

Postharvest Decay Control Recommendations for Florida Citrus Fruit¹

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Decay of citrus fruit is most often caused by fungal pathogens that grow and develop in the hot and wet conditions typical of the Florida climate. The most common postharvest fungal diseases of Florida citrus are Diplodia stem-end rot (*Lasiodiplodia theobromae*), Phomopsis stem-end rot (*Phomopsis citri* [teleomorph *Diaporthe citri*]), and green mold (*Penicillium digitatum*). Sour rot (*Galactomyces citri-aurantii*), anthracnose (*Colletotrichum gloeosporioides*), and, less frequently, Alternaria stem-end rot (black rot) (*Alternaria alternata*) and brown rot (primarily *Phytophthora palmivora* and *P. nicotianae*) can also cause commercially important losses of citrus fruit. Losses from these diseases can be reduced by the practices discussed below.

Humidity Control

Citrus fruit that lose water at low relative humidities after harvest are prone to stem-end rind breakdown, a physiological injury that can predispose fruit to decay. See *Stem-End Rind Breakdown of Citrus Fruit* (<http://edis.ifas.ufl.edu/hs193>) for more information. Rapid handling of fruit at high relative

humidities and application of a protective wax coating to retard desiccation are the best means of reducing fruit water loss. High relative humidity during handling, storage, and transit helps to maintain fruit turgidity and freshness and enhances healing of minor injuries, thereby reducing susceptibility to green mold. When fruit is held in plastic containers, such as pallet boxes, the relative humidity should be 90%–98%. However, when fruit is packed in fiberboard cartons, the humidity should be lower (85%–90%) to prevent carton deterioration.

Sanitation

Effective sanitation practices during postharvest handling can greatly reduce the incidence of decay. All fruit, leaves, and other trash should be removed from the floor and machinery in the packinghouse every day to reduce possible inoculum sources. Decayed fruit should be separated from sound fruit immediately after dumping on the packingline to prevent contamination of the line by fungal inoculum. Decayed fruit should not be left near the packinghouse because spores can be carried by wind

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and insects into the packinghouse. *Decayed fruit should never be repacked within the packinghouse.* Petri dishes with appropriate media should be periodically exposed in the packinghouse to check for the presence of fungicide-resistant strains of green mold.

Hot water (at least 160°F) or an approved sanitizing agent (e.g., chlorine, peroxyacetic acid, etc.) should be used to treat fruit-contact surfaces after the equipment is cleaned at the end of each day. Approved quaternary ammonia (QA) compounds may also be used but require a fresh water rinse if used at concentrations above 200 ppm. Exposure to QA residues above 300 ppm on bin and equipment surfaces can cause peel injury. Empty pallet boxes (pallet bins) should be clean and free of debris before each trip to the field. To prevent the spread of citrus canker (*Xanthomonas citri* subsp. *citri*), consult the latest sanitation requirements (<http://www.fl-dpi.com/chrp/complianceagree.html>).

Use of water dumps and soak tanks for handling Florida citrus is discouraged because of the possibility of fruit infection from fungal contamination in the water. If such tanks are necessary, free chlorine should be maintained in the water at about 100 ppm near a pH of 7 for maximum effectiveness. Free chlorine, at a minimum of 200 ppm, can also be sprayed on equipment and pallet boxes to aid sanitation. Chlorine kills decay fungi on contact, but it has little or no residual activity. The killing action of chlorine is time dependent; some response can occur in 15 seconds, but 1 minute is more effective. Organic matter reacts with free chlorine, binding it so that it is inactive. Free chlorine levels must be high enough to kill decay fungi even after some chlorine reacts with organic matter. Three disadvantages of chlorine are that it can be corrosive, cause metal to rust, and weaken (delignify) wood with continued use. Gaseous chlorine should be handled according to strict safety standards because of its toxic nature.

