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Postharvest Decay Control Recommendations for Florida Citrus Fruit[1]

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Decay of citrus fruit is caused by fungi which grow and develop under hot and wet conditions typical of the Florida climate. The most common postharvest fungus diseases of Florida citrus are stem-end rot (caused by *Lasiodiplodia theobromae* or *Diaporthe citri*) and green mold (caused by *Penicillium digitatum*). Sour rot (caused by *Galactomyces citri-aurantii*) and anthracnose (caused by *Colletotrichum gloeosporioides*) and, less frequently, Alternaria stem-end rot (black rot) (caused by *Alternaria citri*) and brown rot (primarily caused by *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 subjected to dehydration at low relative humidities after harvest are prone to stem-end rind breakdown, a physiological injury which can predispose fruit to decay. Rapid handling of fruit at high relative humidities and application of a protective wax coating to retard desiccation are the best means of reducing stem-end rind breakdown. High relative humidity during handling, storage, and transit helps to maintain fruit turgidity and freshness and to enhance healing of minor injuries thereby reducing susceptibility to green mold. When fruit is held in wooden containers such as pallet boxes, the relative humidity should be 90 to 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 and taken out to reduce possible sources of inoculum. Decayed fruit should be separated from sound fruit on the packingline immediately after the dumper to prevent contamination of the line by decay fungi. Decayed fruit should not be left near the

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packinghouse because spores can be carried by wind 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 periodically treat surfaces that contact citrus fruit. Approved quaternary ammonia compounds may also be used, but require a fresh water rinse if used at concentrations above 200 ppm. Exposure to even residual levels of 300 ppm or more of quaternary ammonia on bin and equipment surfaces can cause peel injury. Empty pallet boxes (pallet bins) should be clean and free from debris before each trip to the field. To prevent the spread of citrus canker (*Xanthomonas axonopodis*) consult the latest sanitation requirements (http://doacs.state.fl.us/canker/complianceagree.htm).

Use of water dumps and soak tanks for handling Florida citrus is discouraged because of the probability of fruit infection from fungi that contaminate the water. If such tanks are necessary, available chlorine should be maintained in the water at about 100 ppm near a pH of 7 for maximum effectiveness. Chlorine at a minimum of 200 ppm can also be sprayed on equipment and pallet boxes to aid sanitation. Chlorine will kill 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 one minute is more effective. Organic matter reacts with chlorine. Chlorine levels must be high enough to kill decay fungi even after reaction of some active material with organic matter. Two disadvantages of chlorine are that it can be corrosive and cause metal to rust and weaken wood by delignification 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. During degreening, fruit are exposed to a natural plant hormone (ethylene) which 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 stem-end rot and anthracnose. Incidence and severity of these diseases are related to the length of degreening and concentration of ethylene used. If degreening is necessary, fruit should first be drenched with a suitable fungicide and then degreened at 82-85°F with 3 to 5 ppm ethylene and 90-95% relative humidity only as long as necessary to obtain adequate degreening (depending on fruit variety and degree of color break). A benefit of these degreening conditions is that they promote a curing effect which reduces the development of green mold.

Fungicides

Residue Tolerances

Three postharvest citrus fungicides approved for citrus are listed in Table 1 with their maximum USA, Canadian, European Union, Japanese, and Codex residue tolerances. Internet links to the latest tolerance can be found at the University of Florida Postharvest Programs and Information website (http://postharvest.ifas.ufl.edu).

Benomyl and Thiabendazole

Benomyl (Benlate) and thiabendazole (TBZ) are benzimidazole fungicides, and are effective against the same types of decay. Benlate is applied only as a preharvest spray and TBZ is applied with bin drenchers and on the packinghouse line. Stem-end rot and green mold are both effectively controlled when either of these fungicides is applied correctly. These materials also provide some control of anthracnose, but do not control sour rot, black rot, and benzimidazole-resistant strains of green mold.

Concentration and Formulation - TBZ should be applied at a concentration of 1,000 ppm (0.1%) as a water suspension or at 2,000 ppm (0.2%) in a water-based wax.

Methods of Application - Benlate and TBZ are only slightly soluble in water; therefore, suspensions must be constantly agitated to insure uniform treatment.

Table 1. Fungicides approved by the U.S. Food and Drug Administration with residue tolerances in the U.S.A., Canada, European Union, and Japan. Residue tolerances established by the Codex Alimentarius are also reported.

Fungicide Chemical Name	Tolerance (ppm)				
	USA	Canada	European Union	Japan	Codex
Imazalil	10	5	5	5	5
Sodium o-phenylphenate (SOPP)	10	10	12	10	10
Thiabendazole (TBZ)	10	10	5	10	10

Preharvest Treatment - Preharvest applications of Benlate 50W at 2 pounds/acre will reduce decay, particularly when postharvest fungicide applications of other fungicides have to be delayed until after degreening. Preharvest Benlate applications in groves should be made two days to three weeks before harvest.

All sales of Benlate were discontinued by December 31, 2002. However, there is no end of use date for growers to apply Benlate. The EPA has proposed cancellation of the tolerance for citrus on January 1, 2008. That date is based on the assumption by the EPA that the last use of Benlate by growers will be in the 2003 growing season ending December 31, 2003. While it will not be illegal to apply Benlate after the 2003 growing season, commodities with residues of benomyl (the active ingredient) in them after the tolerance has been cancelled will be illegal unless it can be demonstrated that the Benlate was applied before the end of 2003.

