

STATUS OF POSTHARVEST FUNGICIDES FOR CITRUS FRUIT¹

A. A. McCORNACK

State of Florida Department of Citrus
Florida Citrus Experiment Station, IFAS
Lake Alfred

ABSTRACT

Four fungicides are cleared by the U. S. Food and Drug Administration for postharvest use on citrus fruits and their hybrids. They are: thiabendazole (TBZ); o-phenylphenol and its salt form, sodium o-phenylphenate (Dowicide 1 and Dowicide A); biphenyl (diphenyl); and borax and boric acid. The isopropyl ester of 2,4-D is cleared for postharvest use on lemons only. The comparative effectiveness of these fungicides is discussed together with formulations and methods of application. The container labeling requirements of the U. S. Food and Drug Administration, as they pertain to postharvest fungicides applied to citrus fruit, are reviewed. The Florida Citrus Commission Regulation 105-1.43, "Fungicide or Fungistat Treatment Required for Fresh Citrus Fruit," which requires all registered packinghouses to use a postharvest fungicidal treatment is discussed. Two fungicides, Benlate and G-20072 which have been effective in experimental trials, are currently under study.

INTRODUCTION

Post harvest decay losses may turn an otherwise high-quality citrus crop into an economic failure. Usually, the sooner a fungicide is applied to citrus fruit after picking, the better the decay control that can be expected. Decay of Florida citrus fruit can be generally classified into stem-end rot, mold, and miscellaneous rots. Most decay is caused by *Diplodia natalensis* P. Evans and *Phomopsis citri* Faw., both of which cause stem-end rot. Practically all mold in Florida is caused by green mold, *Penicillium digitatum* Sacc. Miscellaneous fungi, which usually cause only a small percentage of the total decay, are sour rot, *Geotrichum candidum*

Ferr.; anthracnose, *Colletotrichum gloeosporioides* Penz.; blue mold, *Penicillium italicum* Wehrner; and black rot, *Alternaria citri* Ell. In isolated instances, brown rot, *Phytophthora citrophthora* Leon, may cause extensive decay, especially in humid coastal areas where infection by this soil-borne fungus is more prevalent.

Control of postharvest decay depends on proper fruit handling and on the application of a suitable fungicide. The fungicides approved for postharvest use are: biphenyl; borax and boric acid; 2, 4-D isopropyl ester; o-phenylphenol and its salt form sodium o-phenylphenate; and thiabendazole (Table 1).

APPROVED FUNGICIDES

Biphenyl (diphenyl), as formulated for control of postharvest decay of citrus fruit, has proven to be very effective. This is a vapor-phase fungicide, and even when decay is not controlled, mold sporulation and the resulting soilage due to *Penicillium* spores are usually prevented. Diphenyl is impregnated in porous paper for commercial use and is sold as pads, individual fruit wraps, and liners for gift fruit baskets. This fungicide is most effective in closed containers which maintain the vapor around the fruit. When using ventilated cartons or boxes, the holding room, truck, or rail car should be filled so that there is sufficient concentration of diphenyl vapor to be effective. Two 11 in. x 17 in. pads, which together contain 4.7 grams of diphenyl, should be placed with each 4/5 bu. of fruit. One pad is usually placed on the bottom

Table 1. Fungicides approved* for postharvest use on citrus fruit.

Fungicide	Type of treatment**	Residue tolerance in ppm
Biphenyl (diphenyl)	V	110
Borax or boric acid	W	8
2,4-D isopropyl ester [†]	W,A	5
o-phenylphenol and sodium o-phenylphenate	W,A,S	10
Thiabendazole	W,A	2

*U. S. Food and Drug Administration and U. S. Department of Agriculture.

**Legend: V = Vapor phase
W = Aqueous solution or suspension
A = Aqueous emulsion wax
S = Solvent wax

[†]Approved for lemons only.

Florida Agricultural Experiment Stations Journal Series No. 3732.

¹Cooperative research between the State of Florida Department of Citrus and University of Florida, IFAS, Citrus Experiment Station, Lake Alfred.

of the carton or box and the other on the top layer of fruit. Particularly in ventilated containers, there is some advantage in placing the bottom pad on top of the bottom layer of fruit and the second pad under the top layer.