Effects of Degreening

Citrus fruit harvested early in the season usually have inadequate color development and require degreening before packing. See *Recommendations for*

Degreening Florida Fresh Citrus Fruits (<http://edis.ifas.ufl.edu/hs195>) for more information. During degreening, fruit are exposed to a natural plant hormone (ethylene) that stimulates the breakdown of chlorophyll and unmasks the characteristic orange and yellow colors of the peel. However, ethylene exposure also increases the incidence and severity of decays, such as *Diplodia* stem-end rot and anthracnose. Incidence and severity of these diseases are related to the length of degreening and ethylene concentration used. If degreening is necessary, fruit should first be drenched with a suitable fungicide and then degreened at 82°F–85°F with 3–5 ppm ethylene and 90%–95% relative humidity only as long as necessary to obtain adequate peel color (depending on fruit variety and degree of color break). A benefit of these degreening conditions is that they promote a curing effect that reduces the development of green mold.

Fungicides

Thiabendazole

Thiabendazole (TBZ) is a benzimidazole fungicide and is applied with bin drenchers and on the packinghouse line. Stem-end rot and green mold are both effectively controlled when TBZ is applied correctly. It also provides some control of anthracnose, but does not control sour rot, black rot, and benzimidazole-resistant strains of green mold.

Concentration and Formulation

TBZ should be applied at a concentration of 1000 ppm (0.1%) as a water suspension or at 2000 ppm (0.2%) in a water-based wax. Follow the label if the instructions are different from above because *the label is the law*.

Methods of Application

TBZ is only slightly soluble in water; therefore, suspensions must be constantly agitated to ensure uniformity of solution concentration during application.

TBZ can be applied as a recovery drench on unwashed fruit before degreening, or as a nonrecovery spray or drip on washed fruit that has

been damp-dried with absorber (donut) rolls or by other methods. Recovery drenches should contain chlorine at the proper pH to control fungal contamination, and the concentration of TBZ must be monitored periodically. Following a nonrecovery water application of TBZ to washed fruit, excess fungicide suspension may have to be removed with absorber rolls if dryer capacity is inadequate. Brushing after nonrecovery water applications reduces fungicide residues. Fruit should not be brushed or rolled in the dryer after waxes are applied except for a half turn midway through the drying operation

Imazalil

Imazalil is especially effective against green mold, including benzimidazole-resistant strains, and against mold sporulation. Imazalil is less effective than TBZ for control of *Diplodia* and *Phomopsis* stem-end rot, and it is ineffective against sour rot and brown rot. It has some activity against *Alternaria* stem-end rot (black rot).

Concentration and Formulation

Imazalil should be applied at 1000 ppm (0.1%) as a water suspension or at 2000 ppm (0.2%) in a water-based wax. Follow the label if the instructions are different from above because *the label is the law*.

Methods of Application

These are identical to the recovery and nonrecovery postharvest applications of TBZ described above, except that some heating or other sanitizers (not chlorine) are applied in imazalil bin drenchers because chlorine and imazalil are not compatible. The efficacy of imazalil is reduced in water-based wax formulations.

SOPP

SOPP (sodium o-phenylphenate) reduces green mold and provides some control of *Diplodia* and *Phomopsis* stem-end rot, sour rot, and benzimidazole-resistant molds.

Concentration and Formulation

A 2% aqueous solution of SOPP applied at pH 11.5–12.0 is the most effective treatment. One formulation contains 2% SOPP, 0.2% sodium hydroxide for pH control, and 1% hexamine to minimize phytotoxicity. Water emulsion waxes with 1% SOPP are also available, but they have little fungicidal value. Residues are expressed in terms of o-phenylphenol. Follow the label if the instructions are different from above because *the label is the law*.

