POSTHARVEST DECAYS OF FLORIDA CITRUS FRUIT

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INTRODUCTION

Fresh citrus fruit produced in a humid, high rainfall climate like Florida's generally has potential for higher decay levels than fruit produced in more arid climates. All of the fungi known to cause citrus decay can be found in Florida. Decay levels of 40-50% or more can occur within 2-3 weeks of harvest in extreme instances without proper control measures. All costs of production, harvesting, packing and transportation are lost when decay occurs at the marketplace.

The intent in this discussion is to describe the various decays of Florida fresh citrus and the approaches to effective prevention and control. Consumer confidence in our citrus fruit can be maintained only if it has consistently good keeping quality.

DECAYS OF FLORIDA CITRUS

The major postharvest diseases are listed in Table 1. The causal fungi either have long quiescent periods of several months after invading the fruit before lesions begin to develop or they begin to cause decay within days after infection. The lesions develop either at the stem-end from quiescent hyphae in necrotic tissue on the button (calyx and disk) surface, or anywhere on the intact or injured rind surface from quiescent or germinating spores.

Stem-end Rot (*Diplodia natalensis*) - This is a major decay in the early season on degreened fruit. Spores of this fungus are produced during the summer growing season in pycnidia on deadwood in the tree canopy. They are carried in water during irrigation or rainfall to the button of the fruit where they germinate and become established in dead tissue of the button surface. After harvest, the fungus grows through natural openings formed at abscission. Degreening enhances *Diplodia* stem-end rot because ethylene stimulates abscission. The temperature of 85F used for degreening is also optimum for the growth of this rapidly growing fungus, and the high humidity required in the degreening room to prevent fruit desiccation favors fungal growth.

The fungus penetrates the rind and core of the fruit at the stem-end. The hyphae progress rapidly down the spongy core, usually reaching the stylar-end much sooner by this route, than through the rind. The decay proceeds unevenly through the rind, thereby producing finger-like projections of brown or black tissue. Typically, the decay appears at both the stem and stylar ends of the fruit before involving the whole fruit. Initially, the decay is firm; but later it becomes wet and mushy. Surface mycelium appears only at advanced stages of infection in very moist environments. The decay does not usually spread from infected to healthy fruit in packed containers.

Anthracnose (*Collectotrichum gloeosporioides*) - This is a major decay of only degreened Robinson tangerines. Spores are produced in acervuli on deadwood in the tree canopy and carried in water to fruit surfaces during summer rains. Spores germinate and form appressoria which remain quiescent until fruit are treated with ethylene during degreening. Ethylene stimulates the appressoria to germinate and form infection hyphae which penetrate the uninjured rind, particularly when degreening exceeds 36 hours. The lesions may occur around the button or on any portion of the fruit. They appear firm and silvery-grey and later become softer and brown to black in color. Anthracnose may also develop in the absence of ethylene, but only at injuries, bruises or otherwise weakened areas of the fruit surface.

Table 1. Major postharvest diseases of Florida citrus fruit, causal fungi and type, site and spread of infection.

Disease	Causal fungus	Infection		
		Type	Site	Spread[z]
Stem-end rot	Diplodia natalensis	Quiescent	Natural openings at the stem-end	No
Anthracnose	Colletotrichum gloeosporioides	Quiescent	Intact or injured rind	No
Brown rot	Phytophthora citrophthora Phytophthora parasitica	Active	Intact rind	
Green mold	Penicillium digitatum	Active	Injured rind	No
Sour rot	Geotrichum candidum	Active	Injured rind	
Stem-end rot	Phomopsis citri	Quiescent	Natural openings at the stem-end	No
Stem-end rot (Black rot)	Alternaria citri	Quiescent	Natural openings at the stem-end	No
Blue mold	Penicillium italicum	Active	Injured rind	Yes

z Decay spreads from infected fruit to adjacent healthy fruit in packed cartons.

