBC contain 27.4% sodium compared to 43.4% sodium in SC. Another very significant advantage of bicarbonate salts is that they can be effectively chlorinated, because at the pH of these solutions a substantial portion of the hypochlorite is protonated and active. The addition of 200 µg/ml of sodium hypochlorite to SBC at pH 7.5 slightly but significantly improved control of green mold on lemons, and the hypochlorite will kill spores and other microbes contaminating the solution. A disadvantage of SBC is that heating the solution will cause carbon dioxide evolution into air with a concomitant increase in solution pH. At ambient temperatures, carbon dioxide evolution from bicarbonate solution is not significant and the pH of the solution does not change. Unfortunately, heating sometimes significantly improved carbonate and bicarbonate solution effectiveness in practical tests. Heating of the solutions to 60°C when fruit are not present, a practice used to sanitize SC solutions of contaminating microbes and spores, cannot be done with SBC, but the addition of hypochlorite to SBC should accomplish this task. Other carbonate or

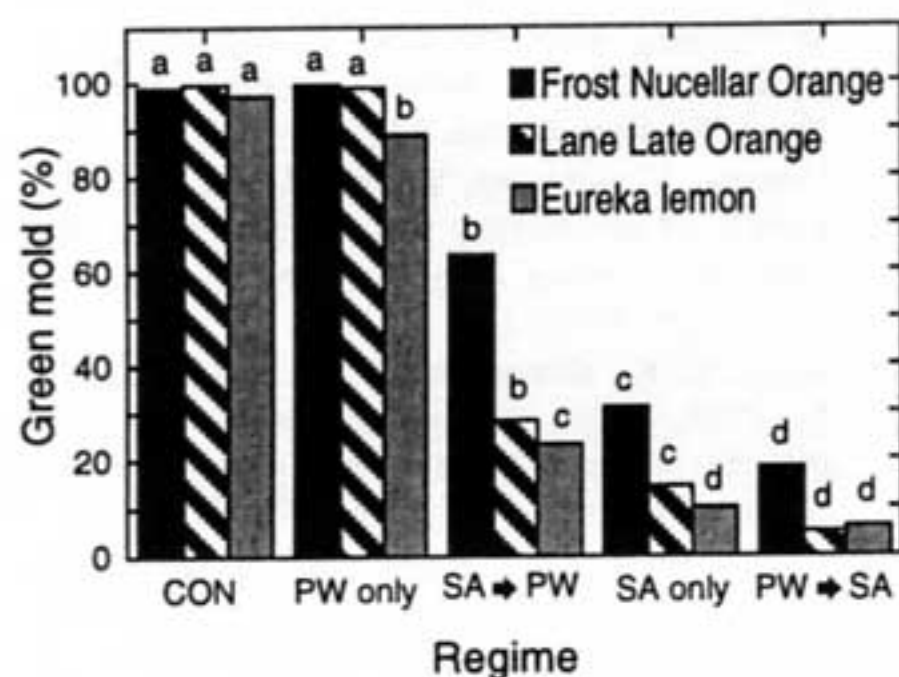


Fig. 4. The incidence of green mold on lemons or oranges after treatment in regimes where the fruit were inoculated and not treated (CON); inoculated and washed with water at high pressure (PW only); treated with sodium carbonate, then washed with water at high pressure (SA → PW); treated with sodium carbonate alone (SA only); or washed with water at high pressure, then treated with sodium carbonate (PW → SA).

bicarbonate salts could be adopted but they are less effective than SBC and SC. In other work, we that showed ethanol and sulfur dioxide could replace SC, although they were less effective (36). Other solutions that are suitable for discharge to sewers or ponds, applied to land as soil amendments or fertilizers, or recycled, should be examined for this application.

The solutions we tested must be rinsed off the surface of the fruit to prevent the deposition of the salts on brushes and belts of packing and sorting equipment, and to prevent staining and desiccation of the fruit

rind. Marloth (26) and Hwang and Klotz (22) reported the effect of carbonate or bicarbonate solutions on spores of *P. digitatum* was primarily fungistatic; many spores remained germinable after exposures of 5 min or longer in 10% (wt/vol) Na₂CO₃ or NaHCO₃. Spores survive the treatments of 1 or 2 min in duration that control green mold on fruit (34); therefore, it is probable that a residue of carbonate or bicarbonate must remain on the fruit, or at least within the wound infection courts occupied by this pathogen, for the treatment to inhibit infection. Water rinsing by

