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# Postharvest handling of pome fruits, soft fruits, and grapes

Canada

Postharvest handling of pome fruits, soft fruits, and grapes.

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# Preface

The first edition of Postharvest handling of pome fruits, soft fruits, and grapes was completed in 1984 a long span of time if one considers the great expansion in biological knowledge over the past 25 years. The second edition was completed in 2000 and many changes have already occurred since that time. This third edition of Postharvest handling of pome fruits, soft fruits, and grapes contains updated disease and disorder sections and also includes specific references for each disease or disorder section. Nearly all the references were available on line from the Postharvest Information Network, Tree Fruit Research and Extension Center, Washington State University, Wenatchee, WA 98801. Thus the reader can quickly look up pertinent information on a postharvest problem if it is missing from the booklet.

As was the case with the second edition, the third edition follows each fruit crop so there is no need to turn to several sections to find information on a particular crop. Information has been updated and pictures have been incorporated into the text so they can be studied while reading the text. The harvesting guidelines have been revised to include new apple and stone fruit cultivars grown commercially since 2000.

Most of the information in this book originated from research done in British Columbia, Canada and the Pacific Northwest of the United States. Although the information in this booklet is directed primarily to growers and fruit packers in these areas it should be equally relevant to others with an interest in postharvest handling of fruit crops.

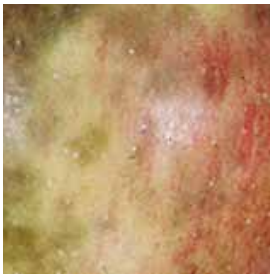
Reference to a company or product is only for purposes of information and does not imply approval or recommendation of the product to the exclusion of other products that may also be suitable. Recommendations for pesticide use in this publication are intended as guidelines only. Any application of a pesticide must be in accordance with directions printed on the product label of that pesticide as prescribed under the Pest Control Products Act. Always read the label.

Because recommendations for pesticide use vary from province to province, your provincial agricultural representative should be consulted for specific advice. A pesticide should only be used if it is recommended by local authorities because they may be aware of specific problems such as fungicide resistance and the need for fungicide resistance management strategies. Further information on specific pesticides can be obtained by contacting the Pest Management Regulatory Agency, Health Canada Pest Management Information Service at

Pest Management Regulatory Agency  
Health Canada  
2720 Riverside Drive  
Ottawa, Ontario  
Address Locator: 6606D2  
K1A 0K9  
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[www.hc-sc.gc.ca](http://www.hc-sc.gc.ca)

## Acknowledgments

Since the third edition retains most of the information from the first and second editions, the acknowledgements in the first edition are still pertinent. I also would like to thank Sarah Godin for help with electronic publishing and Gayle Jespersen for reviewing the manuscript. Finally I would like to acknowledge the agricultural research community who freely provided postharvest information in numerous publications and made them available over the internet.



# Apple Disorders

- Deposits on apples
- Superficial scald
- Soft scald
- Sun scald
- Internal breakdown of Spartan apples
- Braeburn and Fuji browning disorder
- Russet
- Water core
- Bruising
- Bitter Pit
- Lenticel Breakdown

## Deposits on apples

Water with a high calcium content that is applied by overhead sprinklers can leave a white deposit on fruit, which is difficult or impossible to remove by normal washing. An acid bath is therefore needed.

## Acid removal of calcium deposits

Before packing, the fruit is conveyed through a 1.0-1.5% hydrochloric acid (muriatic acid) solution. Only brief contact with the acid solution is necessary (approximately 1 minute) to remove the calcium deposit.

This solution is corrosive, and handling procedures stated on the label should be carefully followed. The fruit is then carried through a 1% soda ash solution to neutralize the acid on the apples. This must be promptly followed by a thorough

rinse to remove the soda ash solution. A commercial preparation that contains phosphoric acid and a detergent is also available for the removal of calcium deposits from apples. A soda ash neutralization step is not necessary, and the fruit is rinsed with water at 55°C to remove the acidic solution.

## Injury from acid bath

Apples can be injured by the hydrochloric acid solution. Contact of only 5 minutes is sufficient to cause leaching of colour and blackened lenticels. Precautions must also be taken with the soda ash because of its alkalinity (pH 10), which can also cause lenticel injury.<sup>1</sup>

## Superficial scald

Superficial scald, also known as common or storage scald, is an important disorder of apples in British Columbia.

Diffuse brown blotches develop on the skin of green apple cultivars and the non-blushed side of red apples. Storage scald only appears after the fruit has been in storage and develops faster at warmer temperatures so packing speeds up its appearance. Apples picked at commercial maturity vary in their susceptibility to storage scald. Cultivars such as 'Braeburn', 'Fuji', 'Gala', 'Golden Delicious', 'Spartan', and 'McIntosh' are low risk, while 'Granny Smith' and 'Red Delicious'



*Superficial scald (Granny Smith)*

are high risk. The causes of scald are complex but it is thought to be caused by oxidation products of alpha-farnesene that are toxic to the cells in the fruit skin. Factors that usually increase the severity of the disorder include immaturity, high fruit nitrogen, low fruit calcium, warm preharvest weather, delayed cold storage, high storage temperatures, high relative humidity in storage, restricted ventilation, extended storage periods, and in controlled atmosphere storage, slow oxygen reduction and high oxygen concentration.

## Control procedures

Low-oxygen storage (i.e., 0.7% O<sub>2</sub> plus less than 0.1% CO<sub>2</sub>) can reduce the likelihood of scald development, although results vary with cultivar and locality. It has been used effectively for 'Red Delicious'.

Postharvest antioxidant drenches or sprays with diphenylamine (DPA) give excellent control of superficial scald. In the Okanagan Valley of British Columbia,

Delicious, Stayman, and Winesap are treated for scald control. Apples should be dipped for 30 seconds to ensure good control of scald. Longer treatment periods may result in higher residue levels. Fruit treated with DPA should not be washed or waxed for 5 days after treatment, according to information from the United States. However, if the treatment time is extended to 1 minute, DPA-treated fruit may be washed and waxed 24 hours after treatment. The maximum allowable residue limit is 5 ppm for DPA.

The use of the ethylene action inhibitor 1-methylcyclopropene (1-MCP) will reduce superficial scald in most apple cultivars. Experiments in Ontario showed that 1-MCP reduced superficial scald in Cortland apples to less than 10% after storage for 120 days and to less than 4% from 93% in 'Delicious' apples stored for 240 days in controlled atmosphere (CA) storage.

## Chemical injury

Scald control with either DPA may cause fruit injury if it is used incorrectly. Wettable powder preparations of DPA solutions may break down, and crystals can precipitate on the fruit causing skin injury.

## Preparation and precautions

The solution should be agitated while it is being prepared in order to obtain a homogeneous product. Concentrations of DPA vary with each manufacturer, and it is important that instructions on the label are followed for preparation of the solutions. To calculate the amount needed, one can use the following formula: strength of solution (ppm)/1,000,000 × size of tank (litres)/1 × 100% /formulation on label = litres of DPA

Thus, for a 1,360 L tank to contain 1,000 ppm DPA using a 25% commercial DPA concentrate, one requires the following:  

$$= 1,000/1,000,000 \times 1360/1 \times 100/25$$

$$= 1,360 \times 4 = 5,44 \text{ L or } 5440 \text{ ml}$$

A wetting agent may be added if the apples are not completely moistened by the solution. If good coverage has been achieved, the film on an apple should not break when the dipped apple is removed from solution.

Scald control is achieved when all the fruit has been covered with solution. Bin immersion always gives complete coverage, but a properly functioning drench system should be as effective.

Table 1. Some suggested levels for scald control in various apple cultivars

Cultivar	Concentration Diphenylamine (ppm)
Cortland	2000
Delicious	2000
Golden Delicious	---
Granny Smith	1500-2000
Idared	1500
McIntosh	1000-1500
Rome	1000-2000
Stayman	1500
Winesap	1000-2000



Good drench systems nearly flood the bins with solution. All discharge openings should be checked for constrictions caused by accumulation of debris. Dirt in the scald control solution may necessitate changing the solution.

Results with emulsifiable DPA solutions indicate good control of scald, even though the dipping solution may appear to be quite dirty. Recommendations on when to discard the solutions appear on the label of the chemical.

## Times of application of scald control solutions

Apples should be treated shortly after harvest to obtain maximum control of scald. In British Columbia, good control of scald can be obtained on fruit dipped as late as 6 weeks after harvest, but other areas in the Pacific Northwest report a significant loss of scald control if treatment is delayed for that long.

## Effect of fruit maturity on scald control

Early picked spur Delicious apples (125-135 days after full bloom) may develop scald in spite of treatment. Higher concentrations of scald inhibitors may prevent the scald, but at the risk of exceeding allowable residue levels in the fruit.

## Combining scald inhibitors with other materials

DPA is sometimes combined with the mold inhibitor thiabendazole for fruit destined for long term storage. It should be emphasized that scald inhibitors should not be combined with calcium chloride or gums in a dip for apples.<sup>2</sup>

## Soft scald

Soft scald, also called ribbon scald or deep scald, is a low temperature disorder. It occurs when susceptible cultivars are stored at temperatures of about 2.2°C or lower. It develops rapidly between mid-November and late December but stops development when the fruit is removed from cold storage. Soft scald is identified by the sharply defined, irregularly shaped, smooth brown areas in the skin of the apple. Delays in cooling after harvest induce ripening, thereby promoting the development of soft scald. Although soft scald varies with the season, the disorder can be controlled by harvesting fruit at the correct maturity and placing in cold storage immediately after harvest.<sup>3</sup>



*Sun scald (McIntosh)*



*Soft scald (Red Delicious)*



## Sun scald

Sun scald appears as a bleached or bronzed area or sometimes as a blackish area on red fruit and bronzing or a reddish blush on yellow or green cultivars. Similar injury may be caused to Jonagold apples by applying sulphur sprays when it is hot. Injury barely apparent at harvest may become quite obvious after several months of cold storage. Evaporative cooling with overhead sprinklers will reduce damage due to sunburn.

Intermittent cooling begins when the air temperature reaches 30°C. Sun scald can be divided into at least three types depending on damage to the fruit finish. They are sunburn browning which is the most common form of sunburn and appears as a yellow, brown or tan spot on the fruit; sunburn necrosis occurs on the tree and appears as a dark brown to black spot and often results in cracking; photo-oxidative sunburn occurs on apples that are suddenly exposed to the sun after growing in the shade. This disorder can also occur in bins that are left sitting in the sun.

The kaolin mineral product, Surround® WP provides reduction in sunburn, sun scald, and heat stress according to its manufacturer. The best sunburn protection with Surround® occurs when it is applied before severe summer conditions and maintained during the hot season. Raynox®, a sun protectant, has also been reported to reduce sunburn. <sup>4</sup>

## Internal breakdown of Spartan apples



*Breakdown (Spartan)*

Spartan apples with flesh calcium levels of less than 225 ppm (dry weight) or 30 ppm (fresh weight) are susceptible to internal breakdown when stored in air. The disorder originates in tissue immediately beneath the skin and usually appears after 90 days of storage. Breakdown is often initiated by bruising and is more prevalent in the calyx half of the apple, which is lower in calcium than the stem portion.

Breakdown is virtually eliminated in CA storage. However, if Spartan apples are stored in air, postharvest calcium treatments are necessary to reduce the incidence of the disorder. The dip solution contains 4% calcium chloride (commercial grade) and 0.15% gum.