'Dancy' tangerines and other mandarin-type citrus fruit should be handled differently than oranges, grapefruit, and lemons. Better decay control is obtained by placing only one diphenyl pad in each ventilated container. Mandarin-type citrus fruit may absorb enough diphenyl after a few weeks contact to exceed the Food and Drug Administration tolerance of 110 ppm (2) if more than one pad is used per 4/5 bu. of fruit. Excessive amounts of diphenyl may be phytotoxic to some mandarin-type fruits (9).

Diphenyl pads, wraps, etc. should be stored in airtight packages in a cool place until needed for use. Exposure to air outside the packages causes loss of effectiveness which is more rapid at higher temperatures.

Borax was used commercially as a post-harvest fungicide for citrus as early as 1924 (8). By 1952, the use of this fungicide was practically discontinued in Florida. In 1969, at the request of the Sunkist Growers, Inc., Ontario, California and the citrus growers of California and Arizona, borax and boric acid were approved for postharvest use on citrus fruit with a total boron residue of 8 ppm (1). Boron occurring naturally in citrus fruit is included in this tolerance. There is no justification at this time for the use of borax as a postharvest fungicide in Florida. Decay control with this fungicide is inferior to that obtained with the other fungicides cleared for postharvest use.

2, 4-D isopropyl ester, a derivative of the plant growth regulator commonly called 2, 4-D, is cleared for postharvest use on lemons with a residue tolerance of 5 ppm (3). Clearance for postharvest use on other citrus fruit has not been obtained. While not classified as a fungicide, under experimental conditions 2, 4-D has controlled decay of Florida lemons "cool colored" at 60° F.

Natural color formation is retarded by 2, 4-D, so lemons should not be treated until the desired color has been obtained. Experimental work (unpublished) showed that a 1/2-minute dip in 500 ppm 2, 4-D isopropyl ester reduced decay and arrested further color change of lemons. Decay was not controlled by a commercial storage wax containing 2, 4-D isopropyl ester applied after

the lemons had obtained optimum color. Decay control obtained with this chemical was less effective with other citrus fruits. In a routine petri dish screening procedure using the common Florida citrus decay fungi, 2, 4-D isopropyl ester was found to have little fungicidal activity. This material is apparently of value because it induces healing of injuries and retards senescence.

Sodium o-phenylphenate (SOPP) and *o-phenylphenol (OPP)* were cleared for postharvest use on citrus fruit in 1956 with a residue tolerance of 10 ppm expressed as OPP (5). SOPP, which is a salt form of OPP, was used for decay control of citrus fruits before this date. Commonly used trade names for OPP and SOPP are Dowicide 1 and Dowicide A, respectively. SOPP is used as a postharvest treatment in Florida and in many other citrus-growing areas of the world. It is applied by various methods including aqueous flood, spray, foam, combined with hexamine in the Dowicide A-hexamine process, and in water-based wax emulsions. OPP is only slightly soluble in water and is applied only in a solvent wax.

SOPP is soluble in water at pH 11 and above. The treating solution must be maintained between pH 11.5 and 12.5. Below this pH range, peel injury may result, and above pH 12.5 decay control diminishes sharply (10). Hexamine added to SOPP makes a safer solution. When the pH drops to a level that might result in peel injury, hexamine forms a complex with the SOPP which causes the SOPP to precipitate from the solution.

Fruit must be in contact with the SOPP for at least 2 minutes to control the stem-end rot fungi. SOPP-treated fruit must be rinsed, as residue on the fruit will interfere with obtaining a good shine. High residues do not increase decay control and may exceed legal residue levels. SOPP controls decay for 2 to 3 weeks at a storage temperature of 70° F. Lower holding temperatures extend the period of effective decay control with this fungicide.

