CITRUS DISEASES-POSTHARVEST

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Introduction

Diseases that occur after harvest can have a significant impact on keeping quality of fresh citrus fruit. Levels of decay can often reach as much as 20-40% in instances when fruit are not treated with fungicides and/or placed in refrigeration. In an effort to enhance sales of fresh citrus, efforts are being made to develop new markets, particularly for export. Decay must be controlled for periods of months in such instances to allow time for distribution and retail before consumption. Other situations of extended storage may occur when consumer demand is weak or when markets are glutted, and also when efforts are made to extend the season into the summer months. Losses that occur during postharvest handling represent economic losses in costs of production, harvesting, packing, marketing and transportation. Decay also causes loss of consumer confidence in fresh citrus quality and discourages repeat sales.

The incidence of decay is quite variable and depends upon the area of production, the variety of fruit, condition of the trees, the environmental growing conditions, harvesting procedures, conditions of packing including effectiveness and method of fungicide application, and the postharvest environment. Due to its sub-tropical growing conditions, the Florida environment is quite favorable for the development of numerous fungi that have potential to cause major postharvest losses (Table 1).

Development of Postharvest Diseases

Preharvest infections. Fungi causing postharvest diseases may possess a long inactive (quiescent) stage after infection before causing disease symptoms, or symptoms may develop shortly after infection (active) (Table 1). The fungi causing diplodia, phomopsis and alternaria stem-end rot become established in necrotic tissue on the button (calyx and disk) surface. *Diplodia* and *Phomopsis* are carried to the button by water borne spores, while *Alternaria* spores are usually airborne. These fungi remain inactive in this dead tissue and do not penetrate into the stem-end of the fruit until the button senesces after ethylene treatment or extended periods of storage.

Fungi causing anthracnose and brown rot develop on any portion of the rind surface. Spores of these two fungi are water borne, but those of the anthracnose fungus have a long quiescent period before disease is expressed. *Colletotrichum*, the cause of anthracnose, survives this period in the form of thick-walled structures called appressoria, that remain attached to the fruit surface. Many

Table Postharvest diseases of Florida citrus, type and site of infection, month of prevalence and varietal susceptibility.

Disease and casual fungus	Infection: Type	Infection: Site	Month of prevalence	Varietal occurrence
Brown rot *(Phytophthora citrophthora)* *(P. nicotianae = P. parasitica)* *(P. palmivora)*	Active	Intact rind	Aug-Dec	Hamlin and navel orange and grapefruit
Diplodia stem-end rot *(Diplodia natalensis)*	Quiescent	Button	Sept-Dec	All varieties
Anthracnose *(Colletotrichum gloeosporioides)*	Quiescent	Intact or Injured rind	Sept-Nov	Robinson and Fallglo tangerines, navel orange, and grapefruit
Green mold *(Penicillium digitatum)*	Active	Injured rind	Dec-June	All varieties
Sour rot *(Geotrichum candidum)*	Active	Injured rind	Nov-Feb	Tangerine, tangelos, navel and Temple oranges
			Apr-June	Late-season oranges and grapefruit
Phomopsis stem-end rot *(Phomopsis citri)*	Quiescent	Button	Jan-June	All varieti
Alternaria stem-end rot *(Alternaria citri)*	Quiescent	Button	July-Sept	Oranges and grapefruit (summer cold storage)
Blue mold *(Penicillium italicum)*	Active	Injured rind	July-Sept	Oranges and grapefruit (summer cold storage)

of these structures have not germinated and do not do so until fruit are treated with ethylene at degreening. After penetration, disease often develops. *Phytophthora* spores splashed to the fruit surface will germinate, and the germ tubes will immediately penetrate the rind and induce brown rot in only a matter of a few days.

Postharvest infections. Green and blue mold and sour rot are wound pathogens that are activated upon the release of moisture and nutrients at injury sites of the fruit rind. Spores of *Penicillia* are airborne to fruit surfaces where infection occurs when injuries are formed during harvesting and/or handling. *Geotrichum*, the cause of sour rot, is present in soil particles that are water-splashed or wind-borne to the button area and fruit surface. *Penicillium* will infect through very minor injuries, such as an abrasive injury from sand particles that damage individual oil glands. *Geotrichum* requires more extensive damage, a frequent example is when fruit are plugged during harvest. These fungi can also contaminate fruit in the packinghouse environment through dispersal in water or from fruit contact with contaminated equipment surfaces.