Brown rot (Phytophthora citrophthora, P. parasitica) - Brown rot is a localized disease, most frequently found on the East Coast, that may recur year after year in the same grove. It may be severe in seasons with unusually long durations of rainfall and wetting caused by slow-moving tropical depressions or hurricanes. Such conditions are more likely to occur in the early fall than later in the season and therefore, it is mostly the early maturing cultivars that are affected. Significant losses are attributed to P. citrophthora which has the potential to produce more inoculum than P. parasitica under comparable climatic conditions. Under wet conditions, zoospores are splashed from the soil onto low hanging fruit. Spores can be produced on these fruit and then be splashed higher into the canopy. Infected fruit surfaces are firm and leathery, light to dark-brown and retain the same degree of firmness and elevation as the surrounding healthy surfaces. Delicate white mycelium forms on the rind under humid conditions. Fruit infected with Phytophthora have a characteristic pungent rancid odor. The disease can spread from infected to healthy fruit in packed cartons.

Green mold (Penicillium digitatum) - This is a major decay which develops only if there are injuries in the rind, but even minor injuries involving only a few oil glands are sufficient to allow infection. Spores of the fungus are airborne and are produced on the surfaces of infected fruit. Large numbers of these spores are produced during the winter months by infections in the grove on fallen, split fruit and in the packinghouse on injured fruit. Initially, the decay appears as a soft, watery, slightly discolored spot. After a few days, sparce white mycelium develops on the lesion surface followed by the production of olive-green spores. The sporulating area is surrounded by a broad zone of white mycelium and an outer zone of softened rind. Spores are easily dispersed if the fruit is handled or shaken or if it is exposed to air currents. Spores from infected fruit in packed cartons will affect the value of the healthy fruit by settling on them and causing soilage. The decay does not spread from infected to healthy fruit in packed cartons.

The incidence of green mold is decreased by the conditions used in the degreening process. High temperatures and humidities of the degreening room favor the healing of any superficial injuries in the flavedo. The fungus grows slowly at the high degreening room temperature and is unable to penetrate many of the injuries before they heal and form a barrier to infection.

Sour rot (*Geotrichum candidum*) - This is a major decay of specialty fruits, such as tangerines, tangelos and 'Temple' oranges, and of quite mature round oranges and grapefruit. Infections occur mostly through those injuries that extend into the albedo. The fungus is present in the soil and is more prevalent on lower fruit of the tree canopy especially in dirt and debris on scarred fruit surfaces or under the button. The fungus may not produce an active lesion unless the peel has a relatively high water content and the fruit are held at high relative humidities.

Initial symptoms of sour rot are similar to those of green and blue mold. The lesion first appears water-soaked, light to dark yellow, and slightly raised. The cuticle is more easily removed from the epidermis than from lesions formed by *Penicillium*. At high relative humidities, the lesion may be covered with a yeasty, sometimes wrinkled layer of white or cream colored mycelium. The fungus degrades the fruit thoroughly, causing it to disintegrate into a slimy and watery mass.

Fruit flies are attracted to sour rot and will spread inoculum from infected to healthy injured fruit in the packinghouse. Hyphae in rotted fruit fragment into chains of spores which contaminate packinghouse equipment and water in drenchers and soak tanks. Sour rot will spread from infected to healthy fruit in packed cartons and throughout cartons in a stack during storage or export. Sour rot is often associated with green mold and is stimulated by its presence.

Stem-end rot (*Phomopsis citri*) - This major decay is more prevalent during the cooler winter months or in fruit placed in cold storage for summer sale. The life cycle of this fungus, which also causes melanose, is similar to that described for *Diplodia*. *Phomopsis* develops more slowly than *Diplodia*, and it usually causes some shriveling of the decayed tissue at the stem-end of the fruit. A clear line of demarcation is formed at the junction between diseased and healthy rind. Decay causes a tan or brown discoloration, and progresses equally rapidly through the core and rind until the entire fruit is encompassed. The decay does not spread from infected to healthy fruit in packed cartons.

Stem-end rot (*Alternaria citri*) - This minor decay can develop either at the stylar or stem-ends of the fruit, causing black discoloration of the peel and core. Airborne spores in the grove produced on ground litter infect dead tissue of the button and tissues at the stylar-end through growth cracks. Quiescent infections at the stylar-end of navel oranges and 'Orlando' tangelos, in particular, will cause premature color break and fruit drop. Infections at the stem-end, similar to those caused by *Diplodia* and *Phomopsis*, develop after harvest but only after lengthy storage. Stem-end rot is not normally found in fruit consumed within 3-4 weeks, but does develop in 8-10 weeks in oranges or grapefruit stored for summer sale. In some fruit, the fungus develops internally and remains undetected until the fruit is peeled for eating. At that time, the core will be composed of rotted, black tissue (black rot).

