Pome and Stone Fruit Storage and Disorder Control

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Fruit treated post-harvest must be labeled properly when marketed. The shipping container or master carton containing the treated fruit, but not the consumer package, must be marked "Treated with (name of chemical) to retard spoilage." The lettering of this statement must be as large as the other lettering on the container. Furthermore, before treating fruit or shipping previously treated fruit, check to see if importing countries will allow entry for sale. This is especially important given the relatively lengthy storage period of apples. Information on the tolerance level of a number of pre- and postharvest chemicals on apples, pears, and cherries for countries around the world is available. The Northwest Horticultural Council (105 S. 18th St. Suite 105, Yakima, Washington 98901) offers this information on its web site (www.nwhort.org). Additional information regarding international registrations and tolerances can be found at the U.S. Foreign Agricultural Service web site (www.fas.usda.gov).

Scald on Apples

Scald is a physiological (non-parasitic) disorder that develops on susceptible varieties of apples during storage and marketing. The most common symptom is a brown discoloration of the skin, which results from reactions involving a volatile oxidizing substance produced naturally by the fruit. Antioxidant chemicals effective against scald are available for use on apple fruit. Treat susceptible varieties of McIntosh, Cortland, Delicious, Fuji, Greening, Stayman Winesap, Turley Winesap, and Rome Beauty (Red Rome) with a scald inhibitor whenever storage of several months or longer is anticipated. The occasional development of scald on Jonathan, Idared, and Golden Delicious is not always severe enough to justify fruit treatment for its control, yet these varieties are sometimes treated.

Control

Storage of fruit in atmospheres having 1.5% oxygen or less reduces the incidence and severity of superficial scald but may not offer complete control. Improved control has been obtained by initial low oxygen stress at 0.5% O_2 for two weeks before CA storage at 1.5% O_2. For chemical control, dip or drench the fruit shortly after harvest with a scald inhibitor. A delay of two weeks in storage considerably reduces scald control with chemicals. It should also be noted that there are some restrictions for the export of fruit treated with scald inhibitors, so knowledge of the destination of stored fruit may be an important consideration in the choice of which scald inhibitor to apply. Inclusion of a fungicide in the drench water may be necessitated to reduce the incidence of decay.

SUGGESTED CHEMICAL

Diphenylamine (DPA), from Decco and Pace International, is a wettable powder or liquid at 1,000 or 2,000 ppm for warm fruit (50 °F or higher) or 2,000 ppm for cold fruit. Apply at least 1,000 ppm to control scald on susceptible varieties including Cortland, Delicious, McIntosh, Mutsu, Rome Beauty, Stayman Winesap, and Turley Winesap. An exception is that 2,000 ppm is required for control on early picked Delicious. Frequent renewal of DPA in the dip tank or drench and good agitation are essential to offset the DPA removed by the fruit, bins, and debris or that which has settled out (DPA is a suspension, not a solution). Treatment with 2,000 ppm is frequently employed to assure an effective concentration of DPA. Test kits for quickly measuring the DPA solution concentration are available from several suppliers and are useful in efficiently maintaining an adequate level of the scald inhibitor. Avoid levels above 2,000 ppm because of injury and residue hazards. Rome Beauty and Golden Delicious may be damaged at lower levels, i.e. 1,500 ppm. If scald control seems necessary for Jonathan, Idared, or Golden Delicious, use 1,000 ppm. It is important to note that DPA tends to "fix" the green color (chlorophyll) in the skin of apples.

DPA use is not permitted for fruit in many export markets.

Drench solutions should contain a fungicide such as thiabendazole. DPA provides the additional benefit of protecting against CO_2 injury in susceptible apple varieties.

Senescence and Internal Breakdown in Apple

Internal breakdown is a senescence or "old-age" disorder, which is retarded in development by good fruit handling and storage practices and by post-harvest treatment of the fruit with calcium chloride. The disorder is characterized by browning of the flesh followed by excessive softening and finally skin discoloration.

Control

Storage of the fruit in controlled atmospheres as indicated in Table 1 will largely control internal breakdown associated with fruit senescence for several months depending on the susceptibility of the cultivar.

SUGGESTED CHEMICALS

1-Methylcyclopropene (1-MCP, SmartFresh), from AgroFresh, is applied to apple, pear, and other fruit as a vapor under physiological conditions and acts by inhibiting the binding of the hormone ethylene to its binding site.

A single exposure can temporarily render plant material insensitive to ethylene when applied at 1 part-per-million. A single 24-hour exposure to 1 ppm 1-MCP will retard apple ripening and senescence during cold storage for 3 to six months if applied before the fruit has begun to ripen significantly. 1-MCP is released from the SmartFresh powdered formulation by adding water. An application unit incorporating an aeration device for the water/SmartFresh solution is used to facilitate and control the release of the 1-MCP from solution. 1-MCP can, in some instances, significantly reduce the incidence of superficial scald. 1-MCP is not particularly effective for stone fruit, although some positive responses have been found for peaches. 1-MCP is arguably too effective for many pear varieties, sometimes preventing fruit ripening altogether but has been used successfully for Bartlet.