Control

Reduction of field inoculum. Good cultural practices that produce trees with minimal deadwood, or removal of deadwood by pruning can aid in reduction of diplodia and phomopsis stem-end rot or anthracnose since dead substrate is required for spore production. Observable reductions in green mold have been achieved by keeping the orchard floor free of fallen fruit to reduce sporulation on infected fruit and occurrence of air-borne spores that contaminate surfaces of fruit in the tree canopy. Brown rot can be reduced by improving ventilation under the tree canopy to shorten durations of high relative humidity and wetness required for inoculum production. Proper irrigation, soil drainage management and planting of trees on well-drained soils will also reduce conditions conducive to inoculum formation.

Harvesting practices. Since major disease losses from mold and sour rot occur as a result of fruit injury, it is obvious that fruit should be carefully harvested to minimize damage. Fruit should not be allowed to contact the soil because soil particles cause abrasive injuries during fruit handling and harbor inoculum of *G. candidum*.

Time of harvest in relation to period of the day or days following irrigation or heavy rainfall can influence development of decay and/or specific peel injuries that lead to decay. In the case of brown rot, harvest can be delayed at least two weeks after infection in the absence of reinfection, to allow infected fruit to fall to the ground. Harvests should also be avoided from poorly drained groves during rainy periods, and from limbs in the lower part of the tree canopy where probabilities of fruit infection are greatest. Turgid fruit harvested in early morning and/or immediately after heavy irrigation or rainfall is more prone to injury during harvest that leads to more extensive development of green mold and sour rot. Delay of harvest for a few days after significant rainfall or harvest of trees on the highest, driest, and most open area in the grove will help ameloriate these quality problems.

Early season harvests that require extensive degreening should be made from trees with minimal dead wood because of the less likelihood of excessive inoculum of the stem-end rot fungi. Efforts to harvest fruit with better natural color development to shorten the time of degreening will also help reduce disease pressure from these fungi.

Containers of harvested fruit should be removed carefully and immediately from the field to minimize physical injuries and heat or sunburn damage to the fruit. Respiration and subsequent off-flavors can be enhanced significantly by physical damage and high temperature.

Degreening. Degreening of citrus fruit with ethylene is required during early-season harvest to enhance the orange and yellow fruit colors that stimulate consumer appeal and that are required if Florida fruit is going to compete successfully with fruit from more arid producing regions.

Temperatures in the range of 82-85°F should be maintained in the degreening room to obtain the most rapid removal of chlorophyll so degreening time can be kept to a minimum. Relative humidities in the degreening room should be maintained above 92% to prevent dehydration and to encourage healing of minor injuries which reduces susceptibility to green and blue mold. Ethylene levels should be maintained at 5 to no more than 10 ppm. These concentrations should be accurately maintained because levels higher than these will not enhance the degreening rate but will stimulate significant development of diplodia stem-end rot and/or anthracnose. Air circulation in degreening rooms must be adequate to equalize conditions of ethylene concentration, relative humidity, and temperature throughout the room atmosphere surrounding the mass of fruit and remove excessive concentrations of carbon dioxide that extend the degreening time causing an increase in decay. The rate of degreening is reduced at concentrations of 0.1% and nearly inhibited at 1.0% or higher.

Dumping, grading, washing & waxing. Fruit are normally mechanically dumped quite rapidly. Efforts should be made to ensure that this process is carefully performed to minimize damage to the fruit. The flow of the fruit must be uniform and trash must be immediately eliminated to prevent fruit injury. Rotten fruit should be removed to prevent contamination of the washer brushes. Fruit should receive some form of aqueous treatment as soon as possible after dumping to remove surface debris, such as sand particles, that might damage the fruit during conveyance. Fruit should be washed a minimum of 20-30 seconds, and brush speeds should not exceed 120 rpm. Washing time should be controlled with a continuous mechanical wipeout or one that is activated when fruit flow is interrupted to prevent brush burn and minimize peel injuries. Sprays of water at high pressure can also be applied during brushing to enhance removal of sooty mold and/or scale but pressures should not exceed 250 psi to prevent fruit damage. Waxes applied after washing are used to retard moisture loss and to enhance fruit appearance. The water emulsion waxes that are used extensively by the industry should be washed thoroughly from the wax brushes at the end of the day. If not, wax deposits may cause matting and hardening of the brushes and subsequent damage of the fruit.