Guar and xanthan gums have been used in British Columbia. The addition of gum to the calcium chloride solution results in a thicker deposit on the fruit and greater uptake of calcium compared with a dip

in a calcium chloride solution only. Calcium content in the fruit increases by approximately 50 ppm (dry weight) with a 4% calcium chloride solution and by 100 ppm or more (dry weight) when 0.15% gum is added. Large fruit (size 88 or larger; 200 g or more) that are low in calcium may not achieve the desired calcium content, even when dipped in the calcium chloride-gum solution. Such fruit should be marketed early or diverted to processing.

Calcium analyses of Spartan apples 3 weeks before harvest should indicate the trend for calcium values in the fruit for that year. However, there is no formula available that will predict actual flesh calcium values at harvest from these analyses.

## Braeburn and Fuji browning disorder

Braeburn browning disorder is a serious problem for this cultivar. The problem is thought to be due to high skin resistance preventing carbon dioxide from venting out of the fruit. The disorder is correlated with cool growing seasons, advanced maturity, and storage in high carbon dioxide and low oxygen atmospheres. Carbon dioxide should remain well below the oxygen level with 'Braeburn'. Fruit stored at 1.5% oxygen should be stored with carbon dioxide below 0.5% at 1°C.

Ventilation of the fruit for 2 to 4 weeks before storing in CA storage reduces the disorder. Storage in high oxygen

atmospheres of 2 to 3% and low carbon dioxide at 0.5% helps prevent the disorder. Use of shellac wax to polish the fruit increases Braeburn browning. Postharvest treatment with DPA prevents the development of carbon dioxide injury in Fuji apples. Maximum retention of firmness and minimum development of brown-heart occurs when delayed CA storage of 4-6 weeks is used on Fuji apples. <sup>5</sup>

## Russet

Russet is a condition in which cork tissue appears on the surface of an apple. Russet is more prevalent on lateral than on terminal fruit, on exposed than on shaded fruit, and on fruit from lower-altitude growing areas. Russet may also be genetic in nature, and cultivars such as 'Golden Russet' are often heavily russeted by harvest time. Some fungicidal and chemical sprays as well as spray surfactants can be phytotoxic and cause russetting. Powdery mildew that is not controlled during the flowering stage may lead to severe russetting of the fruit. Recently it was discovered that yeasts such as *Aureobasidium pullulans* and *Rhodotorula glutinis* could cause russet of apple fruit. In the future it may be possible to suppress yeast-induced russet with fungicides or biological controls. <sup>6</sup>



*Powdery mildew russet (Jonagold)*



*Powdery mildew russet (Summer red)*



*Water core (Mutsu)*

## Water core

Delicious apples are more susceptible to water core than are the other cultivars commercially grown in British Columbia. Sorbitol accumulates in the intercellular spaces of tissue with water core because the enzyme that converts sorbitol to fructose is absent or is present in very low quantities. High levels of sorbitol lead to the accumulation of ethanol and acet-aldehyde and cause browning and breakdown in storage. Incidence of the disorder increases with advanced maturity, and cool nights during harvest tend to promote occurrence of the disorder.

Water core is a physiological disorder that causes apple tissues to appear translucent and fill with a sugar-water solution. Slight water core will disappear in storage but severe water core can cause tissue breakdown in stored apples. Water core is reduced by raising the calcium content of the fruit and is increased by high applications of nitrogen and boron. Harvest of Delicious apples at the proper maturity is probably the best means of avoiding water core. Lots of fruit with moderate to severe water core should be segregated and marketed early, because longer term storage results in breakdown of the apples. The breakdown becomes more intense when such fruit is kept at 20°C for several days.



*Water core breakdown (Winesap)*

## Detecting and segregating apples with water core

There are several promising technologies being researched for the detection of water core. These are light transmittance devices, X-ray absorption devices, mass density sorting, and magnetic resonance imaging. X-ray line-scan technology looks promising but the image analysis needs to be improved to allow for accurate separation under non-oriented packing line conditions. Improvements in computational speed are needed for magnetic resonance imaging to be successful. Light transmittance is only useful for individual fruit. Mass density separation may be the least expensive when water core is related to fruit density.

A commercial mass density sorting method of segregating apples with moderate to severe water core was developed, in which alcoholic solutions were used to float out the sound fruit. Apples with water core have a higher density, sink to the bottom, and are then transported to a separate bin.<sup>7</sup>

## Bruising

Bruising is still the most serious disorder found on apples at the retail level. There are two types of bruising categorized as impact and compression bruising. Impact bruising is the most common and is caused by dropping the apples on a hard surface. Rough harvesting and handling, or mechanical impact on the packingline, produce bruises in apples. Golden Delicious apples are particularly vulnerable to bruising, and special care must be taken with this cultivar. Light-coloured or yellow fruit are more apt to bruise and to retain the bruise than are green fruit. McIntosh apples are sensitive to bruising, particularly when firmness values drop below 5 kg. In a study at

the retail level in seven states across the United States it was found that Pink Lady and Granny Smith are also extremely prone to bruising. Red Delicious is thought to resist bruising but in a study conducted at Washington State University (WSU) numerous small bruises were found but could not be seen through the skin. Susceptibility of Golden Delicious to bruising increased with storage time.

Bruises took longer to disappear and tended to be more intense with longer storage periods. Bruise intensity appeared to reach a maximum in air-stored Golden Delicious in January and February. Studies in Nova Scotia and Washington indicate that lowering storage relative humidity levels will help to reduce bruising and handling apples when warm will reduce bruising later on.

A study with Delicious and Granny Smith apples showed that the longer they are stored the more susceptible they are to bruising. Controlled-atmosphere-stored Golden Delicious apples upon room opening are allowed to remain at 0°C in air for several days to reduce fruit turgor pressure and subsequent incidence of bruising. The delay after opening may reduce the level and severity of bruising.

Harvest factors influence bruising. For example large fruit bruises more easily than small fruit. Furthermore, fruit harvested wet will show numerous finger bruises. The packingline used for apples can also have a large influence on bruising. Use of cushion drops to reduce elevation changes and minimizing turns in the line will reduce bruising. An impact recording device devel-

oped by Techmark, Inc., Lansing, MI (<http://www.techmark-inc.com>) is commercially available that measures impact on apples. It could be used by packers to identify problem areas for bruising.

The relationship of bruising to increased incidence of decay is covered in a later section.<sup>8</sup>

## Bitter pit

Bitter pit is a physiological condition related to low calcium found on apple and usually appears as pits on the lower half of the fruit. It can be confused with stink bug damage or lenticel blotch. The disorder is described in more detail under calcium deficiency in the nutritional disorder section in the appendix.<sup>9</sup>

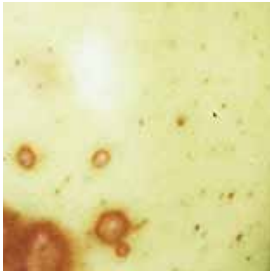
## Lenticel breakdown

Although lenticel breakdown may occur on almost any apple variety it is especially important on Fuji and Gala apples. At first the lenticels only appear darkened but usually after packing depressions appear. Susceptibility to the condition can be identified using the aniline blue dye uptake test (<http://postharvest.tfrec.wsu.edu/aniline-blue.pdf>). Lenticel breakdown is related to use of chemicals in the packinghouse. Fruit should be treated with a minimum of packingline chemicals at the lowest concentration possible and susceptible fruit should be packed early and marketed.<sup>10</sup>



*Water core, vascular pattern*





# Apple Diseases

- Decay factors
- Fruit susceptibility
- Postharvest fungicide treatments
- Superficial mold, Alternaria rot, and moldy core
- Blue mold (*Penicillium expansum* and other *Penicillium* spp.)
- Gray mold and dry-eye rot (*Botrytis cinerea*)
- Sphaeropsis rot (*Sphaeropsis pyriputrescens*)
- Mucor rot (*Mucor piriformis*)
- Bull's-eye rot (*Criptosporiopsis curvispora*)
- Snow mold rot (Low-temperature basidiomycete species)
- Pinpoint scab and storage scab (*Venturia inaequalis*)
- Blister spot (*Pseudomonas syringae* pv *papulans*)

## Decay factors overview

Postharvest losses in apples vary each year according to weather, fruit condition, and time in storage. Weather related problems such as hail increase decay by allowing decay-causing fungi easy entry to the fruit. Rain at harvest allows for increased contamination and infection of the fruit by certain fungi. Over mature fruit or fruit with high levels of nitrogen are much more likely to decay. The length of storage influences decay by extending the time fruit may be infected while at the same time the fruit loses its natural resistance to infection. Generally, high quality fruit are stored in controlled atmosphere storage and are less prone to decay because fungi grow more slowly in the low oxygen atmosphere that is used. On the other hand, the poorer quality fruit used for processing is stored in air where

considerably more fruit is lost to decay by fungi. Losses of up to 10% are possible in storage, and knowledge of the fungi that cause decay and their control is important. Many of the fungal organisms exhibit a variety of symptoms that depend on local conditions, and a trained postharvest plant pathologist should be consulted if there is any doubt about the identity of a particular fungal disorder.

Guidelines have been prepared to help storage operators prevent fruit storage and postharvest chemical injury losses and the resulting insurance claims.

However these guidelines do not address postharvest diseases that are discussed below. <sup>11</sup>

## Packinghouse sanitation

It is important to maintain good sanitary conditions in all packing-house areas to eliminate sources of spore production. Any organic matter (leaves, cull apples, soil) can act as a substrate for fungi and can support the production of spores. The flumes and dump tank accumulate spores and may act as sources of contamination if steps are not taken to keep them free of contamination.

Chlorine readily kills spores and mycelial fragments suspended in dump tanks and flumes, and the fungicidal activity is dependent upon the amount of chlorine available. A level of 50-100 ppm of total chlorine (approximately 5 to 8 ppm active chlorine) provides excellent fungicidal activity. Chlorine, measured as hypochlorous acid can be produced in the packing-

house water by adding chlorine gas, sodium hypochlorite, or dry calcium hypochlorite. Adding 19 fluid ounces of 5.25% chlorine bleach or 2.8 ounces of 65% calcium hypochlorite to 100 gallons of water produces a 100 ppm hypochlorous acid solution. Although chlorine effectively kills spores in water, it does not protect wounded tissue against subsequent infection from spores lodged in fruit wounds. Organic matter in the water inactivates chlorine, and levels of chlorine should be monitored on a regular basis. Chlorine is sensitive to pH; hypochlorite solutions with higher pH values (7.5-8.5) are more stable but less fungicidal, whereas at lower pH values (5.5-6.5) the solutions are less stable but more fungicidal. Note that mixing of acids with hypochlorite can result in the production of chlorine gas.

Systems are available that add liquid or gaseous chlorine to water and automatically monitor and control pH and chlorine levels. Filtration systems have been tested for removing dirt and spores from dump tank water with limited success. They were not capable of removing all the fungal spores but removed larger organic matter allowing lower rates of chlorine to be used.

Excess sodium concentrations can cause damage to apples. A 100 ppm chlorine solution made from sodium hypochlorite will have a 30 ppm sodium concentration. Sodium levels above 100 ppm will damage sensitive apple cultivars. Dump tank water must be regularly changed to prevent sodium from accumulating to levels over 100 ppm and fruit must be rinsed with fresh water. Because chlorine is an element that is corrosive to metal, regular inspec-



Wall contaminated with *Penicillium* spp.



Fungi growing on storage room walls

tions should be made to determine the extent of corrosion in the packing system. Populations and types of microorganisms vary greatly in the dump, flume, and filler systems. Populations of *Botrytis* spp., *Penicillium* spp., and *Mucor piriformis* have been monitored in packinghouses because they are the fungi most often found decaying stored apples. Factors such as the amount of fruit and bin contamination, volume of fruit processed, and use of fungicides affect pathogen populations. In a study conducted in British Columbia, populations of *Penicillium* spp. increased quickly during processing of the first 200 bins of three different apple

cultivars, but stabilized and remained relatively constant thereafter although levels were higher for McIntosh (15,555 propagules/ml) compared to Golden Delicious (5,000 propagules/ml) or Spartan (2,200 propagules/ml). For all varieties, propagule concentrations were sufficiently high (greater than 1,500 per ml) in the immersion water after emptying approximately 200 bins that they posed a significant risk of infecting fruit if injury to the fruit should occur.