Thiabendazole (TBZ) is the most recently approved fungicide for postharvest decay control of citrus. The residue tolerance was established at 2 ppm in or on citrus fruit in 1969 (6). Fruit is treated commercially with TBZ, which is insoluble in water, either as a suspension in water or in a water-based wax. Application is made with a fine spray of sufficient volume to

completely wet the fruit as it passes over rotating soft brushes. Constant agitation of the treating suspension is necessary to insure that TBZ is uniformly applied to the fruit.

TBZ is applied after the fruit is washed and "damp dried" on sponge rubber rollers. TBZ-treated fruit must not be rinsed after treatment. If an aqueous suspension of TBZ is applied to unwashed fruit, a second application is necessary after the fruit is washed. During periods of enforced delay where time between picking and washing exceeds 24 hours or when degreening is necessary, a double treatment can be particularly beneficial.

TBZ is the most effective postharvest fungicide cleared for use on citrus fruits. It requires no pH control and is effective at normal holding temperatures and for a longer period than other approved postharvest fungicides (11).

FLORIDA FUNGICIDE REGULATION

Florida Citrus Commission Regulation 105-1.43 "Fungicide or Fungistat Treatment Required for Fresh Citrus Fruit" became effective August 1, 1968 (4). This regulation states that all citrus fruit shipped by a registered packing-house must be treated with an approval fungicide or fungistat. Fungicides approved by the U. S. Food and Drug Administration and the Florida Department of Agriculture must be used as postharvest treatments to comply with this regulation.

Fungicides or fungistats can be applied in aqueous solution, aqueous emulsion, or in the gaseous state. Residue from the use of these materials must not exceed the residue tolerance set by the U. S. Food and Drug Administration. The Florida Citrus Commission regulation states that the minimum residue shall not be less than 1/20 of the legal tolerance. When two fungicides are applied, only one must meet this minimum residue requirement and this residue requirement shall apply to each fungicide and shall not be cumulative. This regulation does not apply to shipment of fresh Florida citrus fruit certified for export other than to Canada or Mexico.

LABELING CONTAINERS

Federal Food and Drug Administration regulations require that containers (boxes, cartons, or bags) filled with citrus fruit, that have been

treated with a postharvest fungicide, must be labeled with the generic name of the fungicide or fungicides and state why they are used. A typical label might read: "Thiabendazole used as a fungicide" or "Sodium o-phenylphenate used as a fungicide." If both thiabendazole and sodium o-phenylphenate were used, the label could read, "Thiabendazole and sodium o-phenylphenate used as fungicides." The words "added" or "applied" can replace "used." If a container bears a label stating that a fungicide or fungicides have been used, fruit within this container *must* be treated with the declared fungicides.

All consumer packages, if not labeled on the outside, must contain an insert stating the name of any fungicide applied and why it is used. The insert must be visible to the consumer at the time of purchase. Gift packages containing citrus which have had a fungicidal treatment must also be labeled. This can be done by using an insert, as described above, which is clearly visible when the package is first opened. This insert may also be additional information. The outside of the gift fruit container does not then need to be labeled. If the individual fruit is enclosed in a labeled wrapper which gives the required fungicide information, this complies with the Food and Drug Administration regulations.

Responsibility for proper labeling lies with the shipper whose name and address must appear on the container. Countries which import citrus fruit frequently have similar fungicide tolerances to those of the United States, but the shipper should be familiar with the regulations of the country to which the fruit is to be shipped.

EXPERIMENTAL FUNGICIDES

Benlate (E. I. du Pont de Nemours & Co.) and G-20072 (Geigy Chemical Corp.) have shown value for controlling decay of Florida citrus fruit. Benlate, also called benomyl, was first distributed for experimental purposes as Fungicide 1991. Benlate is not soluble in water but has controlled decay when used in a water suspension as a dip, flood, or applied in a water-based wax emulsion. Concentrations as low as 500 ppm have effectively controlled decay (12). No peel injury due to Benlate has been observed. Benlate has very little odor, is nonirritating to the skin, and has low mamalian toxicity.

G-20072 (5-aceto-8-hydroxy-quinoline sulfate) (7) in aqueous solution has given satisfactory

control of decay in most experimental trials, especially with lemons. Mechanical peel injury of 'Pineapple' oranges treated with G-20072 was accentuated when fruit were not rinsed following treatment. Most applications were made as in-and-out or 2-minute dip treatments with G-20072 at a strength of 1,000 ppm. As formulated for experimental use, this fungicide is nonirritating to the skin and has very little odor.