Packaging. Fruit must be properly packed in containers that protect it from physical injury and deformation and predisposition to physiological disorders. Over-filling or bulge packing of fruit into fiberboard cartons will result in fruit deformation or damage that may dispose fruit to decay. The weight of fruit in stacks of packed cartons should be supported by the carton, not the fruit. Cartons should be arranged to provide stability and adequate ventilation for cooling and gas exchange, and should be wrapped with mesh, tape or plastic, and protected with corner boards to provide maximum protection and stability during long transit times typical of export.

Storage. Relative humidities should be around 85-90% to prevent weakening of cartons and near 100% with fruit packed in wood or plastic. Low temperatures are required during storage to retard decay and maintain fruit quality. Development of diplodia stem-end and sour rot is quite effectively reduced at temperatures of 40°F or lower. Care must be taken to avoid damage to certain types of citrus, particularly grapefruit, that are chilling sensitive.

Sanitation. Packinghouse sanitation is one of the most important and least expensive decay control paractices associated with citrus fruit handling and should receive close attention in packinghouse management. Sanitizers commonly used are hot water (160°F), chlorine (200 ppm) (only product approved for direct application to the fruit), quaternary ammonium (2000 ppm), and

1-3% formaldehyde (applied as a fumigant in an enclosed and safely identified area). Sanitation can have a significant impact on the build-up of inoculum of the fungi causing green and blue mold and sour and brown rot. Inoculum of these fungi can accumulate in any type of recirculated or containerized water source, such as drenchers or dump tanks. The pallets and packinghouse line are commonly contaminated by *Geotrichum*, and *Penicillium spp.* can contaminate these areas as well as degreening and storage rooms. Since *Penicillium* spores are carried by wind currents, large populations can exist in the packinghouse environment. The highest population often exists at the dump when spores from fruit containing sporulating lesions formed during storage are released during the dumping process. A significant reduction in green mold has been noted when the dump and primary grade areas, where decayed fruit are first encountered, are spatially separated from the rest of the packingline and loading facilities. Exhaust fans at a totally enclosed dump can be used to remove spores from the packinghouse, and the packingline can be designed so prevailing wind currents do not spread spores from the degreening and dump areas to the rest of the line. Containerized or recirculated water sources should be chlorinated with a constant source of chlorine to maintain at least 50 ppm of free available chlorine at a pH near 7.0. Chlorine at 200 ppm (free available chlorine) can be used in sprays or dump tanks after the dump to reduce populations of decay organisms on fruit surfaces. A contact time of at least two minutes is more efficacious.

Dirt and debris should be removed from the pallets and they should be sanitized before returning them to the field for more fruit. The packingline from the dump through the waxer should be cleaned daily. A significant amount of inoculum can be removed by washing with ambient water containing an approved detergent, but additional cleanliness can be achieved by following the wash with a spray of sanitizer. Fruit and trash should be removed daily for cleanliness and to prevent sporulation of *Penicillium* on infected fruit. Degreening and storage rooms can be washed with detergent and sanitized with sanitizer spray or mist to leave a wet residue on all surfaces. Packed fruit with green mold should never be repacked in the packinghouse to prevent dissemination of airborne spores, many of which may be resistant to the fungicide treatment.

<u>Decay control products</u>. Growth regulators applied during fruit production have exhibited some impact on the development of certain postharvest decay pathogens. Applications of gibberellic acid that retard fruit senescense have suppressed development of sour rot and the rate of spread of green mold lesions. An application of 2,4-D to retard fruit drop also significantly reduces postharvest development of stem-end rot by sustaining juvenility of button tissue. Postharvest decay control treatments (Table 2) are still needed even if growth regulators are used.

Control of brown rot can only be achieved with preharvest applications of copper and/or fosetyl Al (Aliette) because no postharvest treatments are available. These products are usually applied between August and September to blocks of trees with a history of brown rot or at the occurrence of disease outbreaks. Aliette has a 30 day waiting period after application to harvest. Preharvest application of benomyl (Benlate) one day to three weeks before harvest controls diplodia and phomopsis stem-end rot, green mold and some control of anthracnose.

Table 2. Products for control of citrus postharvest diseases.

