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EFFECT OF HOT WATER AND GAMMA RADIATION ON POSTHARVEST DECAY OF GRAPEFRUIT

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Abstract. **'Marsh' seedless white Florida grapefruit (*Citrus paradisi* Macf.) were inoculated after harvest with a spore suspension of green mold (*Penicillium digitatum* Sacc.) and treated by immersion in hot water (50°C for 5 min) or irradiation with gamma rays (250 Gy) from a Cobalt-60 source or a combination of the two treatments. Fruit were wrapped individually with shrink film after hot water treatment and before irradiation and were stored with wrapped control fruit at 24°C for 9 days. Fruit treated with hot water developed less green mold rot than untreated fruit, even when treatment was delayed for 72 hr after inoculation. Fruit irradiated after a delay of 2 hr, but not 24-72 hr, after inoculation developed less rot than untreated fruit. Development of green mold rot was not significantly different in fruit treated with both hot water and irradiation than with hot water alone. No visible injury or off-flavors were detected in any of the fruit.**

Postharvest treatments that can control decay of a commodity without damaging the commodity or leaving a potentially harmful residue are always in demand. Hot water and radiation leave no chemical residues, but can injure citrus depending on water temperatures and times or radiation dosages needed for control of decay (1,3,5,7). The Food and Drug Administration is considering approval of ionizing radiation at doses up to 1 kGy for treatment of fruits and vegetables. Combination treatments of citrus with hot water and gamma radiation have been reported to work synergistically to control green mold rot of citrus (2). In this report, we present an evaluation of the effect of hot water and gamma radiation treatment, alone and combined, on the development of green mold rot in inoculated grapefruit.

Materials and Methods

Florida 'Marsh' white grapefruit obtained from Florida packinghouses were stored at 10°C until needed for tests. Green mold spores were obtained from a naturally infected grapefruit and used to inoculate other grapefruit and maintain a fresh supply of heavily-sporulating inoculum. Inoculum for tests was prepared as a heavy suspension of 10^6 spores/ml of tap water containing 0.05 ml of Tween 20 wetting agent per liter. The concentration of spores was measured with a haemocytometer. Grapefruit were then inoculated by rolling each one over a spiked stick submerged in the inoculum. The nails protruding through the stick at 2.5-cm intervals made up to 8 or 9 wounds around the equator of the fruit. Each wound was approximately 3 mm deep and 1 mm wide. Fruit were then placed on absorbent paper to drain and partially dry.

Hot-water, radiation, and hot-water plus radiation treatments were applied at 2, 24, 48, or 72 hr after inoculation. Twenty fruit were used per treatment and the test was replicated 3 times. Hot-water treatments were done by placing nonwrapped, inoculated grapefruit in a mesh bag and immersing in tap water at 50°C for 5 min. Control fruit were treated similarly, but in unheated (27-30°C) water for 5 min.

The inoculated grapefruit were all wrapped with Cryovac 955, a cross-linked polyolefin film, 0.6 mil thick. The wrapping was used for convenient handling, prevention of spread of infection from fruit to fruit, and reduction of contamination of equipment, rooms and personnel. Film was applied to each fruit with a Weldotron model 6001 hot-wire sealer, and then shrunk by passage through a Weldotron model 7001 heat tunnel.

Irradiation was done with a Gammacel 220 irradiator using a cobalt-60 source. Wrapped fruit were exposed to 250 Gy of gamma radiation at a mean dosage rate of 260-270 Gy/min.

After treatment, all fruit were held at 24°C for 9 days, and then examined for green mold rot. Fruit that did not mold were examined for rind injury and tasted for off-flavors in informal taste tests.

Percentage data for green mold rot were converted to the arcsin of the square root of the percentage for statistical analyses. Individual treatments were compared to the control using Dunnett's (4) two-sided test. The Student "t" test was used for comparisons between individual treatments.