Alternative methods of controlling spores in the dump tank are to change the water frequently or to heat the dump tank water. Spores of *Penicillium* spp. can be killed by heating in water at 54.4°C for 30 minutes. Tests conducted in Oregon heating dump-tank water for 25 minutes at 54.4°C indicated that heat treatment was an effective, economical method to reduce dump-tank spore loads, decay and the number of times tanks must be emptied. Their tests were conducted with the fungicide, sodium ortho-phenylphenate (SOPP) at a concentration of 0.35% added to the dump-tank water. SOPP is not available in Canada, but heat alone would destroy most of the contaminants in the dump-tank water. Debris will continue to accumulate in the dump-tank so emptying and cleaning cannot be eliminated entirely.

Contamination of the surfaces of wooden picking bins with spores of decay fungi has been recognized since 1931. In British Columbia, some fruits are harvested commercially and placed in wooden bins that contain about 454 kg of fruit. In the packinghouse, fruit are often sized, and then returned to these bins for long-term storage. As fruit rot in the bin, spores of

the decay fungi often contaminate the surfaces of the wood. These spores may survive until the following season and serve as a source of inoculum for infection of freshly harvested fruit.

In studies conducted by Dr. R. A. Spotts at Oregon State University, Hood River, Oregon on pieces of wood and plastic used in bins contaminated with decay fungi (*Penicillium expansum* and *Alternaria alternata*) it was determined that steam was the most effective treatment on both wood and plastic surfaces for reducing fungal contamination. Chlorine compounds and quaternary ammonia were effective disinfectants but less effective than steam. Most treatments appeared of similar effectiveness on plastic and wood.

Fungi will grow on surfaces contaminated with fruit pulp or juice and apparently clean surfaces if the relative humidity remains at 95 to 100% for long periods of time. This is precisely the conditions present in cold storage rooms filled with large volumes of slowly respiring fruit. Thus fungi often grow on storage room walls.

A chlorine wash is effective for surfaces sterilization of storage rooms but offers no residual protection; regrowth can occur in 2-3 months. A thorough cleaning and an application of whitewash is another good way of keeping the storage room free of fungal growth. The whitewash is made by mixing 135 kg of hydrated lime and 0.91 kg of copper sulfate in 473 L of water; apply the mixture under pressure. Before the whitewash is applied, all decayed and crushed apples should be removed, and the floors and walls scrubbed and rinsed.<sup>12</sup>

## Fruit susceptibility to decay bruises, wounds, and punctures

Studies indicate that bruising and skin punctures substantially increase the susceptibility of fruit to decay. Because bruising of apples is influenced by firmness and maturity, one would expect more bruising with advanced maturity and longer storage periods.

## Maturity and quality factors

Over mature fruit and fruit with mineral imbalances are more susceptible to infection. Fruit calcium should be increased by foliar calcium sprays during the growing season. Fruit with a high calcium content is less prone to decay or physiological disorders than fruit with a low calcium content. The minimum amount of nitrogen fertilizer necessary to maintain plant vigour should be used. Fruit high in nitrogen are more prone to various postharvest problems than lower N fruit.<sup>13</sup>

## Postharvest fungicide treatments

Postharvest decay can be reduced by preharvest applications of fungicides. Several fungicides that are registered for pin point scab control will also reduce postharvest decay when applied within a few weeks of harvest. These materials should only be applied if the fruit is destined for long term storage or if storing cultivars that are prone to decay.

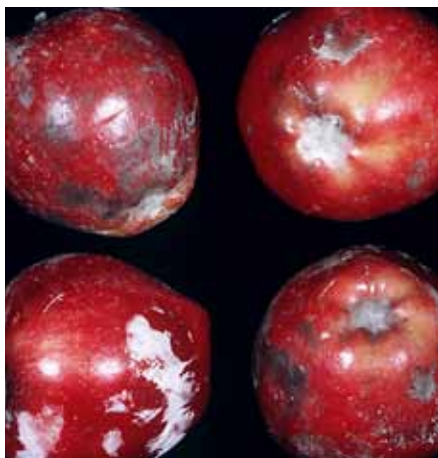
Thiabendazole is the only fungicide registered for postharvest use on apples as a dip, flood or spray. If fruit will be packed soon after harvest and rain does not occur during harvest, a drench is not necessary. If a drench is used, the solution must be changed regularly to avoid buildup of fungal spores that are not controlled by thiabendazole such as *Mucor piriformis* and *Alternaria alternata*. Thiabendazole must be agitated constantly.

The depth to which fruit are immersed should be minimized as much as possible when dumping bins. Immersion forces contaminated water into wounds and cores and increases rot. Fruit should receive a thorough fresh water rinse after leaving the dump tank and flumes. Spores of common decay pathogens such as *P. expansum* and *Botrytis cinerea* that survive and contaminate the fruit after it leaves the dump tank may be prevented from infecting by application of a thiabendazole line spray.



## Superficial mold, Alternaria rot, and moldy core

Stem and calyx-end mold on apples can be common in cold storage and have been a major cause of concern to packinghouse managers; however these molds are superficial and do not infect the fruit. Research has shown that storing apples at 0°C in apple bags (1.4 kg) at high relative humidity for a month can lead to growth of superficial molds. The fungus most commonly isolated from the calyxes of infested apples has been *Alternaria alternata*. The mold growth could have been prevented by lowering the relative humidity in the cold room to around 95%. Treatment of apples before bagging with sodium hypochlorite (150 ppm) is ineffective. Other superficial molds will grow in cold storage on apples coated with aphid exudate. The exudate contains sugars and amino acids that are readily utilized by various saprophytic fungi. These fungi will continue to grow in cold storage, and the extent of the growth over a long period can be quite alarming. The apples can be cleaned with a soap wash and may be run, packed, and handled in the normal manner.



*Superficial mold*

## Alternaria rot

Alternaria rot is characterized by round, brown to black, dry, firm, shallow lesions around skin breaks. Advanced rots become spongy, and the affected flesh is streaked with black. However this decay is seldom responsible for major commercial losses. Only 3.3% of the apples in a recent survey of apple decay in British Columbia were infected with *Alternaria* spp.

## Core rot

Fungal invasion of the apple core is particularly prevalent in apple cultivars having open calyxes such as Delicious. When infected fruit are cut in half, the seed cavity, or core region is overgrown with mold. The organism most commonly found is *A. alternata* although many other fungi have been identified. Infection likely occurs through calyx tubes that remain open and allow spores to enter the seed cavity. There are no effective control measures.<sup>14</sup>

## Blue mold (*Penicillium expansum* and other *Penicillium* spp.)

Blue mold, also known as soft rot or wet rot is the most prevalent of the postharvest rots in apples. It is characterized by a light brown discolouration during the early stage of infection. The decayed tissue is mushy and can be separated from healthy tissue by flushing with water. Blue mold infections can occur even at 0°C and usually originate from

wounds. Lenticels on any part of the apple may also become infected especially in over-mature or long-stored fruit. A large mass of blue green spores develops as the rot radiates from the point of infection. Spore production is accelerated at higher temperatures, and these spores become a source of infection for other fruit.

Several species of *Penicillium* have been isolated from naturally infected apples with blue mold but *P. expansum* is the most common and economically important species. This mold produces a heat-resistant toxin (patulin) and fruit with this decay should not be used for processing. Of 10 isolates identified to species from British Columbia, eight were identified as *P. expansum*. Three other species of *Penicillium* found in this area are *P. crustosum*, *P. brevicompactum* and *P. solitum*. Although lesion development resulting from infection by these other species of *Penicillium* is relatively slow at packinghouse cold storage temperatures compared to those caused by *P. expansum*, lesions do develop after relatively short periods at higher temperatures.

Preharvest fungicide and calcium sprays reduce the incidence of some postharvest diseases and may also reduce blue mold. Recently the use of pyrimethanil before harvest was registered for the control of blue mold in Canada. Biological control agents especially in combination with thiabendazole have been effective in reducing blue mold in the United States. Thiabendazole was the only fungicide registered in Canada for postharvest control of *Penicillium* spp. until recently when

fludioxinil was registered. The effectiveness of thiabendazole may be considerably diminished by benomyl resistant *Penicillium* spp. In British Columbia, 145 isolates of *Penicillium* spp. from fruit collected at three packinghouses from 1991 to 1993 were screened for benomyl-resistance. Resistant isolates were found at all three locations and averaged 22.9% over the three years of the study. Therefore thiabendazole should not be expected to give complete control because of the presence of resistant biotypes. An integrated approach, involving careful handling of fruit and strict hygiene in both orchard and packinghouse, must be used for controlling blue mold.<sup>15</sup>

## Gray mold and Dry-Eye rot (*Botrytis cinerea*)

Gray mold is an important postharvest disease of apples in British Columbia second only to Blue mold. Occasionally the initial infection is via the cut stem, but more often the fungus infects through skin breaks. The development of soft, spongy areas of rot (in contrast with the mushy rot of blue mold) in affected fruit is a significant characteristic of this disorder. In advanced stages, the decayed flesh has a sweet, cider like odour. As the rot progresses, a mass of gray spores may form on the surface, which produce the typical gray colouration. Often, infection spreads from fruit to fruit during storage, producing “nests” or “pockets” of decayed fruit. Tough black resting bodies (sclerotia) may eventually form on infected fruit.

A number of morphologically different isolates of *Botrytis* spp. have been observed in Okanagan apples. One atypical isolate liquefies apple tissue, and rots caused by this isolate are soft and watery, typical of blue mold. *Botrytis mali* has been reported as a cause of apple decays, but the validity of this species remains uncertain.

The fungus can infect fruit in two ways: indirectly by infecting flower parts, remaining quiescent until the fruit ripens, or directly via wounds on mature fruit. Control measures include clearing the orchard of dead plant material, spraying the trees with fungicides such as a mixture of benomyl and captan immediately after blossoming, and dipping the fruit after harvest in a fungicide such as thiabendazole. Although benomyl-resistant strains of *B. cinerea* and hence resistant to thiabendazole occur in British Columbia, they are sensitive to diphenylamine used to prevent storage scald.

Dry-eye rot occurs infrequently in British Columbia. Affected fruit become visible in the orchard about 1 month after petal fall. Small areas of brown, rotted tissue develop adjacent to the blossom end of the fruit. Dry-eye rot is considered relatively unimportant in the spread of post-harvest gray mold although prolonged storage of apples from orchards with a high incidence of infection may be at risk for possible secondary rot problems.<sup>16</sup>



Blue mold



Gray mold at Calyx (Red Delicious)



Dry-eye rot (Gala)

## Sphaeropsis rot (*Sphaeropsis* *pyriputrescens*)

Sphaeropsis rot was first reported in Washington on pears and later found on apples where it is considered a more important disease. The disease is characterized by a stem and calyx-end rot. The decayed tissue is firm and brown. The fungus will form pycnidia in advanced cases that are black and in the decayed tissue. Sphaeropsis rot can be confused with gray mold but differs by having a distinct antiseptic odor.<sup>17</sup>

## Mucor rot (*Mucor piriformis*)

Mucor rot occurs sporadically in British Columbia on low grade fruit contaminated with soil containing spores of *M. piriformis*. This fungus is capable of infecting and growing in apples stored at 0°C. Previously, Mucor rot was considered of minor importance but has become an important cause of apple decay in Canada and the United States. Information on the disease cycle, epidemiology, and control of Mucor rot will be covered under pears where it is considered a more important disease.

