

low-pressure overhead sprays, typically used for this purpose, did not influence SC effectiveness significantly, while high-pressure water washing significantly diminished its efficacy. High-pressure water washing, and probably other fruit-washing procedures that employ extensive brushing, soaps, and high water volumes, reduce SC effectiveness because this residue is removed. Presumably, the residue persists through low-pressure water rinses but it is substantially removed by high-pressure water washing of fruit. We were unable to correlate rind sodium content and SC effectiveness because the sodium content of the rind of lemons and oranges was naturally high (about 130 µg/g fresh wt) and variable.

Citrus fruit should be cleaned before SC treatment because the effectiveness of SC treatment will be diminished if they are washed rigorously afterward. Two other benefits of washing the fruit before SC treatment were considered. First, residual SC remaining on treated fruit would not contaminate the water of the pressure washer. SC would raise the pH of the water and diminish the efficacy of the sodium hypochlorite used to sanitize the pressure washer water. Second, if the fruit are cleaned before they enter the SC tank, the solution will remain cleaner and require less frequent replacement. A disadvantage of this sequence is that cleaning of fruit may require higher water pressure that may increase the risk of mechanical injury to the rind. Some managers report SC treatment prior to pressure washing partially cleans and conditions soiled fruit so cleaning can be accomplished with lower water pressure.

Washing inoculated fruit with water applied at high pressure alone did not reduce the incidence of green mold on oranges, and slightly but significantly reduced it on lemons. Pressure washing also may have affected a mechanical removal of some of the germlings. Other workers reported that green mold incidence is reduced when wounds on fruit are rigorously rinsed and then inoculated, because washing removes nutrients that stimulate *P. digitatum* spore germination (1) or removes rind oils that retard the lignification of wounds (3). The inoculum may have been reduced by mechanical removal of the germlings by high-pressure water washing in our tests.

The risk of SC injury to citrus fruit has been discussed previously (13,23,35,36). In the present work, rind injuries were only associated with SC treatments at 56°C or higher. Therefore, the risk of injury is low because these temperatures are above that needed for the control of green mold (35). In addition to visible scalding injury to the rind, harsh chemical (16) or hot-water treatments exceeding 48°C (17,27) can render the fruit susceptible to infection without obvious wounds, although *P. digitatum* typically requires wounds for infec-

tion to occur. Compared to hot water alone, SC is effective for the control of green mold at much lower temperatures (35,37), so the risk of injury to the fruit is reduced (21,24). A reason to use SC at higher temperatures (50°C) is to control brown rot, caused by *Phytophthora* spp. (14). Its control requires temperatures (25) that occasionally injure fruit (24). Brown rot is usually of less concern than green mold (10) and is associated with high rainfall and poor cultural practices (14). Carbonate and bicarbonate treatments inhibit the growth of the pathogen, but do not injure the fruit or its defensive responses. SC treatment at 40°C did not influence the synthesis of phloroglucinol-positive compounds within wounds associated with inhibition of infection by *P. digitatum* by lemon fruit (37; R. R. Stang, personal communication).

The effectiveness of SBC and SC was significantly improved when these treatments were followed by the fungicide imazalil or *P. syringae* strain ESC10. The combination of bicarbonate or carbonate followed by the biological control antagonist *P. syringae* overcomes significant shortcomings of either of these treatments alone. Biological control antagonists are poor eradicants that are usually incapable of controlling green mold when the fruit are inoculated 24 h before treatment (34), while imazalil, SC, and SBC can control these infections. SC and SBC do not provide persistent protection of the fruit from re-infection after treatment, while residues of imazalil or biological control antagonists persist for long periods after treatment and protect fruit from re-infection. Apparently, the residual of the bicarbonate or carbonate solutions that remained in inoculated wounds on the fruit was tolerated by the antagonist but inhibitory to the pathogen. For this combination to be used reliably under commercial conditions, a study of the tolerance of the antagonists to the bicarbonate and carbonate solutions and the influence of their residues on the populations of the antagonists in wounds on fruit is needed.

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