Calcium Dip or drench the harvested apples in a 2.5% solution of calcium chloride ($CaCl_2$) containing 20 pounds of actual calcium chloride per 100 gallons of water. The calcium chloride should be either Food Grade or Technical Grade that meets Food Chemical Codex specifications. It may be combined with DPA applied for scald control (see above). The treated fruit should be stored immediately or put under cover to avoid loss of the material (i.e., by rainfall), which must remain on the fruit during the storage period to be effective. The apples must be washed when prepared for use or marketing. Apples with enlarged, poorly corked lenticels, poor finish due to russeting, or mite injury in the calyx cavity may be damaged by calcium chloride. Include fungicide in the treatment solution to minimize the occurrence of fruit rots.

Bitter Pit

Bitter pit appears as dry, brown spots of tissue before and after harvest. Its development can be retarded during storage by treatment with calcium chloride. It may be used on Delicious and Northern Spy.

Control

Dip or drench the harvested apples as for internal breakdown. It should be noted, however, that better control of bitter pit is achieved through the use of several preharvest calcium sprays applied throughout the growing season.

Decay

Decay of pome and stone fruits during storage is primarily the result of infection by fungal (mold) organisms. For some fungi, because they exist in orchard soils and on organic debris in the orchard and in bins, they enter the storage environment in on the fruit, on equipment used in transport, and on packaging. For apple, a significant spore load is known to occur on the bins in addition to the fruit and these spores can be readily spread via drenchers used to apply fungicides. In storage, humid conditions coupled with rapid air flow from the fans in the refrigeration systems can result in sporulation and additional spreading. Fruit-to-fruit contact is also an important route for disease spread.

Common decay organisms include *Penicilium expansum* (blue mold) and *Botrytis cinerea* (gray mold) in pome fruit and *Monilinia fructicola* (brown rot) and *B. cinerea* in stone fruit. Excessive moisture can also result in decay from yeasts for stone fruit.

Good postharvest decay control begins in the field. It is important to minimize the spore load entering the storage environment and, importantly, to exclude rotting fruit, which promote decay 'nesting.' A solid fungicide program, especially close to harvest, will also reduce post-harvest rot. Several fungicides can be applied up to the day of harvest (e.g., Indar and Orbit, for brown rot control and Elevate for brown rot and gray mold control).

Once in storage, low temperatures limit the growth of and infection by fungal organisms. There is an approximate 3-fold reduction in the activity of fungal organisms with every 18°F (20 °C) decline in temperature. While low temperature is perhaps the most important means to control decay, significant benefit can be obtained from treatments that slow fruit development such as controlled atmosphere storage and the ethylene action inhibitor SmartFresh. These treatments delay the onset of fruit ripening and can slow ripening once underway. By prolonging the period of fruit maturation and ripening CA and SmartFresh help prevent the decline in resistance to decay associated with fruit aging.

Only a handful of postharvest fungicides are registered in the United States and fewer internationally. For Michigan growers, the following options exist:

Pome Fruit Control

Mertect 340-F (thiabendazole), from Syngenta, is a broad-spectrum fungicide useful against blue mold rot, bull's eye rot, and gray mold. It is applied as a dip or drench and is commonly co-applied with diphenylamine for superficial scald control. The addition of DPA enhances the effectiveness of Mertect. However, resistant strains of *Penicillium sp*. have been detected in Michigan, which may lead to a loss in effective decay control in the storage environment. The residue tolerance for thiabendazole in Canada is half that of the United States.

Captan (captan), available from a number of sources, is a broad spectrum fungicide that is effective against Botrytis, Gloeosporium and Rhizopus rots but only marginally effective against blue mold. It can be applied as a spray or dip. Tolerances for residue levels in the EU and in Canada are significantly lower than for the United States. Captan can be used in combination with thiabendazole.

Penbotec 400 SC (pyrimethanil), from Pace Int'l., was registered for the United States in 2004. This is a reduced-risk fungicide that is effective against most postharvest decays for pome fruit, especially blue mold and gray mold. It is compatible with DPA and calcium in the dip or spray tanks. State registrations at this time are limited to Washington, Oregon, Michigan, Pennsylvania, Virginia, and New York allow postharvest application. Pyrimethanil is effective against decay in stone fruit as well, but is not yet labeled for this use.

Stone Fruit Control

Scholar (fludioxonil), from Syngenta, is a reduced-risk fungicide labeled for post-harvest treatment of stone fruit for protection against brown rot, gray mold, Rhizopus rot, and Gilbertella rot. It can be applied as a spray or dip. Only one application may be made. Treated fruit should not be stored in direct sunlight as this may degrade the chemical.

Captan (captan), as previously noted for pome fruit, is a broad-spectrum protectant fungicide that can be applied as a post-harvest dip or spray for control of various storage rots (e.g., Botrytis, Rhizopus). In some instances, visible residues may occur.

Rovral (iprodione) is no longer labeled for post-harvest use on stone fruit.