## Bull's-eye rot (*Cryptosporiopsis* *perenans*)

Bull's-eye rot occurs sporadically in British Columbia and usually can be traced to specific orchards. The disease causes spots to form on the apple that vary with cultivar, but are usually brown with light and dark concentric rings. Some spots may be uniformly brown. The decayed flesh is mealy and not easily separated from surrounding healthy tissue. In the orchard the fungus causes cankers on apple branches where it produces spores that can infect fruit anytime between petal fall and harvest. Because



*Bull's-eye rot, early (Golden Delicious)*

spores are rain dispersed, fruit infections may occur at harvest if prolonged wet weather occurs just before or during harvest. Rot symptoms do not develop in the field and only appear on apples after a storage period of 4-5 months.

Control of bull's-eye rot is enhanced by removing and burning cankers during winter pruning. An early spray of captan

tanked mixed with thiophanate-methyl at petal fall may prevent early season infection, because there are some indications that infections can be initiated early in fruit development. Postharvest treatment with thiabendazole or fludioxinil is effective only if the fungus has not become established deep in lenticels as a result of early-season infection. Rapid cooling of fruit and storage under controlled atmosphere conditions with low (1%) oxygen reduce the incidence of bull's-eye rot. The extent of infection in apples can be estimated by holding a sample of the fruit at 18-21°C and high relative humidity for a month. Lots of fruit with a high incidence can be marketed earlier than sound fruit. Recent studies



*Bull's-eye rot, advanced (Golden Delicious)*

indicate that freezing the fruit and storing at 21°C will lead to even earlier symptom development. Bull's-eye rot is rarely seen on pears in British Columbia but the same treatments used for apples are effective on pears.<sup>18</sup>



## Snow mold rot (Low-temperature- basidiomycete species)

A sterile, white, fungus classified as a low-temperature-basidiomycete (LTB) grows at temperatures near 0°C and causes an occasional rot of apples and pears in cold storage in British Columbia and Oregon. Snow mold rot, also known as *Coprinus* or LTB rot, is characterized by circular, dark-brown lesions with light centres, 0.5-25 mm in diameter. Early symptoms are similar to bull's-eye rot, and the two diseases can only be differentiated by culturing the fungus on appropriate media. The LTB fungus grows well at 10°C, but the bull's-eye fungus does not. In its advanced stages the LTB fungus produces a mass of white mycelia that covers the surface of infected apples. The fungus infects exclusively through lenticels followed by direct penetration of cambial cells in the lenticel cavity.

The LTB fungus isolated from fruit compared to an LTB strain that caused severe snow mold of winter wheat, alfalfa, and grasses had the same host range and optimum temperature. Thus orchard litter infected by snow mold would be a source of inoculum for this disease, especially if the litter were to come in contact with fruit during harvest. Grass infected with snow mold will inoculate apples when in contact with them if the apples are not protected by an effective fungicide. Fungicides that have been found to prevent infection are dithiocarbamates such as ziram and metiram and sterol-inhibiting fungicides.

An application of ziram 10 days before harvest gave good control of Snow mold rot in Oregon. Myclobutanil effectively reduced the incidence of Snow mold rot in inoculated apples in British Columbia indicating that it would also make a good preharvest spray for the control of this disease.

The orchard cover crop will affect the incidence of Snow mold rot. More Snow mold rot occurred in stored apples if white clover was present. Mixed grasses with a clean strip in the tree row is the most desirable cover when horticultural factors and Snow mold rot are both taken into consideration. Mixed grasses consisting of Kentucky bluegrass and fescue led to the lowest level of Snow mold rot when compared to covers containing which clover.<sup>19</sup>



*Snow mold rot (Golden Delicious)*



*Snow mold rot, internal (Spartan)*



*Snow mold rot, calyx (Spartan)*

## Pinpoint scab and storage scab (*Venturia inaequalis*)

Apple scab is an important disease in the interior of British Columbia especially in the North Okanagan and Creston valleys. The disease is primarily an orchard problem, but late-season infection can lead to the development of apple scab in storage. Although pinpoint scab and storage scab are used interchangeably in the industry, there is a distinct difference between the two forms. Pinpoint scab occurs as a result of prolonged rainy periods late in the season, i.e., during the last half of August. Lesions caused by these late season infections are tiny, black, and look like pinpoints. They occur most often either in the stem end, where water collects and remains longer than on the sides of the fruit, or beneath the skin, where they are invisible at time of picking. These invisible lesions continue to grow during storage and eventually appear as jet-black tarlike spots. This phase is called storage scab. All scab infections occur in the orchard--the disease does not spread in storage. Pinpoint scab and late season infections can be prevented by preharvest sprays of fungicides recommended for apple scab. Postharvest treatments are ineffective because the fungus has caused the damage by the time the fruit is harvested.<sup>20</sup>

## Blister spot (*Pseudomonas syringae* pv *papulans*)

Blister spot is caused by a bacterium that has been identified in British Columbia on Mutsu and Fuji apples. It is a serious problem on Mutsu (Crispin) cultivar apples in Ontario, Michigan and New York. The first symptoms of the disease are raised blisters that develop on fruit lenticels from early to the middle of July. The blisters become purplish-black and range in diameter from 1 to 5 mm at harvest. The application of well timed copper-based fungicides has provided control in Ontario. In British Columbia, a biological control, *Bacillus subtilis* (Serenade®) reduced the disease in one trial when compared to the control.<sup>21</sup>



Blister spot (Fuji)



Pin point scab (Spartan)



Storage scab



# Apple storage conditions and problems

- Cold storage
- Controlled atmosphere (CA) storage
- Effect and detection of ammonia
- Carbon dioxide injury
- Low oxygen injury
- Freezing injury
- Heat injury
- Waxing



## Cold storage

Apples are stored at  $-1^{\circ}\text{C}$  to  $0^{\circ}\text{C}$  when stored in regular air storage. McIntosh and Newtown are susceptible to internal disorders at lower storage temperatures and are often stored at temperatures above  $0^{\circ}\text{C}$ .

The influence of palletizing patterns on cooling rate is described in the section on pears, which follows. Cooling rates can be markedly affected by the patterns, and the time required to cool apples to a core temperature of  $0^{\circ}\text{C}$  which varies from 2 to 90 days. Delayed cooling in palletized apples can result in accelerated softening of the fruit.<sup>22</sup>

## Controlled-atmosphere (CA) storage

The CA storage conditions recommended for British Columbia-grown apples are presented in the table below. Storage quality of CA stored apples can be improved by shortening the time between harvest and attainment of the desired storage temperature and atmosphere (Rapid CA). Reducing loading time and oxygen reduction time to a total of 6 days or less yields the best storage results. Rapid CA maintains flesh firmness of apples picked over a wide range of maturities. It is effective as a prestorage high carbon dioxide treatment and superior to a postharvest calcium chloride treatment in controlling firmness loss in Golden Delicious apples.

CA storage requires large amounts of electrical energy with the highest demand occurring during the cool down period. Practices that reduce energy demand

can be implemented in packinghouses without loss in fruit quality. Some of these practices are as follows: 1) use of refrigeration cycling; 2) expanded room temperature monitoring; 3) uniform air circulation; 4) and accurate stacking of bins with uniform spacing.<sup>23</sup>

## Effect and detection of ammonia

Almost all the refrigeration systems in British Columbian storage facilities use ammonia as the refrigerant. The presence of this gas in the storage room can result in injury to fruit in the room. Apples are injured by 0.2% ammonia. The extent of injury depends on length of exposure and concentration of ammonia in the atmosphere. Brief exposures of fruit to ammonia causes lenticel discolouration. Thorough ventilation or removal of the fruit from the ammonia contamination is sufficient to reverse the discoloura-

Table 2. Apple storage conditions

Cultivar	Country	Oxygen level (%)	Carbon dioxide level (%)	Temperature (°C)	Storage Life (months)
Braeburn	USA	1.5	0.5	0 to 1	10
Cortland	Canada	1.5	1.5	3	8 to 10
Elstar	Netherlands	1 to 12	2.5	1.8	7
Empire	USA	1.5	1.0	3.5	5 to 6
Fuji	USA	2.0	0.5	1	12
Gala	Canada	1.5	1.5	0 to 0.5	8
Royal Gala	USA	2	1.5	0 to 1	7
Golden Delicious	USA	2	1.5	0 to 1	9
Granny Smith	USA	1.5	0.5	0 to 1	10
Jonagold	Canada	1.5	1.5	0 to 0.5	10
McIntosh	Canada	1.5	1.5	3	8 to 10
Mutsu	USA	1.5	3	0	6 to 8
Red Delicious	USA	1.5	1.5	0 to 1	12
Rome	USA	1.5	3	0	7 to 8
Spartan	Canada	2.5	2.5	0 to 0.5	10

tion in red cultivars. Golden Delicious apples are likely to suffer some permanent injury. Long term exposure to or high concentrations of ammonia produce permanent injury in all types of fruit.

Ammonia can be detected in rooms by the use of commercial instruments, a filter-paper method, or by the apple ammonia test. Filter-papers for ammonia detection are made by immersing about one-half the length of a 1.5 x 12 cm paper in a solution containing 2 g of ninhydrin dissolved in 100 ml of acetone, 1 ml of 0.02 M KCN, and 0.038 M  $MnCl_2 \cdot 4H_2O$ . The paper turns a reddish-blue in the

presence of ammonia. Typical colour development requires about 20 min at room temperature although the boundary between treated and non-treated paper is darkened much earlier. Levels of 50 ppm ammonia are detectable by this method. Ammonia can also be detected by cutting an apple in half and observing if the apple turns a dark blue.



Ammonia injury (Golden Delicious, Granny Smith, Bartlett Pear)



Ammonia injury (Red Delicious)



Carbon dioxide injury (McIntosh)



Regular inspections of sealed CA rooms will help minimize the potential of undetected leaks. The proper placement of windows in CA rooms helps in detecting minor damage before major damage occurs. <sup>24</sup>

## Carbon dioxide injury

Carbon dioxide injury (McIntosh) Carbon dioxide injury may occur in fruit that is kept in CA storage. A relatively high concentration of carbon dioxide interferes with oxidation of succinic acid, which can accumulate to toxic levels in the cells. Cultivars and individual fruits vary in their susceptibility to injury. External carbon dioxide injury appears as a brown, usually roughened lesion in the skin, well defined and partly sunken. Carbon dioxide injury is associated with low oxygen, immaturity, rapid establishment of carbon dioxide levels before the fruit is cooled, and free moisture on the skin of the fruit. Internal carbon dioxide injury, also called brown heart, is evident as brown necrotic cortex or core tissue. The external appearance of the fruit remains normal. Susceptibility to internal carbon dioxide injury increases

with fruit maturity and size, delayed cooling, low storage temperature, and low oxygen. <sup>25</sup>

## Low oxygen injury

With the apparent advantages of very low oxygen storage of apples and pears, low oxygen injury is likely to occur. The injury is caused by the accumulation of ethyl alcohol in the fruit, which reaches toxic levels under anaerobic conditions. Anaerobic conditions for 4 days or more with Cox's Orange apples results in severe damage. Symptoms of alcohol injury vary with the cultivar, oxygen concentration, length of exposure, and temperature. Dark brown water-soaked lesions in the skin are a common characteristic of low oxygen injury. As the severity of the injury increases, the cortex and core tissue may become brown, moist, and water-soaked. <sup>26</sup>

## Freezing injury

Freezing injury on the surface of the fruit results in a brown discolouration of the skin, often accompanied by water-soaked areas with irregular outlines. During

storage the lesion may become sunken because tissue loses moisture more readily after freezing damage. The average freezing point for apples is -2°C. Freezing can occur with a range of -1.4 to -2.3°C. Apples can sustain temperatures of 1 to 2°C below their freezing point for 24 to 48 hours without any visual injury after thawing. <sup>27</sup>

## Heat injury

Brief exposure of apples to hot air or hot water can cause injury in the fruit. Scald-like symptoms develop in apples allowed to remain for 1 minute in water that is 58°C or exposed for 5 minutes to air that is 60°C.