Table 3. Incidence of green mold after sodium carbonate treatment followed by a water rinse and 3 weeks of storage at 10°C

Rinse volume per fruit (ml)	Green mold incidence (%) ^a			
	Test 1	Test 2	Test 3	Mean
Inoculated, not treated	96.8 a	96.7 a	84.6 a	92.7 a
0	9.6 b	22.7 b	11.7 b	14.7 b
2	20.0 b	12.0 b	13.3 b	15.1 b
10	13.6 b	16.1 b	5.8 c	11.8 b
50	19.2 b	18.0 b	8.8 bc	15.3 b

^a Test 1 = lemons, *n* = 5 replicates of 25; test 2 = lemons, 4 replicates of 75; test 3 = oranges, 4 replicates of 60. Test 1 was a laboratory test; tests 2 and 3 were done with commercial packing equipment.

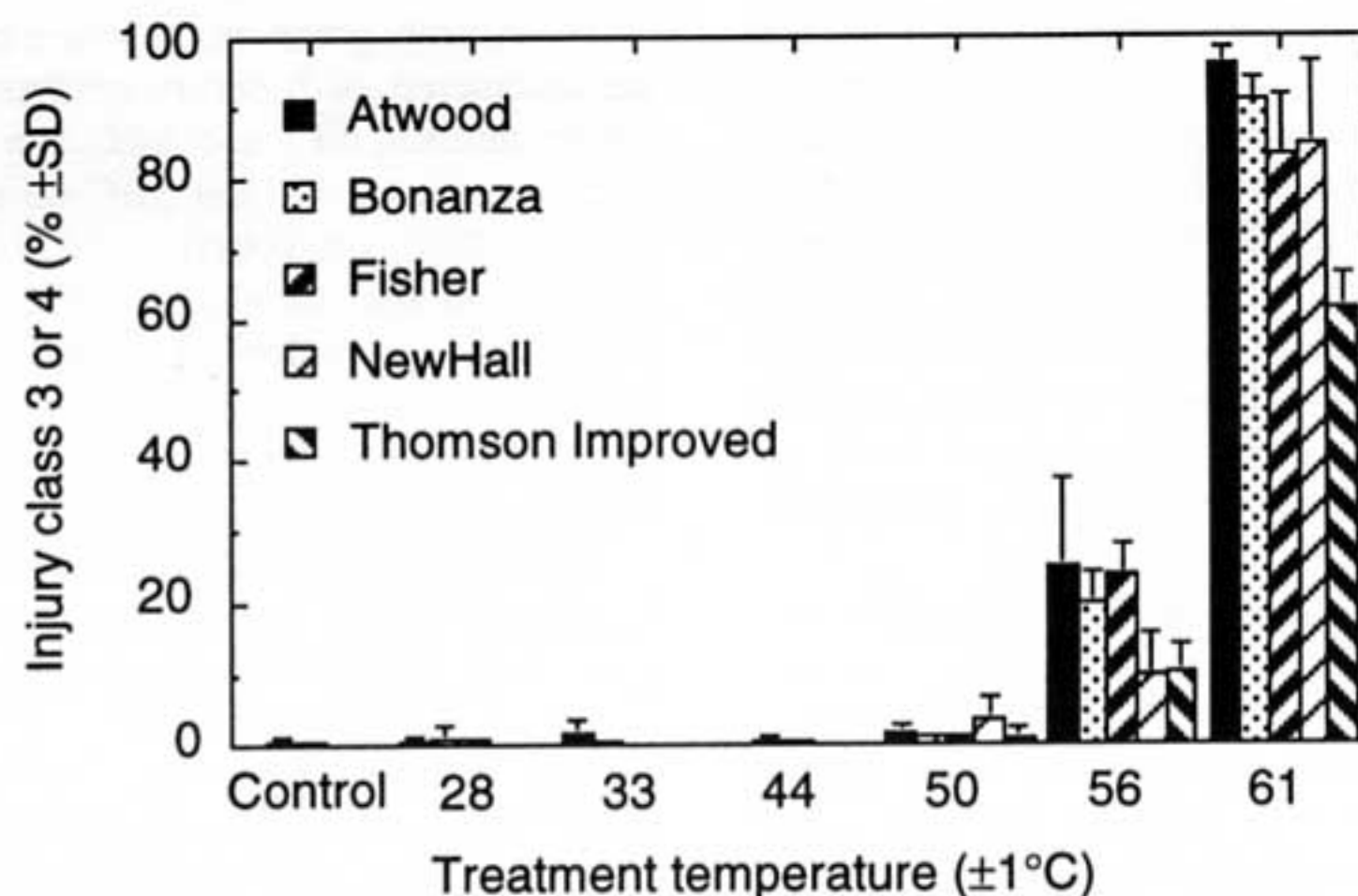


Fig. 5. Influence of the temperature of sodium carbonate treatment (3% wt/vol for 1 min) on the appearance of oranges after treatment and storage at 10°C for 3 weeks. Injury classes: 1 = no rind blemishes; 2 = slight blemishes present; 3 = moderate blemishes present; and 4 = severe rind injury.