Application Tips

Storage operators opting to use postharvest fungicide treatments should consider the following:

1. *Keep treatment solutions agitated*. Mertect 340F and Captan will settle to the bottom of the treatment reservoir without agitation as when the system is shut down at night. The settled product is relatively difficult to get back into suspension. Postharvest drenchers and hydrocoolers should be outfitted with an agitation system capable of resuspending any sediment that settles to the bottom of the tank following system shut down. If the agitation system is inadequate, fungicide concentrations will fall and may decline below effective levels.

2. *Keep drench solutions clean*. Soil and other orchard debris carries decay inoculum and make it more difficult to keep postharvest chemicals in suspension. Bins and equipment should be washed at some point prior to the harvest season with a high-volume stream of non-recycling water. Regular cleaning of drenching or hydrocooling equipment and the treatment solution reservoir will also minimize spread of decay spores. For DPA, empty and clean tanks at least as frequently as is required on the label.

3. *Keep drench solutions recharged*. There is a loss of chemical over time as drench solutions are continually used. It is advisable to recharge the drench solutions regularly according to instructions included on the postharvest labels of the products being used. Some manufacturers make kits available for testing the fungicide concentration.

Recommended Storage Conditions for Michigan Apples

COLD STORAGE

Cultivar	Temperature (°F)
Jonathan	36
Honeycrisp	36 to 38 (Holding 7 to 10 days at >50 °F improves control of soft scald)
All Other Varieties	32

CONTROLLED ATMOSPHERE STORAGE

		Standard CA[z]		Low O_2 CA[y]		1-MCP
Cultivar	Temp (°F)	$\%O_2$	$\%CO_2$	$\%O_2$	$\%CO_2$	Responsiveness*
Honeycrisp		not currently advised		not currently advised		-
McIntosh						
Most strains	38	2 - 2.5	2.5 1st mo., then 5	1.5	<3.0	+/-
Marshall Mac	38	3 - 3.5	2.5 1st mo., then 5	not advised		
Empire[wx]	38	1.8 - 2.0	<1	1.5	<1.0	+
Jonathan[x]	32	1.8 - 2.0	3 - 5.0	1.5	<3.0	++
Jonagold	32	1.8 - 2.0	3	1.5	<3.0	++
Gala	32	1.8 - 2.0	3	1.5	<3.0	+
Gingergold	32	1.8 - 2.0	3	1.5	<3.0	++
Cameo[x]	32	1.8 - 2.0	3	1.5	<3.0	+
Red Delicious[x]	32	1.8 - 2.0	3	1.5	<3.0	+
G. Delicious[x]	32	1.8 - 2.0	3	1.5	<3.0	+
Idared[x]	32	1.8 - 2.0	3	1.5	<3.0	+
Rome[x]	32	1.8 - 2.0	3	1.5	<3.0	+/-
Law Rome[x]	32	1.8 - 2.0	3	1.5	<3.0	+/-
N. Spy[x]	32	1.8 - 2.0	3	1.5	<3.0	+
Mutsu[x]	32	1.8 - 2.0	3	1.5	<3.0	+
Fuji[x]	32	1.8 - 2.0	1	1.5	<1.0	+

[z]For CA storage operations with facilities available, operators should consider CA storage at 2.5% O_2 with up to 3% CO_2 for late harvested apples to extend market quality through December.

[y]Fruits for low oxygen CA should be preclimacteric in ethylene (less than 0.1 ppm). The low oxygen atmosphere should be established within 7 days of beginning to load the room. Accurate and dependable O_2 analyzers must be employed and calibrated with gas standards for CA storage below 2% O_2.

[x]These varieties have given excellent quality retention for mid-term CA when stored at 1.5% O_2 with up to 3% CO_2 at 38 °F and for long-term CA at 32 °F except Empire, which should be kept at 38 °F.

[w]Empire are prone to low temperature CA injury when stored at 32 °F and they are prone to external and internal CO_2 injury when stored in CA at 32 °F and with CO_2 above 1%. 1-MCP enhances susceptibility to CO_2 injury; DPA can prevent CO_2 injury symptoms.

*Responsiveness to 1-MCP is judged the extent of response and the reliability of response. The indicators ++, +, +/-, - refer to high sensitivity, moderate sensitivity, low or variable sensitivity, and no appreciable benefit, respectively.

NOTE: The CA room can be safely sealed and O_2 pull-down begun when fruit temperature is below 50 °F. Every attempt should be made to have the CA room atmosphere below 5% O_2 within 7 to 10 days after starting to load the room in order to achieve maximum advantage for CA technology.

Recommended Storage Conditions for Michigan Stone Fruit

COLD STORAGE

Species	Temperature (°F)	Chilling temperatures (°F)
Peaches & Nectarines	31 - 32 for optimal long-term holding*	36 - 45
Plums	31 - 32*	36 - 45
Apricot	31 - 32*	36 - 45
Sweet cherry	31 - 32	not chilling sensitive

*Chilling injury occurs in some peach, nectarine, plum, and apricot cultivars; symptoms develop faster and more intensely when fruit are stored at chilling temperatures above 32 °F.