Prominent lobes in Delicious are readily injured by heat. The problem of heat injury can arise from faulty thermostats or temporary halts in packing, which expose the fruit to hot water or hot air for several minutes. <sup>28</sup>



*Carbon dioxide injury, internal (McIntosh)*



*Low oxygen (alcohol) injury (McIntosh)*



*Freezing injury (McIntosh)*

## Waxing

The procedure of waxing apples probably has more variables than any other handling method in the packinghouse. Little factual information is available on the subject, and a good wax finish is the result of considerable manipulation and intuition, based on experience. However, consultation with packinghouse personnel and wax producers resulted in the information that follows.

Estimates range from 400 to 800 bins of fruit for each barrel of wax (approximately 250 L). The heavier the wax coating, the fewer are the bins that will be covered per barrel. Thickness of coating is a subjective measurement, because one level of gloss can be acceptable to one person but not to another. Consequently, this subjective evaluation determines the number of bins treated per barrel of wax.

## Cleaning the fruit

A good detergent wash is recommended for removing dirt and some of the surface wax. Water in the dump tank should be 32-35°C and in the rinse, 49°C. For apples that have a heavy coating of natural wax, it may be necessary to use a special cleaning solution. Suppliers of apple wax and detergents should be contacted about the availability of such cleaning solutions.

## Temperature before waxing

Skin temperature of the apple must be higher than the dew point of room air; otherwise, moisture tends to collect on the cool surface. Temperatures below 10°C may cause waxing problems, but an upper limit has not been established. High skin-temperatures suggest a warm core-temperature, which may have an adverse effect on storage quality of the fruit.

Ten to twelve brushes should be adequate from the detergent application to the warm-water rinse.

A dry apple is necessary for a good wax finish, and the drying step after the rinse is therefore a very important one. Approximately 40 brushes are needed to dry the fruit. If the air above the brushes is humid, it would be advisable to vent it outside or to provide drier air from some other source blown over the moist apples.

## Drying waxed fruit

Wax is usually applied by a single nozzle that moves across the fruit. The rotating brushes that move the fruit forward complete the waxing step. Rates vary from approximately 5.5 to 9.5 L per hour, depending on volume of fruit and its rate of movement. No more than five brushes are needed in the waxing step. Additional brushes may increase or decrease the wax layer if the quantity of wax applied is heavy or light, respectively. However, more brushes may be added if buffing is inadequate.

Because the solvents in each wax preparation are different, drying times will vary. Temperatures of 50-70°C for the drier have been suggested. Drying times vary with thickness of the wax layer, type of solvent used in the wax, and rate of movement. Consequently, there are no guidelines in this regard, and the operator must manipulate the variables at hand so that a proper drying job is done. It should be mentioned that drying times are reduced when hot temperatures are used. Furthermore, exposure of apples to 50°C for 5 minutes can produce scald-like injury, and travel time should be 2 minutes or less with the 60°C drying tunnels.

Humid air should not be used in the drying tunnels because it impedes removal of solvents from the wax on the fruit. Outside air, which is drier, is preferable and helps to reduce drying time of the waxed fruit.



*Hot air injury (Spartan)*

## Cultivars and waxing

Lighter wax coatings are recommended for Golden Delicious apples, to prevent lenticels from becoming prominent.

Carnauba waxes are preferred for this cultivar. Brush speeds should be reduced with this cultivar because of its tendency to suffer skin discolouration.

Winesap apples have a high content of cuticular wax and often cannot be waxed easily. A stronger detergent, an alkaline solution, or an acidic solution may be needed to remove some of the wax.

## Problems with waxing

Advanced maturity results in more wax deposit on the apple. Similar deposits can be induced in fruit left at ambient temperatures for several days in the orchard or on the slab at the packinghouse. Fruit with a high content of cuticular wax does not attain a good wax finish, and the fruit may have to be cleaned with special detergents (see section entitled "Cleaning the fruit").

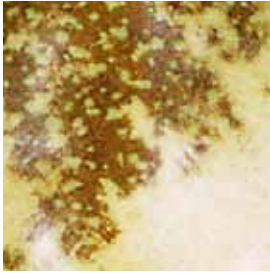
Some unfortunate experiences have been reported in waxing apples with shellac waxes. Given the right circumstances, such waxed fruit turns milky white and no reversal of the condition is possible. Temperature is perhaps the most important factor. When the temperature gradient between fruit and ambience is large, sweating is induced in the apples. The condensation of the moisture causes the shellac to become partly solubilized and subsequently results in a white, translu-

cent appearance. Heavy shellac coatings tend to aggravate the problem.

Whitening may also occur when too much residual moisture is present during the waxing operation.

A carnauba wax is recommended for export apples because the finish does not whiten, but the gloss with a carnauba wax is not as high as that achieved with a shellac wax. However, a lower gloss may more than compensate for the risk of overseas shipping of apples waxed with shellac waxes.

The longer the storage period the less likely it is that an ideal wax finish will be retained. There is little one can do about the situation, and perhaps a less than ideal finish should be accepted.<sup>29</sup>



# Pear Disorders

- Scald
- Pink end, or premature ripening, of Bartlett pears



## Scald

Pears can be broadly classified into two groups based on ripening characteristics. The first group is characterized by Bartlett which does not ripen normally at low temperatures, and with prolonged storage loses its ability for normal ripening at any temperature. As the condition evolves fruit become yellow and ultimately develop a dark discolouration of the skin called senescent scald. The pears remain firm, but the skin turns brown and sloughs off rather easily. Pears so affected do not ripen and should be discarded. Senescent scald can be prevented if Bartlett pears are cooled promptly at harvest, not stored beyond 90 days, and kept at  $-0.5^{\circ}\text{C}$  during storage.

The other group of pears characterized by Anjou ripen slowly in cold storage and generally do not lose the capacity for normal ripening as a result of extended

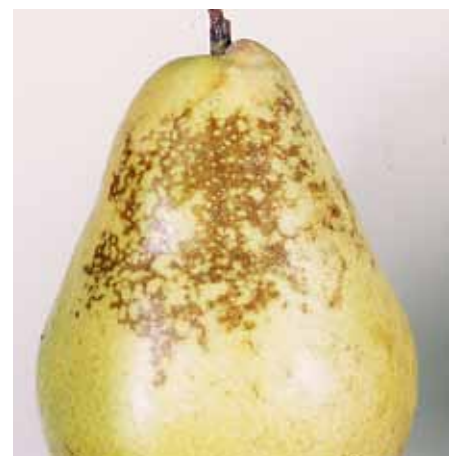
storage. These pears are subject to storage scald, called Anjou scald or superficial scald. Fruit could be safely stored for 3 to 4 months (short term storage) in Oregon if placed at 0.5% oxygen for 8 to 10 weeks followed by air storage at  $-1^{\circ}\text{C}$  for up to 2 months. Fruit destined for long-term storage at 1.5% oxygen required a pre-storage drench of 1,000 ppm ethoxyquin solution.<sup>30</sup>



*Senescent scald (Bartlett)*



*Premature ripening- note pink colour of calyx*



*Superficial scald (Anjou)*

## Pink end, or premature ripening, of Bartlett pears

If sufficient chilling occurs in Bartlett pears during the 30-day period preceding harvest, ripening can be induced while the fruit is attached to the tree. Such pears develop a pink colouring around the calyx button. Ripening can be stimulated to the extent that pears become fully ripe on the tree. Night temperatures of 10°C or less and day temperatures of 20°C or less are especially conducive to pink-end development.

Pears with pink end have a short storage life and should be marketed promptly. Depending on the severity of the disorder, harvested fruit may continue to ripen and undergo complete breakdown. Breakdown in prematurely ripened pears occurs first at the calyx end, where the light brown colour of affected tissue is clearly visible through the skin of the fruit.<sup>31</sup>



*Typical breakdown associated with premature ripening*





# Pear Diseases

- Overview
- Blue mold (*Penicillium* spp.)
- Gray mold (*Botrytis cinerea*)
- Phacidiopycnis rot (*Phacidiopycnis pirii*)
- Mucor rot (*Mucor piriformis*)
- Snow mold rot (Low-temperature *basidiomycete* spp.)



## Overview

Pears have many of the same disease problems as apples, so the same considerations as described under apples regarding packinghouse sanitation also apply to pears. Pears are very prone to wounds made by the stem of one fruit puncturing another fruit during harvest. These wounds are extremely susceptible to decay but quickly become resistant. Therefore, if possible pears should not be handled immediately after harvest until they have been conditioned by storage at 20°C for 2 days or 2 weeks at -1°C. Blue food colouring can be used to enhance visibility of wounds making it possible to remove a higher percentage of wounded pears before they are packed. Pears are also very susceptible to stem end decay caused primarily by *B. cinerea* and occasionally by *M. piriformis*. Pears packed and stored in boxes that develop stem end decay must be repacked adding significantly to their handling costs. <sup>32</sup>

## Blue mold (*Penicillium* spp.)



Blue mold (Bartlett)

As with apples, *P. expansum* causes blue mold rot in pears, indicated by a soft and watery rot that is easily separated from healthy tissue. Infection occurs on the cheek of the pear, where cuts, abrasions, or punctures are found, but fruit can also become infected through lenticels

on unbroken skin, particularly at bruise sites. The high humidity that prevails in polyethylene box liners favours the development of decay. Delays in cooling fruit after harvest also increase the chance of blue mold.

Anjou pears should not be stored for long periods (not longer than 5-6 months) without a protective fungicide treatment of fludioxinil or thiabendazole. Thiabendazole is insoluble in water and must be agitated during application. Pears in a soda lime flume system should be thoroughly rinsed before fungicide is applied, because residues of soda lime inactivate thiabendazole. Furthermore *Penicillium* spp. may have developed resistance to this thiabendazole and therefore it is only effective on sensitive isolates of this fungus. Fludioxinil can be applied in a drench prior to storage or as a dip/wash, or as a line spray prior to packing. It is compatible with DPA, chlorine, and waxes and will protect fruit from Blue mold decay for several months. <sup>33</sup>

## Gray mold (*Botrytis cinerea*)

Gray mold is common in pears stored for long periods. The rot develops in storage from incipient infections present at harvest principally at the stem or calyx end. The fungus grows and sporulates on dead and dying plant material in orchard cover crops, especially during moist cool weather. Infection can occur any time that spores contact wounds or susceptible tissue. Gray mold rot is firm on un-ripened fruit and not easily separated from healthy tissue. The appearance of the mold is influenced by cultivar, degree of ripeness, and storage temperature. As the fruit ripens, the rot becomes softer but is never as soft and translucent as that of blue mold. Often, infection spreads from fruit to fruit during storage, producing pockets of decayed fruit. For this reason the disease is sometimes called nest or cluster rot. Under humid conditions, surface mycelia and conidia form to give a characteristic gray appearance. Small hard black resting bodies (sclerotia) of the fungus may appear on rotted surfaces of fruits in the advanced stages of decay.

*B. cinerea* is a common saprophyte on decaying organic matter on the orchard floor. Conidia are carried in orchard soil or produced on other organic matter brought into the storage on bins and containers. The conidia may be air-dispersed but are more commonly water-dispersed in flumes in packinghouses. Thus spores of the fungus often build up in solutions

used to treat pears for scald and in the dump tank.