Results and Discussion

The hot-water treatment, in comparison with the unheated water control, reduced the percentage of green mold-rotted grapefruit regardless of whether treatment was delayed from 2 to 72 hr after inoculation (Table 1). Greatest reduction in green mold incidence occurred after a delay of 24 or 48 hr. Microscopic examination of the area of inoculation showed spore germination in 24 hr, but not in 2 hr, after inoculation. Vegetative tissue, such as the germ tubes of spores, are reported to be more sensitive to high/low temperatures than dormant spores (6). Radiation was very effective in reducing the percentages of green mold-rotted fruit when applied 2 hr after inoculation, when only ungerminated spores were present in the inoculation site. When spores had time to germinate and mycelia began to develop and penetrate host tissue, radiation had no significant effect on the development of green mold rot. The combination of hot water and radiation caused a highly significant reduction of green mold rot of fruit over that of the control, though significance was somewhat less after a delay of 72 hr. Mean percentages of green mold rot were less for the combination treatment than either treatment alone, but there was no indication of a synergistic effect of hot water and radiation under the conditions

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Table 1. Effect of hot water and gamma radiation, alone or combined, on the development of green mold of grapefruit when applied 2, 24, 48, or 72 hr after inoculation.[z]

Treatment	Percentage fruit with green mold rot[y] 2 hr	24 hr	48 hr	72 hr
Water (24-27°C; 5 min)	71.7	—	—	—
Hot Water (50°C; 5 min)	30.0*	16.7**	13.3**	35.0*
Radiation (250 Gy)	15.0**	56.7	51.7	51.7
Hot Water + Radiation	13.3**	10.0**	6.7**	28.3*

[z]Each figure represents the mean of 3 replicates or a total of 60 fruit. Decay was determined after holding the fruit at 24°C for 9 days after inoculation.
[y]Means followed by a single or double asterisk are significantly different from the unheated water control at the 5% or 1% level, respectively, as determined by Dunnett's two-sided test (4).

of these tests. The reported synergism (2) was minimal at 250 Gy and was based on research (8) that showed an increase in the radiosensitivity of fungi as a result of the combination of heat with irradiation.

Nonrotted fruit from the various treatments showed no visual signs of internal or external injury and no off-flavors. Additional work is needed to determine the possible effects of wrapping and prolonged storage on the effectiveness of hot water and radiation for decay control.

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EFFECTIVENESS OF POSTHARVEST FUNGICIDES FOR THE CONTROL OF CITRUS FRUIT DECAYS

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Abstract. **Thiabendazole and benomyl were the most effective fungicides for the control of *Diplodia natalensis* Pole Evans stem-end rot, a major decay of early degreened fruit. This decay was also significantly reduced by imazalil and guazatine, but the level of control was not as consistent as that obtained with thiabendazole or benomyl. Control of *Diplodia* stem-end rot was not obtained with DF-100 or potassium sorbate. Sour rot, caused by *Geotrichum candidum* Lk. ex Pers., was controlled with guazatine and etaconazole but not with DF-100, Purogene, fenpropimorph or potassium sorbate. Green mold, caused by *Penicillium digitatum* Sacc., was effectively controlled with imazalil, guazatine and thiabendazole. However, efficacy of thiabendazole was greatly reduced in the presence of strains of *P. digitatum* with resistance to the fungicide. Potassium sorbate and DF-100 significantly reduced green mold only in some tests, but even then they were not as effective as imazalil or guazatine. Purogene did not control green mold and at high rates it significantly increased the decay. Of the fungicides tested, benomyl, thiabendazole, imazalil, and potassium sorbate are presently labeled and approved for application to citrus fruits to control postharvest decays.**

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Postharvest decays frequently cause extensive losses of Florida citrus fruit before or after it reaches the consumer. A significant proportion of this loss can be prevented by applying effective fungicides to the fruit soon after harvest. A program to evaluate, identify, and aid in the registration of effective fungicides for decay control in citrus has been pursued at the Lake Alfred Center for many years. Efforts to develop new fungicides are necessary for several reasons. Improvements in efficacy, safety and expense may be realized. Use of registered fungicides can be discontinued at any time due to unforeseen health or environmental hazards. Furthermore, some pathogens, particularly *Penicillium,* can develop resistance to fungicides causing them to be ineffective.

The purpose of this report is to describe recent studies where the effectiveness of certain fungicides was evaluated for the control of 3 major decays of Florida citrus fruit, namely *Diplodia* stem-end rot, sour rot, and green mold.

Materials and Methods

In vitro evaluation of the fungicides was performed by incorporating the materials into sterilized Difco potato dextrose agar before pouring the media into petri dishes. After the media solidified, the plates were inoculated with the various fungi as described previously (10). Inhibition of growth was measured for each fungus at specific times after inoculation when substantial growth had occurred on the control plate.