Blue mold (*Penicillium italicum*) - This is a minor decay with a life cycle like *P. digitatum*. Blue mold develops less rapidly than green mold at ambient temperatures, but will still develop at low temperatures. It is, therefore, more often encountered than green mold in fruit held in cold storage.

Initial symptoms are very similar to those of sour rot. The diseased tissue is soft, watery, slightly discolored, and easily punctured. The lesions do not enlarge as rapidly as those of green mold. A white, powdery growth of mycelium develops on the lesion surface and is soon followed by the development of a blue spore mass, leaving only a narrow white fringe of mycelium around the lesion. A pronounced halo of water-soaked, faded tissue is present between the fringe of mycelium and sound tissue. Blue mold, unlike green mold, will also spread in packed cartons causing pockets of diseased fruit to develop. In addition, blue mold also creates a problem in packed cartons through soilage, as with green mold.

Control of Postharvest Diseases

Cultural practices - Some cultural practices have been shown to reduce certain postharvest diseases by affecting inoculum production. Incidences of *Diplodia* and *Phomopsis* stem-end rot are less in fruit harvested from trees with small amounts of dead wood in the canopy. Trees with less dead wood can be produced by using effective cultural practices and by pruning dead wood from the tree canopy. Brown rot is reduced by cultural practices which minimize long periods of wetness in the field. These are proper irrigation management, mowing to prevent ground vegetation growing too tall, pruning to remove low hanging branches, and soil drainage.

Harvesting practices - Care in harvesting is as important as fungicide treatment for reducing decay development. By minimizing scratches, punctures and plugging with careful harvesting and handling, the 2 major wound decays, green mold and sour rot, can be reduced significantly. Contamination by the sour rot fungus can be minimized by preventing the fruit from contacting the soil during harvest. Harvesting by pulling rather than clipping can reduce the incidence of *Diplodia* stem end rot (SER) by removing at least some of the buttons that harbor the pathogen.

Diplodia SER and anthracnose can be reduced if the degreening time is decreased by spot-picking for natural color or by delaying harvest until more color develops. Following known infection periods of brown rot, harvesting should be delayed for 4 to 6 days until infected fruit drop to the ground to minimize the risk of infected fruit reaching the packinghouse.

Packinghouse practices - Effective and careful packinghouse handling is needed to prevent fruit desiccation and injuries that encourage decay development. Proper conditions of humidity, ethylene and temperature should be maintained during degreening and storage. *Diplodia* SER and anthracnose are significantly enhanced by ethylene concentrations exceeding those required for optimal degreening. Humidity levels of at least 90% are required during degreening to heal minor injuries and enhance resistance to green mold.

Airborne populations of *Penicillium* can be minimized by exhausting spores from the dump area and controlling air movement from the dump to the packing area. Sanitary practices should be applied to prevent the accumulation of spores on equipment surfaces, in treating solutions, and in the atmosphere of the packing and storage facilities. Disinfectants such as chlorine, quaternary ammonium chloride, formaldehyde and alcohol are useful for preventing inoculum build-up of green mold and sour rot.

Airborne populations of *Penicillium* should be routinely checked for resistance to postharvest fungicides. Fungicide-treated fruit infected with *Penicillium* should never be repacked in the packinghouse for the fear of releasing resistant spores into the atmosphere. Alternate applications or mixtures of fungicides of unrelated chemistry should be used to suppress sporulation and to delay the possible buildup of resistance.

Immediate cooling of packed fruit effectively delays development of decay, particularly *Diplodia* SER and sour rot.

Table 2. Relative effectiveness of the approved postharvest fungicides against citrus fruit decay.

Fungicide	Stem-end rot Diplodia	Stem-end rot Phomopsis	Stem-end rot Alternaria	Green mold	Blue mold	Sour rot	Anthracnose	Brown rot
Thiabendazole	+++[z]	+++	0	+++	+++	0	+	0
Benomyl	+++	+++	0	+++	+++	0	++	0
SOPP[y]	+	+	0	++	++	+	0	0
Diphenyl	+	+	0	++	++	0	0	0
Imazalil	++	++	+	+++	+++	0	0	0

z Control: 0 = none; + = some; ++ = moderate; +++ = good

y Sodium orthophenylphenate

<u>Chemical control</u> - Effective control of the major decays except sour rot can be obtained with fungicides. An objective rating of the efficacy of the fungicides approved for citrus is presented in Table 2. Thiabendazole and benomyl are chemically similar as are SOPP and diphenyl. *Penicillium digitatum* and *P. italicum* can become resistant to fungicides, but development occurs more slowly to imazalil than to the other fungicides. Specific whole fruit residue tolerances are established for each fungicide and these may vary somewhat among countries. For example, Japan has established tolerances only for thiabendazole, SOPP and diphenyl.