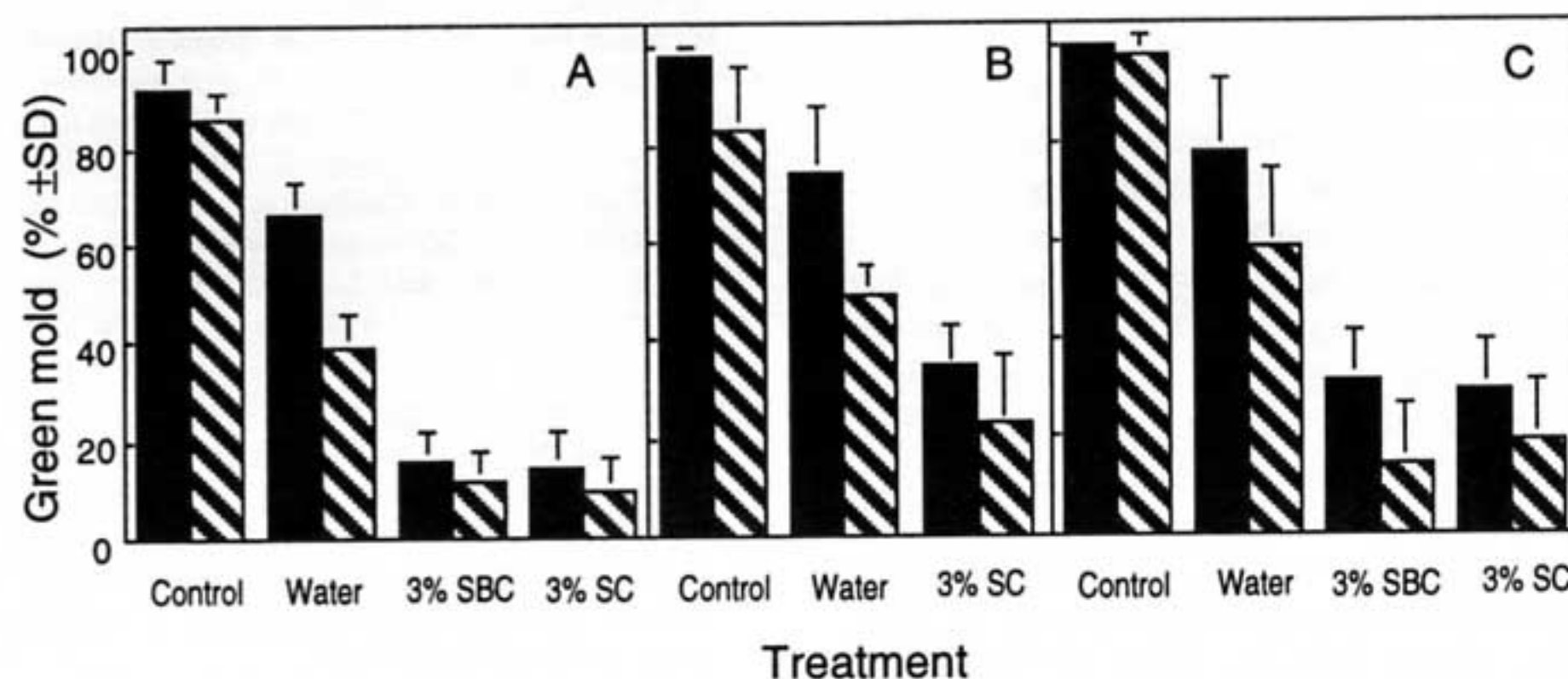


Fig. 6. The incidence of green mold on cv. Valencia oranges after immersion in water or in solutions of 3% sodium bicarbonate (SBC) or 3% sodium carbonate (SC) alone (solid bar) or each followed by the application of *Pseudomonas syringae* strain ESC10 (striped bar). (A) Treatment solution temperature = 45°C; (B) and (C) treatment solution temperature = 40°C.