LITERATURE CITED

1. Anonymous. 1969. Borax and boric acid; tolerance for residues. Fed. Reg. 34: 14650.
2. Anonymous. 1960. Tolerance for biphenyl revised to include all citrus fruit and hybrids. Fed. Reg. 25: 13631-2.
3. Anonymous. 1967. 2,4-D; tolerances for residues. Fed. Reg. 32: 12473.
4. Anonymous. 1968. Fungicide or fungistat treatment

required for fresh citrus fruit. Fla. Citrus Comm. Reg. 105-1.43.

5. Anonymous. 1967. Tolerance of 10 ppm for o-phenylphenol in citrus fruits. Fed. Reg. 32: 9159.

6. Anonymous. 1969. Thiabendazole; tolerances for residues. Fed. Reg. 34: 2021.

7. Anonymous. 1967. Technical information sheet. Geigy Agr. Chem. 3 p.

8. Fulton, H. R., and J. J. Bowman. 1924. Preliminary results with borax treatment of citrus fruits for prevention of blue mold rot. J. Agr. Res. 28: 921-968.

9. Hayward, F. W., W. Grierson, and G. J. Edwards. 1965. Packaging methods and diphenyl relation to keeping quality of tangerines and 'Valencia' oranges. Proc. Fla. State Hort. Soc. 78: 244-249.

10. Hayward, F. W., and A. A. McCornack. 1968. Changes in Dovicide A-hexamine relation to residues of o-phenylphenol of citrus fruits. Proc. Fla. State Hort. Soc. 81: 285-290.

11. McCornack, A. A., and G. Eldon Brown. 1967. Thiabendazole, an experimental fungicide for fresh citrus fruit. Proc. Fla. State Hort. Soc. 80: 232-237.

12. McCornack, A. A., and G. Eldon Brown. 1969. Benlate, an experimental postharvest citrus fungicide. Proc. Fla. State Hort. Soc. 82: 235-238.

STORAGE LIFE OF PREPARED GRAPEFRUIT HALVES¹

W. F. WARDOWSKI

Florida Extension Service, IFAS

G. ELTON BROWN

AND

PAUL J. FELLERS

State of Florida, Department of Citrus

Florida Citrus Experiment Station

Lake Alfred

ABSTRACT

Prepared grapefruit halves held at 45° F were subject to decay, especially by *Penicillium digitatum* (green mold) during the winter months. Heat treatments at 85° F for decay control only accelerated breakdown of the prepared halves. Chlorine water applied to the cut surface extended the 12-day holding period by no more than 1 day. Thiabendazole applied before cutting the fruit had no effect on keeping quality of grapefruit halves. Prepared grapefruit halves were individually wrapped with shrink film in small trays. Three types of shrink film, with and without grapefruit essence, did not differ in their effect on the keeping quality of the prepared halves. The shelf-life of the prepared grapefruit halves at 45°F was 1 week during the period of high *P. digitatum* activity.

INTRODUCTION

There is an interest in prepared grapefruit halves for the fast food trade. While there is resistance to preparing grapefruit halves in restaurants and institutions, it is believed that a prepared product requiring less labor would readily be accepted. The ultimate usefulness of prepared grapefruit halves is to sell more grapefruit.

Information from independent research projects on prepared grapefruit halves and citrus gels (3) was used in the production of gel-coated grapefruit halves (5). After a few days, halves prepared without a gel coating exhibited an unappetizing drying of the cut surface, especially the albedo, while halves coated with gel were not subject to drying (5).

Interest by the industry in selling prepared grapefruit halves prompted a study to determine the effect of several variables on the shelf-life of this product.

EXPERIMENTAL METHODS

Commercial packs of 32 count U. S. No. 1 'Marsh' grapefruit were purchased for each of the tests. Storage temperatures were 45° F., approximating the temperature used in the fast food trade.

Except where noted, there were 10 halves per treatment and each half was individually