Methods of Application

SOPP may be applied as a soap or foam to replace the detergent during washing. This application provides less fungicidal efficacy than an aqueous flood recovery treatment, but it helps kill inoculum from decayed fruit on the brushes and reduces the chance of infecting healthy fruit during the washing process. Unwashed or washed fruit treated with a foam or flood of SOPP should be rinsed with fresh water after treatment. Application times less than 2 minutes provide less decay control, while time exceeding 2 minutes may cause peel injuries. Washer brushes should be rinsed at the end of each day's run to remove SOPP residues that may cause matting of the brushes. Concentrations of SOPP solutions applied with hexamine should be maintained near 2.5° with a Brix hydrometer standardized at 20°C. The pH of aqueous solutions lacking hexamine *must be maintained* at 11.5–12.0 to prevent peel injury. The maximum legal residue tolerance for SOPP may be exceeded if waxes containing SOPP are applied to fruit previously treated with aqueous applications of SOPP.

Copper, Aliette[®], Phostrol[®], and ProPhyt[®]

These fungicides are applied before harvest for control of brown rot in fruit from blocks of trees that historically develop the disease or in seasons when climatic conditions favor brown rot development. Aliette[®] has a preharvest interval of 30 days before fruit can be harvested following fungicide application.

Summary of Fungicide Treatments

Effective fungicide treatments are summarized in Table 1 for the control of specific postharvest

diseases that predominate during various months of the season.

Grading before Fungicidal Treatment

Efforts should be made to apply postharvest fungicides only to fruit that are to be packed. Extensive grading after washing minimizes fungicide application to nonpackable fruit. The only exceptions are fruit that have been drenched with TBZ or imazalil before degreening and/or washed with SOPP after dumping. The Florida average packout of 40%–50% means that fungicidal costs can be reduced by not treating the remaining 50%–60% of nonpackable fruit.

Refrigeration

Decay development can be delayed by refrigeration (Table 2). Varietal and seasonal differences in susceptibility to chilling injury must be considered when selecting temperatures for cooling, storing, or transporting citrus fruits. Chilling injury is a physiological disorder that occurs when most citrus fruit (especially grapefruit, lemons, and limes) are stored at low—though not freezing—temperatures. It is most often characterized by areas of the peel that collapse and darken to form pits after at least 3–6 weeks at low shipping and storage temperatures. See *Chilling Injury of Grapefruit and Its Control* (<http://edis.ifas.ufl.edu/hs191>) for more information.

Chilling injury is often confused with another physiological disorder called postharvest pitting, which is associated with low oxygen concentrations (< 9%) within waxed fruit and is visible as collapsed oil glands. Waxes that greatly restrict gas diffusion (e.g., some shellac formulations) can increase resistance to chilling injury but may make the fruit much more susceptible to postharvest pitting. Symptoms of postharvest pitting require only about 2–4 days to develop after waxing and appear in fruit held at relatively warm (> 50°F) temperatures. Though holding grapefruit at temperatures above 50°F greatly reduces the potential for chilling injury, it can also lead to the development of severe postharvest pitting in fruit coated with such waxes that restrict gas diffusion. Thus, holding such

grapefruit at lower temperatures (e.g., 45°F) may represent the best compromise to minimize the occurrence of both disorders.

Values listed in Table 2 represent the optimum holding temperatures for different types of citrus in Florida. If receiving loading bays are not refrigerated and shipping distances are relatively short (i.e., 1–3 days), consider shipping fruit at 50°F to reduce condensation ("sweating") during delays as the fruit is moved into the cooler.

Precautions

The postharvest fungicides mentioned in this publication have been approved by the Food and Drug Administration and the Environmental Protection Agency *only* if residues do not exceed the specified tolerances. If postharvest fungicides are handled, applied, or disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, pollinating insects, and fish or other wildlife, and may contaminate water supplies. Handle all pesticides with care. Follow instructions and heed all precautions on the container label. *Remember that the label is the law.*