Postharvest Treatment - 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 (do-nut) 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 will reduce 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 Benlate or 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 1,000 ppm (0.1%) as a water suspension or at 2,000 ppm (0.2%) in a water base wax.

Methods of Application - These are identical to nonrecovery postharvest applications of TBZ described earlier. The efficacy of imazalil is reduced in water 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 to 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 have little fungicidal value. Residues are expressed in terms of o-phenylphenol.

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 infection of

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 which 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 to 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, 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 time limitation of 30 days before fruit can be harvested following fungicide application.

Summary of Fungicide Treatments

Effective fungicide treatments are summarized in Table 2 for the control of specific postharvest diseases that predominate during various months of the season.

Grading before Fungicidal Treatment

Applying Fungicides to Graded Fruit - Efforts should be made to apply postharvest fungicides only to fruit that are to be packed. Extensive pre-grading after washing minimizes fungicide application to non-packable 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 to 50% means that fungicidal costs can be reduced by not treating the remaining 50 to 60% of non-packable fruit.

Refrigeration

Decay development can be delayed by refrigeration (Table 3), especially when used with fruit that has been treated with a postharvest fungicide. 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, but non-freezing temperatures. It is most often characterized by areas of the peel that collapse and darken to form pits after at least 3 to 6 weeks at low shipping and storage temperatures. For **un-waxed fruit,** early season grapefruit should be shipped at 60°F to avoid chilling injury. The temperature may be reduced to 55°F and then to 50°F for fruit that is more mature. Late-season

Table 2. Major postharvest decays, seasonal development, fruit susceptibility, and effective fungicide treatments.

Disease	Months of Prevalence	Varietal Susceptibility	Treatments[z]
Brown Rot	Aug - Dec	Hamlin and Navel Orange, and Grapefruit	Preharvest (Aliette[y], 5 lbs/A; ProPhyt[x], 4 pints/A; copper[x], 4 lbs metallic/A)
Diplodia SER[w]	Sept - Dec	All	Preharvest (Benlate[v], 2 lbs/A) Bin drench (TBZ[u] or Imazalil[t] 1000 ppm) Packingline (TBZ, 1000 ppm aqueous, 2000 ppm water wax)
Anthracnose	Sept - Nov	Robinson and Fallglo tangerines, Navel orange and Grapefruit	Preharvest (Benlate, 2 lbs/A) Bin Drench (TBZ, 1000 ppm)
Green Mold	Dec - June	All	Preharvest (Benlate, 2 lbs/A) Bin Drench (TBZ or Imazalil, 1000 ppm) Packingline (SOPP[s], 2%; TBZ and/or imazalil[r], 1000 ppm aqueous, 2000 ppm water wax)
Sour Rot	Nov - Feb Apr - June	Specialty fruits Grapefruit and oranges	Packingline (SOPP, 2%)

Table 2. Major postharvest decays, seasonal development, fruit susceptibility, and effective fungicide treatments.

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)

[z]Postharveest materials are specified as ppm or % of active ingredient. Preharvest fungicides except copper are indicated as rates of formulation.
[y]Apply Aug - Dec, 30 day preharvest interval.
[x]Apply Aug - Dec, 0 day preharvest interval.
[w]Stem-end rot.
[v]Apply within 3 weeks of harvest, 2 day preharvest interval.
[u]TBZ - thiabendazole.
[t]Use when TBZ residues are a problem for fruit going to juice.
[s]SOPP - sodium orthophenylphenate.
[r]Effective for sporulation control on fruit within packed cartons.

grapefruit picked from trees with new spring growth may again become highly susceptible to chilling injury as well as to decay. Sixty °F is a good shipping temperature for late-season grapefruit and represents a compromise between excessive chilling injury and disease. **Waxed** citrus can be held at somewhat lower temperatures because waxing reduces citrus fruit susceptibility to chilling injury. Transit temperatures for fruit that has been held in storage should not exceed storage temperatures.

Table 3. Optimum holding temperatures for maximum quality and shelf life of fresh Florida citrus fruit.

Type of Citrus	Optimum Holding Temperatures (°F)
Grapefruit	50 - 60
Lemons, limes	50
Mandarin-type fruits	40
Oranges	32-34

[z]Waxed citrus should be held at somewhat lower temperatures to reduce potential postharvest pitting development and because waxed fruit are less susceptibility to chilling injury.

Chilling injury is often confused with another physiological disorder called postharvest pitting that is caused by low-oxygen concentrations (< 9%) within **waxed** fruit and is visible as collapsed oil glands. Waxes that greatly restrict gas diffusion (e.g., shellac) into citrus fruit 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 to 4 days to develop after waxing and appear in fruit held at relatively warm (> 50°F) temperatures. Though holding fruit at temperatures above 50°F greatly reduces the potential for chilling injury, it can also lead to the development of severe postharvest pitting in waxed fruit. Thus, holding **waxed** grapefruit at lower temperatures (e.g., 45°F) may often represent the best compromise to minimize the occurrence of both disorders.

Values listed in Table 3 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 to 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, fish or other wildlife, and may contaminate water supplies. Handle all pesticides with care. Follow instructions and heed all precautions on the container label.