Control of gray mold starts in the orchard by clearing the orchard of dead plant material. Prevent fruit from contacting dust and dirt by using clean bins and avoid bruising and stem punctures. Packinghouse dump tank water should be changed often to reduce the number of spores that accumulate during dumping. Fruit should pretreated with pyrimethanil before harvest and/or dipped, sprayed, drenched, or flooded with fludioxinil or thiabendazole if it is to be stored for 3-6 months.<sup>34</sup>



Gray mold/*Botrytis* rot at stem-end (Anjou)



Gray mold spread in storage by fruit to fruit contact

## Phacidiopycnis rot (*Phacidiopycnis piri*)

Phacidiopycnis rot was first reported in Washington and is a serious problem on Anjou pears in that state and to a lesser degree a problem in British Columbia. It appears as a decayed area on the stem-end, calyx end or at wounds on the fruit skin. As the disease develops the decayed area turns brown and then black but the margin of the decay retains a water soaked appearance. The disease is caused by *Phacidiopycnis piri* which produces two types of conidia, macroconidia and microconidia that are useful in its identification. It differs from Gray mold with a distinct odour and having a watersoaked margin and from Sphaeropsis rot by having an odour different from the odour of Sphaeropsis rot. Thiabendazole applied before storage will control Phacidiopycnis rot.<sup>35</sup>



Phacidiopycnis rot (*Phacidiopycnis piri*)



## Mucor rot (*Mucor piriformis*)

*M. piriformis* causes decay in pears which may be at the stem or calyx-end, in the core region or anywhere on the fruit surface. Infected fruit is soft, watery, and light brown with gray whisker-like appendages protruding from cracks in the fruit skin. Since 1971 when Mucor rot was first identified in Canada, the disease has been regularly observed on Anjou pears in British Columbia. The fungus accumulates in the orchard on infected fallen fruit and becomes incorporated into the orchard soil. Soil adhering to picking bins is a very important source of inoculum. The fruit is contaminated directly by soil containing *M. piriformis* or indirectly by dump-tank water that has been contaminated.

In order to reduce the likelihood of contaminating pears with *M. piriformis* spores it is advisable to collect and destroy fallen fruit from the orchard before they can be colonised by this fungus. During harvest bins should be placed on wood chips or some surface which prevents direct contact with soil, and fruit should never be removed from the ground and placed in the harvest bin. In the packinghouse fruit should be dumped into water containing 50-100 ppm chlorine to insure that propagules of *M. piriformis* are killed and the dump tank should be emptied and thoroughly cleaned whenever the water becomes dirty. If this is not feasible a spray rinse with clean water immediately after the pears have left the dump tank will reduce contamination.<sup>36</sup>

## Snow mold rot (Low-temperature *basidiomycete* spp.)

In British Columbia snow mold rot (Coprinus rot or LTB rot) has been observed on pears that have been stored for extended periods. Studies on pathogenicity by the low-temperature basidiomycete fungus showed that Anjou and Bartlett pears are very susceptible to infection. It is often mistaken for bull's-eye rot. Infected areas are dark brown, variable in size, slightly sunken, and often have a tuft of white mycelia in the centre of each lesion. The disease appears as white mycelial growth on the surface of infected fruit and creates a nest of infection from which it expands to other fruit.

Inoculum for snow mold infection may be from orchard debris that fell into the bin during harvest or from windfall fruit placed in the bin. A few contaminated fruit are all that is necessary for infection to spread during storage. Growth of the rot is slow if temperatures are kept near 0°C, and infected lots can be repacked for the retail market provided they are sold promptly. Low relative humidity during repacking and storage helps to reduce subsequent infection of the repacked fruit. Thiabendazole is not effective in controlling this fungus, however a preharvest spray with a dithiocarbamate fungicide has been reported to prevent snow mold rot.<sup>37</sup>



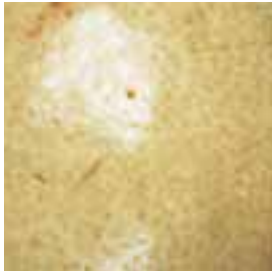
Gray mold showing sclerotia (Anjou)



Mucor rot at stem-end (Anjou)



Snow mold rot (Anjou)



# Procedures and Problems in Packing of Pears

- Flotation of pears
- Skin abrasion and scuffing



## Flotation of pears

Pears such as Anjou with a density of 1.03 do not float because their density is slightly higher than pure water with a density of 1.00. In order to allow them to float out of bins and through the dump tank it is necessary to add a salt to elevate the water density. Sodium sulfate, sodium metasilicate (water glass), or sodium carbonate (soda ash) can be used. The pH of a 6% solution of sodium sulfate is 4 to 6.5 depending on source of material, 11.2 for a 7.5% solution of sodium silicate and approximately 10 for a 5% solution of sodium carbonate. All three flotation materials are compatible with chlorine when used as a dump tank disinfectant. The density of water with these salts added is measured along a scale known as specific gravity. The specific gravity of pure water is 1.00 and increases as salts are added. Specific gravity is measured with a hydrometer

which is a sealed, weighted glass tube with a scale marked off along its length. The hydrometer is floated in the solution and read where the scale intersects the water line. A specific gravity of 1.02 is sufficient to float pears, and the quantity of salt needed to obtain this value can be derived from Figure 1.

Pears left for an extended time in alkaline solutions may develop discolouration of the lenticels. Insufficient rinsing after flotation can also cause darkening of the lenticels. Some difficulty has been encountered with solubility of sodium sulfate. Apparently, warm water is required to dissolve the salt, and lumps form when cold water is used. Extensive corrosion of equipment has also been encountered with sodium sulfate and soda ash. One packinghouse reported less scuffing when sodium silicate is used as the salt in the flume system. Sodium silicate is slippery, and spills are difficult

to remove unless cleaned up promptly. It may gel at low pH values so should never be mixed with acids.<sup>38</sup>

## Skin abrasion and scuffing

Skin marking can be a significant problem in pears, especially when dry belt-sorting is used. No chemical treatments to prevent the problem are available. Flotation has reduced the incidence considerably.

Immature fruit or fruit of advanced maturity is more susceptible to scuffing than fruit harvested at the proper maturity. Longer storage periods increase the likelihood of skin marking during the packing of pears.

Studies on pears in British Columbia suggest that pears should be packed cold, and not warmed during packing. Warming the pears appears to increase

skin marking. Bartlett pears stored above 0°C continue to ripen slowly during storage, show signs of yellowing of the skin, and are very susceptible to marking when packed.

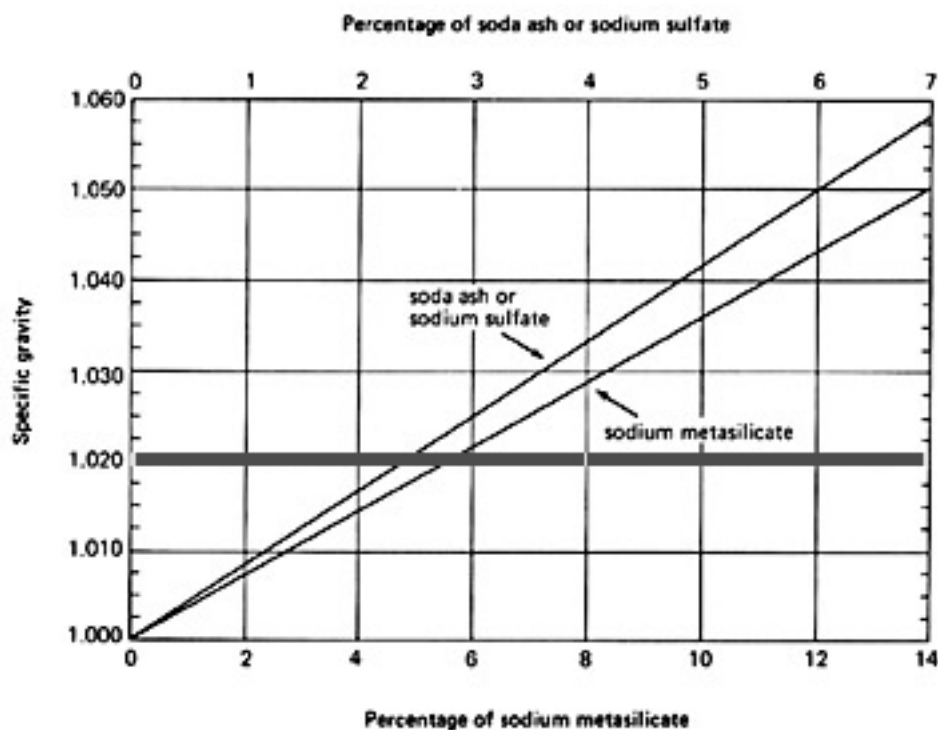
Pears in flotation systems should be kept somewhat moist on the sorting table to reduce the possibility of friction marking.<sup>39</sup>

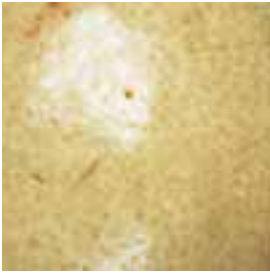


*Friction marking (Bartlett)*

## Fig. 1 Flotation of Pears

Specific gravity of soda ash, sodium sulfate, and sodium metasilicate solutions. Courtesy of C. Pierson, United States Department of Agriculture, Tree Fruit Research Laboratory, Wenatchee, WA.





# Storage Conditions and Problems

- Cold storage conditions
- Effect of cooling rate on pears
- Freezing injury
- Effect of palletizing on cooling rate
- Forced air cooling



## Cold storage conditions

Temperatures of  $-1^{\circ}\text{C}$  to  $-0.5^{\circ}\text{C}$  are recommended for the storage of pears. Conditions for CA storage are  $2.2 \pm 0.2\%$  oxygen and  $0.7 \pm 0.3\%$  carbon dioxide. Approximate storage periods for Bartlett and Anjou in regular storage are 90 and 150 days, respectively. <sup>40</sup>

## Effect of cooling rate on pears

Note:  $32^{\circ} = 0^{\circ}\text{C}$  and  $30^{\circ} = -1.1^{\circ}\text{C}$

The rate of cooling is very important in the storage of pears, especially with such cultivars as Bartlett. Slow rates of cooling result in accelerated ripening during storage, and a reduced storage and shelf life are inevitable. Delays in cooling pears have a detrimental effect on storage life, and results can be disastrous if delayed cooling is accompanied by slow cooling (Table 3).

Table 3. Effect of cooling rate and delayed storage on incidence of core breakdown in Bartlett pears

Days to reach core temperature of $-1^{\circ}\text{C}$	Delays before cooling (days)	Core breakdown * (%)
1	0	8
4	0	21
8	0	62
14	0	83
2	1	64
2	14	100

\* 8 weeks of storage at  $-1^{\circ}\text{C}$  followed by 7 days at  $20^{\circ}\text{C}$ . <sup>41</sup>



Effect of storage temperature (Anjou)



Differential ripening caused by improper cooling (Bartlett)



## Freezing injury

Pears have an average freezing point of  $-2.2^{\circ}\text{C}$ , and in years when the soluble-solids content is low, freezing is a distinct possibility. Bartlett pears with soluble solids of 8% may have a freezing point of  $-1.7^{\circ}\text{C}$  or higher. Particularly vulnerable to freezing are pears in the top bins opposite the refrigeration coil also and in the bottom bins, where cold air may stratify if bins have been stacked incorrectly.