Residue Tolerances

Chemical residues on fruits and vegetables are monitored by industry and regulators to assure compliance. The United States and other countries set maximum residue limits (MRLs) on fresh produce for various chemicals. U.S. MRLs are rarely exceeded when the label instructions are followed. However, when MRLs set by importing countries are lower than those of the United States, use of these pesticides usually must be discontinued or modified to keep from exceeding the country's tolerances. When no tolerance is stated, then any detectable residue will usually violate tolerances. The limit of detection for chemical residues is often around 0.01 ppm, depending on the testing laboratory and chemical of interest. Violations can lead to rejected product, possible additional requirements for future shipments, and even potential increased market

restrictions for all growers/shippers of the product in the same state or country. In addition, individual buyers may set their own more restrictive standards. Similar to buyer-imposed food safety standards, buyer-imposed MRL standards, especially from large buyers, can significantly impact how pesticides are used in the field and packinghouse.

Because MRLs for various export markets change frequently, growers, packers, and shippers are encouraged to stay informed about such changes through their respective trade groups and through one or more web resources. A table of citrus MRLs for domestic and important export markets is posted on the University of Florida Postharvest Resources website (<http://postharvest.ifas.ufl.edu>) and is updated as needed throughout the year. This site also includes links to other useful MRL sites, such as the U.S. Foreign Agricultural Service's International MRL database (<http://www.mrldatabase.com/>) and sites for specific markets, such as the European Union, Canada, and Japan. While all these websites are useful as a starting point, no guarantee can be made as to their accuracy; always verify these values with other knowledgeable sources.

Table 1. Major postharvest decays, seasonal development, fruit susceptibility, and effective fungicide treatments

Disease	Months of prevalence	Varietal susceptibility	Treatments ^a
Brown rot	Aug–Dec	'Hamlin' and 'Navel' orange, grapefruit	Preharvest (Aliette ^{®b} , 5 lbs/a; Phostrol [®] , 4.5 pints/a ^c ; ProPhyt ^{®c} , 4 pints/a; copper ^c , label rate)
Diplodia SER ^d	Sept–Dec	All	Bin drench (TBZ ^e or imazalil ^f , 1000 ppm) Packingline (TBZ, 1000 ppm aqueous, 2000 ppm water wax)
Anthracnose	Sept–Nov	'Robinson' and 'Fallglo' tangerines, 'Navel' orange, grapefruit	Bin drench (TBZ, 1000 ppm)
Green mold	Dec–June	All	Bin drench (TBZ or imazalil, 1000 ppm) Packingline (SOPP ^g , 2%; TBZ and/or imazalil ^h , 1000 ppm aqueous, 2000 ppm water wax)
Sour rot	Nov–Feb Apr–June	Specialty fruits Grapefruit and oranges	Packingline (SOPP, 2%)
Phomopsis SER	Jan–June	All	Packingline (TBZ and/or imazalil, 1000 ppm aqueous, 2000 ppm water wax)
Alternaria SER	July–Sept	Oranges and grapefruit (summer storage)	Packingline (Imazalil, 1000 ppm aqueous, 2000 ppm water wax)
<p>^aPostharvest materials are specified as ppm or % of active ingredient. Preharvest fungicides except copper are indicated as rates of formulation.</p> <p>^bApply Aug–Dec, 30-day preharvest interval.</p> <p>^cApply Aug–Dec, 0-day preharvest interval.</p> <p>^dStem-end rot.</p> <p>^eTBZ - thiabendazole.</p> <p>^fUse when TBZ residues are a problem for fruit going to juice.</p> <p>^gSOPP - sodium o-phenylphenate.</p> <p>^hEffective for sporulation control on fruit within packed cartons.</p>			

Table 2. Optimum holding temperatures for maximum quality and shelf life of fresh Florida citrus fruit

Citrus type	Optimum holding temperatures (°F)
Grapefruit	50–60
Lemons, limes	50
Mandarin-type fruits	40
Oranges	32–34

Note: Somewhat lower temperatures can be used if fruit coatings are used that substantially restrict gas permeability (e.g., some shellac formulations).