Field use of fungicides for the control of postharvest diseases is restricted to applications of copper or benomyl. Copper can be applied as early as August or September to early- or mid-season cultivars for controlling brown rot. A second treatment may be needed if the year is unusually wet. Benomyl can be applied within 3 weeks of harvest, and it is applied particularly to provide protection against Diplodia SER and green mold when the postharvest fungicide treatment is delayed, as it may be if the fruit has to be degreened. Use of the benomyl spray may encourage buildup of resistant strains of green mold in the field which then are not effectively controlled with applications of benomyl or thiabendazole in the packinghouse.

Control of decay in degreened fruit can also be achieved by applying drenches of benomyl or thiabendazole to pallets of fruit before degreening. Treatments have been applied to pallets on the truck or after unloading. Fungicide suspensions should be chlorinated (50-100 ppm free, active chlorine, pH 6.5-7.5) to eradicate *G. candidum*, *Phytophthora spp.* and resistant spores of *Penicillium* that may accumulate in the drencher. Once the drench suspension becomes dirty, an environmentally safe procedure is required for disposal.

Sodium orthophenylphenate is commonly applied in a drench or foam during the washing process for decay control and for disinfecting fruit to comply with the canker regulations. Not only does this treatment provide some control of decay in infected fruit, it also sanitizes the brushes and reduces contamination of healthy fruit by *Penicillium* or *Geotrichum*. Recovery drench applications of SOPP for 2 minutes provide better decay control than foam applications for 30-45 seconds. The fungicide may be phytotoxic if proper pH and treatment time and conditions are not maintained, particularly on tender, early-season degreened fruit.

Benomyl, thiabendazole or imazalil are commonly applied in aqueous non-recovery sprays or mists to washed fruit rotating on brushes saturated with the fungicide. Problems with contamination or dilution do not occur with this system like they do in recovery drenches. Excess water should be removed from the washed fruit to prevent dilution of the fungicide. Removal of some of the fungicide residues by brushes in polisher-driers may occur and possibly reduce efficacy of imazalil against sporulation of Penicillium. With the increased use of water waxes, many packinghouses apply benomyl, thiabendazole or imazalil in the wax in a similar nonrecovery application. Since some loss in efficacy occurs, concentrations of the fungicides are doubled in wax applications. Even then, control with imazalil of Diplodia SER or green mold developing in post treatment injuries is not as effective as with aqueous applications. Benomyl is unstable in highly alkaline water waxes (pH 9-10), and suspensions should be used immediately. Equipment breakdowns that interrupt the fungicide applications are quickly discerned because of the lack of wax coverage.

Diphenyl is a volatile fungistat that prevents decay only while an effective concentration is present in the atmosphere surrounding the fruit. The major use of the material is to prevent sporulation of Penicillium. The fungistat is impregnated into pads that are inserted in the carton at packing. These pads must be stored in air-tight containers before use to prevent loss of diphenyl. Early harvested fruit and fruit stored at higher temperatures tend to absorb more diphenyl. Oranges and mandarins absorb at least twice as much diphenyl per unit of fruit surface as lemons or grapefruit. The odor imparted in diphenyl is objectionable to some consumers. However, it is detectable for only 2 or 3 days after fruit are removed from the atmosphere. Decays will resume development within a week after the fruit are removed from the diphenyl vapors.

SUMMARY

Good cultural, harvesting, handling and fungicide practices culminate in effective decay control. Lack of attention to any one of these factors will reduce control efficiency. With the recent development of some quite effective fungicides, the fresh fruit industry has tended to place less emphasis on these other factors, particularly that of good harvesting practices. The importance of careful harvesting can not be overemphasized because, in spite of effective fungicides, keeping quality of some cultivars, particularly 'Dancy' tangerine, has been deteriorating over the last few years. If present harvesting practices persist, the 'Dancy' may eventually disappear from the market.

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