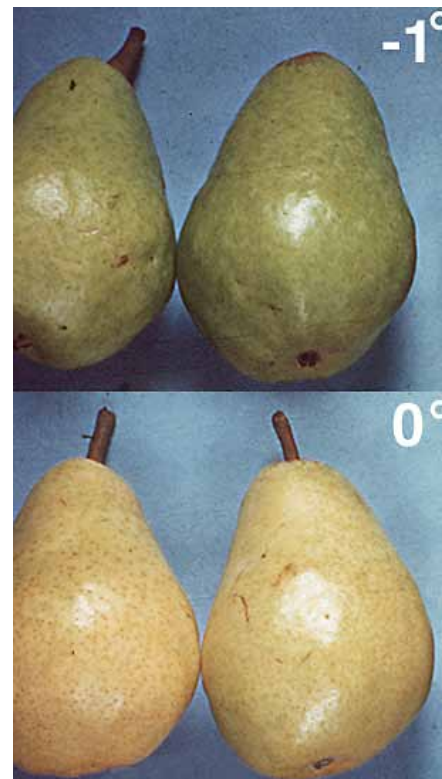
Frozen tissue has a glassy appearance and can be thawed without permanent injury; however, prolonged freezing results in desiccation and the formation of internal cavities.<sup>42</sup>

## Effect of palletizing on cooling rate

A study with several approaches to stacking packed cartons of Anjou pears on a pallet has shown a remarkable difference in cooling rates of the fruit. Cartons with a minimum amount exposed surface contained fruit that varied from fully green to fully ripe. Tight-fill cartons had a slower rate of cooling than tray-pack cartons, given the same stacking arrangement (see thermocouples 1 and 7 or 2 and 6 in Fig. 2).<sup>43</sup>

## Forced-air cooling

Rapid reduction of fruit temperature can be achieved with forced-air cooling. In this procedure, cold air is rapidly drawn through pallets, and cooling times can be reduced from days for conventional cooling to several hours. Two rows of pallets 1-1.5 m apart in a cold room are covered with plywood, and a large fan is placed at the front entrance to the pallets. All air passages except those through the cartons in the pallets are blocked to ensure cold-air movement through the cartons.<sup>44</sup>



*Effect of storage temperature (Bartlett)*

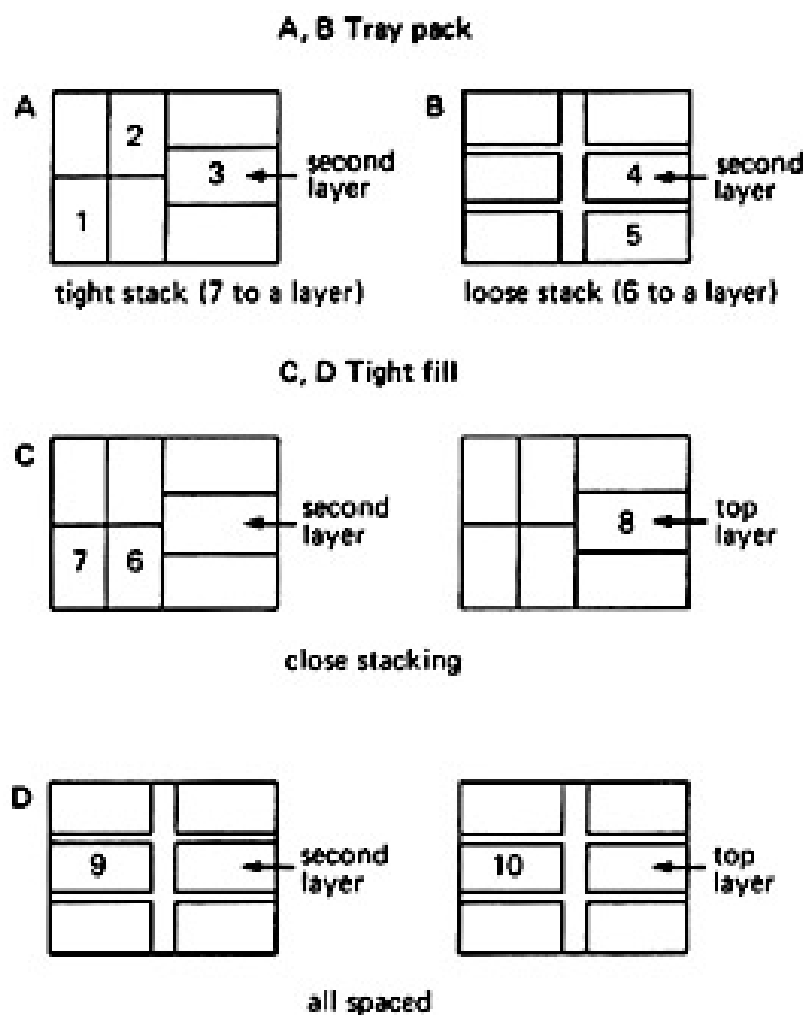


*Freezing injury (Bartlett)*



**Fig. 2**

Effect of stacking within a pallet  
on cooling rate of Anjou pears.  
Effect of palletizing on cooling rate.



Thermocouple	Half cooling time (hours)	Days to reach core temperature of 0°C
1	68	9.3
2	140	19.5
3	148	20.2
4	62	9.6
5	51	7.9
6	670	92.6
7	140	19.2
8	228	31.0
9	55	7.8
10	49	7.2



# Apricot Diseases

- Overview
- Brown rot (*Monilinia* spp.)
- Shot hole (*Wilsonomyces carpophilus*)
- Red fruit blemish (*Alternaria alternata*)
- Rhizopus rot (*Rhizopus stolonifer*)



## Overview

Apricots grown in the interior of British Columbia are susceptible to postharvest decay. Fungicides such as fenbuconazole applied immediately before harvest will often suppress decay especially fruit brown rot caused by *Monilinia* spp. Postharvest decay caused by *Rhizopus* spp., *Monilinia* spp., *Botrytis cinerea*, and *Penicillium* spp. can be prevented by dipping or drenching the apricot fruit in fludioxinil. See the label for details. For best control, fruit should be picked in the morning when they are cool, and immediately placed in cold storage at a temperature below 10°C to prevent mold growth. If possible the fruit should be dipped in a sodium hypochlorite solution of 55 to 70 ppm available chlorine and rinsed with clean tap water (Note: For 100 ppm available chlorine add 4 ml of 5.25% sodium hypochlorite to a litre of water).<sup>45</sup>

## Brown rot (*Monilinia* species)



*Brown rot*

Brown rot, a major disease of apricots, is caused by two closely related fungi, *Monilinia fructicola* and *M. laxa*. *M. fructicola* is by far the most common species found in British Columbia. In spring the primary features of brown rot are blossom blight, twig blight, and green fruit rot. Apricot is very sus-

ceptible to blossom blight. Inoculum from blossom blight may lead to fruit rot or decay after the fruit is picked. Infection of fruitlets during or shortly after flowering may lead to quiescent infections on green fruit that become active after harvest.

Brown rot on ripening or mature fruit develops as a spreading, firm, brown decay. In years when brown rot is a serious problem, postharvest treatment of apricots with fludioxinil is essential. Rots occur more readily on riper fruit because of the higher sugar content.

Fungicides must be applied to protect blossoms and developing fruit from infection, especially if there were high levels of inoculum present in the orchard in the previous year and spring weather is wet. Removing fruit, mummies and blighted twigs from trees after the final harvest reduces the amount of brown rot inoculum. The hours of wetting neces-

sary for blossom infection decrease from 18 hours at 10°C to 5 hours at 25°C. Generally one or two fungicide sprays are applied but highly susceptible cultivars of apricot with a history of brown rot infection may require four sprays. Fruit are relatively resistant to brown rot when green but become susceptible again when fruit begins to colour about 3 weeks before harvest. Colouring fruit must be protected from infection with fungicides. Application of a fungicide one day prior to harvest will protect the fruit for about a week. Fungicides do not control infections once they have become established and thus do not control quiescent infections. Control of insects is important at this time because they may vector spores and provide wounds for infection.

Fludioxinil is registered for control of post-harvest brown rot on apricots in Canada. Rapid cooling such as hydro cooling or cold storage will delay development of brown rot. If hydro cooling, it is advisable to disinfect the water with chlorine.

## Shot hole (*Wilsonomyces carpophilus*)

Shot-hole disease, also known as Coryneum blight and pustular spot, is especially important on apricots. Small purplish-red circular spots develop that are raised and rough. The disease is controlled by dormant application of a fixed copper or Bordeaux spray and an organic fungicide spray, such as ziram, captan, iprodione, or chlorothalonil, immediately after fruit set. Sprinkler irrigation that wets leaves

and fruit can increase disease incidence. Pruning diseased wood is the only way to remove perennial infections.<sup>46</sup>



Shot hole

## Red spot fruit blemish (*Alternaria alternata*)

A superficial red spot fruit blemish of apricots caused by *A. alternaria* has been reported in Washington. Red spot fruit blemish is known as Alternaria rot on other stone fruit crops in British Columbia. In California this disease is called fog spot because the red spots are common when wet weather occurs during fruit set and maturation. The symptoms occur as numerous scattered red dots on the upper fruit surface 18 days after shuck fall. The spots eventually become light tan with necrotic centres and red halos. Control of red spot fruit blemish has not been attempted in British Columbia although both captan and iprodione are effective against *Alternaria* spp.<sup>47</sup>

## Rhizopus rot (*Rhizopus stolonifer*)

Rhizopus rot and brown rot fungi often occur together on apricot. The fungus does not grow at temperatures slightly below 10°C so is kept in check by immediately cooling the fruit. Fruit contaminated with *Rhizopus* spp. spores is reduced by rinsing with chlorinated water. Treatment with fludioxinil as a dip or drench before storage will prevent infection by both Rhizopus and Brown rot.<sup>48</sup>



# Apricot Packing and Storage Conditions

- Packing
- Storage



## Packing

Apricots delivered to the packinghouse are cooled to 10°C before packing to prevent accelerated ripening of the fruit.

## Storage

Apricots are stored at 0°C. Although CA storage is possible for apricots, it has not been used in British Columbia. In British Columbia, packed fruit is required to be cooled promptly to 0°C; the minimum requirement that fruit be cooled to is 4.5°C in 24 hours and 0-0.5°C in 48 hours. Shipping temperatures for apricots must not exceed 4.5°C.



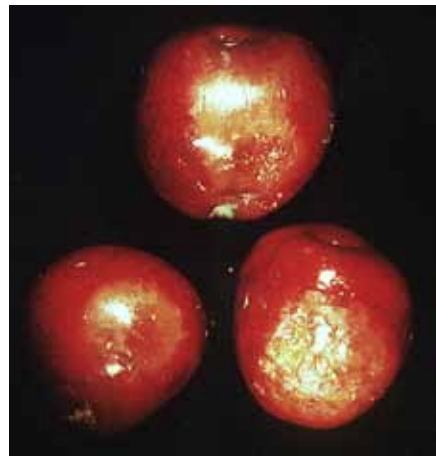
# Cherry Disorders

- Bruising
- Cracking
- Surface pitting



## Bruising

Bruising can occur when cherries are harvested into unpadded buckets. Impact bruising during harvest causes internal flesh discolouration followed by exudation of liquid droplets and formation of a slight depression. A study in California found that Black Tartarian cherries dropped into unpadded buckets showed 25% internal browning, whereas those dropped into padded buckets showed only 2% browning. Browning developed within 24 hours of dropping at both 21 and 1.5°C although exudation of surface liquid only occurred at 21°C. Bruised sweet cherries will develop water-soaking and browning of the fruit flesh, and such bruised areas are more susceptible to infection by fungal pathogens.<sup>49</sup>



*Bruised cherries*



*Cherries wet by rain with cracked cherry*

## Cracking

When a water droplet remains on the cherry skin for an extended period it is absorbed by osmosis, causing the cells below the skin to increase in volume stretching the epidermis until it splits. Cracking often begins at the stylar scar because it is not protected by cutin and absorbs water rapidly.