Treatments	Diseases
Preharvest	
Copper	Brown rot
Fosetyl Al (Aliette)	Brown rot
Benomyl (Benlate)	Diplodia and phomopsis stem-end rot; green mold; anthracnose
Postharvest	
Sodium orthophenylphenate (SOPP)	Green mold; sour rot
Thiabendazole (TBZ)	Diplodia and phomopsis stem-end rot; green mold; anthracnose
Imazalil	Green mold; diplodia, phomopsis and alternaria stem-end rot
Soda ash[z]	Green mold
Borax[z]	Green mold
2-4, dichlorophenoxyacetic acid (2,4-D)[z]	Alternaria and diplodia stem-end rot
Aspire (*Candida oleophila*)	Green mold
Bio-Save™1000 (*Pseudomonas syringae)*	Green mold

[z] Used primarily in California.

Applications of fungicides to fruit before degreening are much more effective for control of stem-end rot and green mold than later applications on the packingline. For this reason, most of the commercially degreened fruit in Florida is treated in a truck bin drencher where individual truck loads of fruit are treated with fungicide. Thiabendazole (TBZ) is used most commonly, but imazalil has been used recently in some instances to exclude TBZ residues in juice from fruit eliminations. Drench suspensions must be chlorinated to eliminate fungal inoculum not controlled by the fungicide, primarily spores and mycelium of *Geotrichum*. Chlorine and imazalil are incompatable, so another form of disinfestation is needed, such as heat, with occasional shock treatments of chlorine followed by a recharge with imazalil.

Sodium orthophenylphenate (SOPP) is utilized in the washing process where it is applied as a recycled drench or nonrecovery spray or foam. This is the only fungicide with some activity against sour rot, and it provides control of green mold. It also maintains the washer brushes in a more sanitary condition by inactivating inoculum of the fungi that cause sour and brown rot. The application is followed by a water rinse to remove excess material that has not been absorbed into injuries at sites of infection. An automatic wipe-out system is needed in the event of equipment breakdown to prevent rind injury that may occur from excessive brushing and exposure of fruit to the fungicide.

Imazalil and/or TBZ may be applied to washed fruit in aqueous applications before waxing or in the water emulsion wax. Higher concentrations of the materials are used in wax applications because of reduced fungicide efficacy. Eradicant activity of imazalil is particularly impacted by incorporating it into wax that prevents systemic movement of imazalil into the rind. Sporulation control activity of imazalil is not significantly altered by application in wax. These products are effective against diplodia and phomopsis stem-end rot and green and blue mold. TBZ has some activity against anthracnose and imazalil against alternaria stem-end rot.

Two biological products , Aspire (*Candida oleophila*) and Bio Save™1000 (*Pseudomonas syringae*) may be applied in aqueous applications to washed fruit to control green mold. The organisms are compatible with storage but not pack waxes. They compete for nutrients in injuries to prevent the green mold fungus from estabilishing an successful infection. The products are less effective eradicants than chemicals and must be applied immediately after harvest to effectively control infections that occur at injuries during the harvesting process. Control of green mold is usually not as effective or consistent as that observed with aqueous applications of imazalil or TBZ, and control of stem-end rot has not been observed. The biologicals may be useful to combat strains of *Penicillia spp.* that have developed resistance to chemical fungicides.

Resistance of pathogens to chemical fungicides. *Penicillia spp.* develop resistance to fungicides. In normal populations of these fungi, strains exist naturally that possess resistance to chemicals. These strains occur so infrequently that they normally do not make up any significant proportion of the population. However, under extreme selection pressures, such as when a chemical is used continually in a confined environment of a packinghouse or storage facility, resistant strains can predominate. This situation is particularly exacerbated when treated fruit are stored repeatedly in a facility for an extended period of time. A resistant strain infects and sporulates, and these spores reinfect treated fruit leading to the additional accumulation of resistant spores which then predominate the environment. Use of SOPP, TBZ or imazalil that have different modes of action will help minimize the rate of resistance development, but eventually individual strains can develop with resistance to all three chemicals. In these instances, the only known solution is the proper use of sanitary practices and the application of broad spectrum biocides such as soda ash, borax and/or biologicals to the fruit before storage and application of the chemicals with specific modes of activity as final treatments immediately before shipment.

Conclusion

Postharvest diseases are one of the major factors impacting keeping quality of fresh citrus fruit. Proper methods of harvesting, handling, sanitation, storage and refrigeration are indispensable if the quality at harvest is to be maintained until the product is consumed.

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