# Postharvest Chemical Treatments for Control of Blue Mold of Apples in Storage

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ABSTRACT

Heated suspensions of benomyl or Thiabendazole [2-(4-thiazolyl) benzimidazole] used as postharvest dips (3 min at 45 C) effectively controlled blue mold in wounded and inoculated Golden and Red Delicious apples during 2 months at 0 C followed by 1 week at 21 C. Comparable tests with heated tap water did not control decay. Heated fungicides were equally effective at concentrations of 100 and 500 μg/ml. At 100 μg/ml, heated fungicides appreciably reduced decay in either punctured or bruised apples. Unheated fungicides were equally effective at 100 and 500 μg/ml on punctured apples, but were considerably less effective on bruised apples. Phytopathology 61:1308-1309.

Spalding et al. (3) reported that dip treatments in unheated suspensions of either benomyl or Thiabendazole [2-(4-thiazolyl)-benzimidazole] (TBZ) controlled blue mold rot of apples caused by *Penicillium expansum* (Lk. ex Thom) infecting through punctures. Treatment with unheated benomyl was only partially effective, and TBZ was ineffective when the fungus entered through bruises. Treatment of bruised apples for 45 sec in heated (55 C) suspensions of either benomyl or TBZ prevented blue mold rot during storage. However, the high temperature of treatment increased internal breakdown of apples, and sometimes caused skin injury. Objectives of the current work were to determine whether a lower temperature could be used to achieve control without injury, and to test lower fungicide concentrations.

Golden and Red Delicious (size 113, US Fancy) apples, obtained soon after harvest and held at 0 C until treated, were used for the study. Fruit was removed from storage 24 hr before treatment and held at 21 C to warm. Tests were replicated 2 or 3 times, each replicate coming from a different orchard. A tray-packed carton of 100 apples was used for each treatment within a replicate. Apples were bruised or punctured by pressing the fruit down on the head of a thumbtack or a nail (3). When infection in bruise and puncture wounds was studied on Red Delicious (Table 1), a bruise and puncture were made on opposite sides of the same apple. With Golden Delicious (Table 2), bruise wounds were made on opposite sides of each apple. Apples were inoculated immediately after wounding by immersion in a suspension of blue mold spores ($25 \times 10^4$ spores/ml), then allowed to dry at room temperature for 2 hr before dipping in either tap water or fungicides. After treatment, fruit were allowed to dry before repacking in trays within cartons. Polyethylene liners were used in the Golden Delicious cartons. Apples were examined after storage for 2 months at 0 C followed by 1 week at 21 C. After treatment and storage, the Golden Delicious apples were compared for firmness and color and cut to check for internal breakdown. Firmness was measured with a Magness-Taylor pressure tester (1.1-cm plunger) on two sides of each of 20 uniform apples. Color was estimated by comparison with the USDA standard color chart.

Chemical suspensions of 100, 250, and 500 μg/ml were prepared in tap water on the basis of active ingredient. Benomyl (E. I. DuPont de Nemours & Co., Wilmington, Del.) was tested as a 50% wettable powder (WP), and TBZ (Merck & Co., Rahway, N.J.) as a 60% WP.

A 3-min dip in heated (45 C) benomyl or TBZ effectively controlled blue mold in bruised Golden

TABLE 1. Influence of concentration of unheated or heated fungicide and water on blue mold control in bruised and punctured inoculated Red Delicious apples

| Postharvest dip treatment | % Blue mold rot after 2 months at 0 C plus 1 week at 21 C[a] | | | |
|---|---|---|---|---|
| | At bruised tissue | | At punctured tissue | |
| | Unheated | Heated | Unheated | Heated |
| *3 min* | *21 C* | *45 C* | *21 C* | *45 C* |
| Tap water | 42 d | 41 d | 97 b | 97 b |
| Benomyl (500 μg/ml) | 17 bc | 1 a | 13 a | 9 a |
| Benomyl (250 μg/ml) | 20 bc | 1 a | 17 a | 16 a |
| Benomyl (100 μg/ml) | 29 cd | 1 a | 26 a | 23 a |
| Thiabendazole (500 μg/ml) | 29 cd | 0 a | 6 a | 2 a |
| Thiabendazole (250 μg/ml) | 31 cd | 5 ab | 17 a | 5 a |
| Thiabendazole (100 μg/ml) | 36 d | 6 ab | 25 a | 19 a |

[a] Treatment means not followed by a letter in common are significantly different from each other (5% level, Duncan's multiple range test) except that significance is at 1% level within blocks.

TABLE 2. Influence of duration of dip treatment in heated water or fungicides on blue mold control in bruised tissue of inoculated Golden Delicious apples

| Postharvest dip treatment (45 C) | % Blue mold rot after 2 months at 0 C plus 1 week at 21 C[a] | | |
|---|---|---|---|
| | 1 min | 3 min | 6 min |
| Tap water | 46 c | 49 c | 36 bc |
| Benomyl (500 μg/ml) | 12 ab | 3 a | 2 a |
| Thiabendazole (500 μg/ml) | 13 ab | 3 a | 1 a |

[a] Treatment means not followed by a letter in common are significantly different from each other (5% level, Duncan's multiple range test).

Delicious apples (Table 2), while neither a 3- nor 6-min dip in heated water controlled decay. No skin injury was observed in any treatment. Firmness, color, and internal breakdown of the Golden Delicious apples after storage did not differ significantly among treatments (data not shown).

In tests using bruised Red Delicious apples, fruit dipped for 3 min in heated (45 C) or unheated (21 C) water developed about the same percentage (41-42%) of blue mold rot during storage (Table 1). Heated benomyl and TBZ effectively controlled blue mold; results with 100 μg/ml did not differ significantly from those with 500 μg/ml. At all concentrations tested, heated fungicides reduced the percentage of decay more than did unheated fungicides. Unheated benomyl at 250 μg/ml partially controlled blue mold at bruises, but unheated TBZ was not effective at any concentration tested.

In punctured and inoculated Red Delicious apples, fruit dipped for 3 min in heated (45 C) or unheated (21 C) water developed about the same percentage (97%) of blue mold rot during storage (Table 1). Apples dipped in heated or unheated suspensions of 100 to 500 μg/ml of either benomyl or TBZ developed much less blue mold rot than did apples dipped in water. The extent of blue mold rot in apples dipped in either fungicide, heated or unheated, did not differ significantly at the 1% level.

Control of blue mold rot in apples by either benomyl or TBZ at 45 C does not appear to involve the direct action of heat on the fungus, since control of blue mold on bruised and inoculated fruit was not significantly better with a 6-min heated water dip than with a 1-min dip. Blue mold thus appears less sensitive to heat treatment than rots caused by *Gloeosporium* spp. (2) or *Trichoseptoria fructigena* (1), which have been controlled by a 6-min treatment in 45 C water. Residue data supplied by Merck & Co. on treated fruit sent to them for analysis show that more fungicide is deposited on fruit dipped at 45 C than at 21 C. The possibility that heating increases the concentration of fungicide reaching the spores does not exclude the possibility that heat may in some way make spores more sensitive to inactivation or destruction.

LITERATURE CITED

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