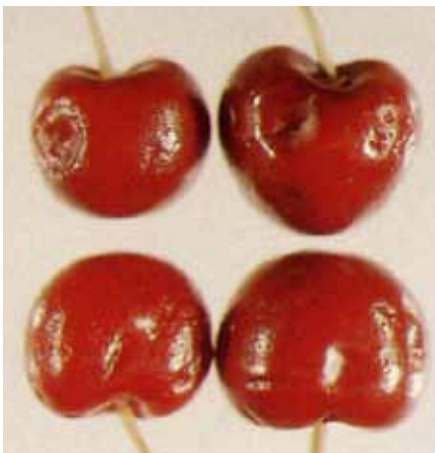
Certain cherry cultivars such as Lapins are resistant to cracking. Spraying with soluble organic or inorganic calcium salts reduces cracking in some cases. Unless the duration of rain is short, attempts to remove water from the fruit surface by blasting with air have been ineffective. There is no evidence to implicate hydro-cooling as a cause of cracking.<sup>50</sup>



## Surface pitting

Considerable surface pitting has occasionally been found in Van cherries and to a lesser extent in Lambert cherries. Bruising and mechanical injury are responsible for the disorder. Other factors that promote surface pitting are immature fruit and packing of cold fruit.

Reduction in pitting can be achieved through careful harvesting and handling, and improvements in packing facilities. A single spray of gibberellic acid applied about 3 weeks before normal harvest (the straw-yellow stage of fruit maturity) can improve several aspects of fruit quality. The treatment delays red colour, increases fruit firmness and size, and delays the period of maximum sensitivity to rain splitting. Furthermore, gibberellic acid-treated fruit are less likely to develop cherry pitting. Preharvest application of calcium is another approach to reducing pitting in sweet cherries. Weekly applications of 77% calcium chloride starting 3-4 weeks before harvest has been reported to be effective in Washington although fruit size may be reduced slightly.<sup>51</sup>



*Surface pitting (Van)*



# Cherry Diseases

- Overview
- Brown rot (*Monilinia* spp.)
- Rhizopus rot (*Rhizopus* spp.)
- Alternaria rot (*Alternaria* spp.)
- Penicillium rot (*Penicillium* spp.)
- Gray mold (*Botrytis cinerea*)
- Shot Hole (*Wilsonomyces carpophilus*)



## Overview

Cherries are not as susceptible to post-harvest decay as apricots or peaches unless cracked. However, they should be cooled immediately after harvest to less than 10°C. Preharvest fungicide sprays applied immediately before harvest will usually protect fruit from decay especially if a postharvest dip of 55 to 70 ppm available chlorine followed by a rinse in clean tap water is used. (Note: For 100 ppm available chlorine add 4 ml of 5.25% sodium hypochlorite to a litre of water). Postharvest decay caused by *Rhizopus* spp., *Monilinia* spp., *Botrytis cinerea*, and *Penicillium* spp. can be prevented by dipping or drenching the sweet cherry fruit in fludioxinil.<sup>52</sup>

## Brown rot (*Monilinia* spp.)

As with apricots, cherries are susceptible to brown rot infection during the blossom

phase. Optimum temperature for blossom infection is 25°C. Cherries become highly susceptible to *Monilinia* species again during the fruit colouring stage. Injured cherries cracked by rain are particularly susceptible to infection. Brown rot spores germinate and infect fruit quickly in the presence of moisture and favourable temperatures of 20-26°C. Lower temperatures reduce but do not prevent growth of the fungus. Brown rot is characterized by the presence of a brown powdery growth on the surface of the cherry. Decay of the fruit and subsequent spore production may occur in a few days, so the disease can spread quickly. Mummified fruits and blighted twigs should be removed from the orchard before the next growing season. Decay can be prevented during the growing season with timely fungicide sprays alternated with or used in combination with fungicides having different modes of action. Fungicide resistance is an important consideration and measures should be taken to manage it before it becomes a problem.

To reduce postharvest decay rapid cooling is important. Quick removal of field heat in cherries can be obtained with hydro-cooling. The water in the apparatus should be chlorinated to prevent buildup of spores and subsequent contamination of the fruit. Fludioxinil is registered for control of postharvest brown rot on sweet cherries in Canada and should be used to prevent decay immediately after the fruit is harvested.



*Brown rot on cherries*

## Rhizopus rot (*Rhizopus* spp.)

Rhizopus rot on cherries is characterized by a mass of aerial mycelia on which structures called sporangiophores are attached. Sporangiophores are covered with minute gray to black sporangia (pinpoint size), which give a gray appearance to the rot. The sporangia rupture easily, freeing spores which are disseminated in air to other fruit. The infected tissue is soft and watery. Once the fungus is established on fruit it can spread quickly to nearby fruit resulting in clusters of infected fruit.

The fungus exists on dead plant material and its spores are very common in the atmosphere. Green fruit is resistant to infection. Mature fruit is infected at wounds sustained when harvesting and handling.

Rhizopus rot is controlled by storing the cherries at temperatures below 4.4°C. Fludioxinil can be used to prevent the disease from occurring if applied before infection occurs. <sup>53</sup>

## Alternaria rot (*Alternaria* spp.)

Alternaria rot appears as a dark green, felt-like growth that occurs most frequently on the stylar end of the cherry. Lesions are circular to oblong and may cover one-third to one-half of the fruit. The disease occurs on overripe fruit or where rain has caused the fruit to crack and expose the flesh to infection. Careful

handling of the fruit to avoid injuries is imperative. No chemicals are registered for the control of Alternaria rot. However iprodione, registered for the control of brown rot, is also effective against Alternaria rot. <sup>54</sup>

## Penicillium rot (*Penicillium* spp.)

Penicillium rot on cherries can cause serious problems in packed cherries shipped to distant markets. *Penicillium* spp. cause circular light brown lesions that become covered with white mold, subsequently becoming blue-green as spores are formed. Spores of the fungus are common in the atmosphere but it can only attack injured or overmature fruit. In cherries it is most important to avoid injuring or storing of rain split fruit. These fruit will become infected and act as a source of inoculum to infect other fruit. Cooling the fruit (0-4°C) will slow the rate of decay especially if the fruit is hydro cooled first. Fludioxinil will prevent infection by *Penicillium* spp. if the fruit is treated immediately after harvest. <sup>55</sup>



*Penicillium* rot



*Rhizopus* rot



*Alternaria* rot

## Gray mold (*Botrytis cinerea*)

Gray mold of cherries can be a serious problem in British Columbia. *Botrytis cinerea* also causes green fruit rot of cherries. *B. cinerea* will only infect floral parts of cherries following periods of prolonged wet, cool weather. If the wet weather persists green fruit rot may develop, otherwise, a latent infection may occur that can develop as rot when the fruit ripens. Gray mold is prevalent in fruits which have been stored for some time because the fungus nests and spreads on to adjacent sound fruit.

Orchard sprays with fungicides effective against *B. cinerea* during blossom and prior to harvest should help prevent infection. Careful handling to reduce injuries and efficient cooling will reduce decay. Fludioxinil will prevent infection by *Botrytis cinerea* if the fruit is treated immediately after harvest.<sup>56</sup>

## (*Wilsonomyces carpophilus*)

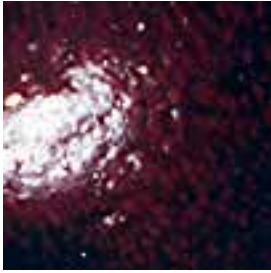
Leaves and fruit infected with the shot hole fungus have characteristic small round holes, 3-10 mm in diameter distributed over their surfaces. On fruit, lesions develop mostly on the upper side and eventually become corky and rough. Leaf lesions eventually drop out producing the shot hole appearance. The disease is spread by water and sprinkler irrigation that wets leaves and fruit. A single dormant spray of Bordeaux mixture or a fixed copper formulation applied in the fall provides protection throughout the winter. An organic fungicide such as ziram, captan, iprodione, or chlorothalanil should be applied at husk fall if shot hole was a problem in the previous year.<sup>57</sup>



Gray mold



Shot hole



# Cherry Storage conditions



Cherries can be stored for up to 5 weeks at 0°C before serious losses in quality occur. Polyliners are recommended to reduce moisture loss. Molds which colonize the stylar scar and receptacles of cherries reduce storage life. Fruit treated with multiple applications of fungicides had a mold free storage life of 8 weeks (7 weeks at 1 to 4°C plus 1 week at simulated retail temperatures of 20 to 21°C) in recent trials conducted at the USDA-ARS Tree Fruit Research Laboratory, Wenatchee, WA. The limitation that molds place on cherry storage life is especially important in modified-atmosphere packaging (MAP). Fruit quickly decay when taken from their packages. Research on either a biological solution or the use of specific fungicides could make MAP a useful means of prolonging the storage life of cherries.<sup>58</sup>





# Peach and Nectarine Disorders

- Split Pits
- Woolliness

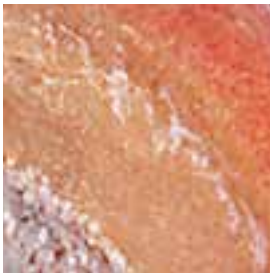


## Split pits

Split pits are common in Okanagan peaches. Large fruit on lightly cropped peach and nectarine trees are likely to possess cracked or split pits. Cultural operations such as excessive thinning of the crop, untimely application of irrigation water, or girdling of the trunk just before or during pit-hardening favour split pits.

## Woolliness

Woolliness of peaches and nectarines is characterised by lack of juice and flavour and a mealy texture. It is the result of harvesting immature fruit and can be reduced by intermittent warming during the storage period or by holding the fruit at 20°C for one or two days before cooling.



# Peach and Nectarine Storage Conditions

Peaches can be stored at 0° C for 2-4 weeks. Early varieties are limited to about 2 weeks of storage, and late varieties to as long as 4 weeks. Longer storage periods cause undesirable changes in texture and flavour.





# Peach and Nectarine Disease

- Overview
- Brown rot (*Monilinia* spp.)
- Rhizopus rot (*Rhizopus stolonifer*)
- Powdery mildew (*Sphaerotheca pannosa*)



## Overview

Peaches and nectarines grown in the interior of British Columbia are very susceptible to postharvest decay when mature. For most effective control, fruit should be cooled as soon as possible after harvest. They should be dipped in a sodium hypochlorite solution of 55 to 70 ppm available chlorine and rinsed in clean tap water. (Note: For a 100 ppm available chlorine solution add 4 ml of 5.25% sodium hypochlorite (commercial bleach solution) to a litre of water) This will destroy spores of decay-causing fungi on the fruit surface but will not kill any internal pathogens that may have infected the fruit before harvest. Fludioxonil and dichloran are registered for postharvest decay control on peaches and will provide control of Brown rot and Rhizopus rot. It should be used if fruit are to be kept for a week or more. <sup>59</sup>

## Brown rot (*Monilinia* spp.)



*Brown rot*

Peaches are highly susceptible to brown rot, especially when they are ripe. Brown rot develops as a rapidly spreading, firm, brown decay. It appears as circular brown patches on the fruit (frequently at the stem end), followed by the development of fluffy, light brown masses of spores on the

surface of the rot area. Visible decay may be apparent within 48 hours of infection. In British Columbia the fungus survives the winter on mummified fruits and blighted twigs in the orchard. The sexual stage (apothecia) of *Monilinia* species has not been observed in recent memory so is of no concern for disease control. Wet weather during the spring months induces the fungus to produce and disseminate spores from previously infected tissue.

Fruit infected shortly after blossom where the fungus becomes quiescent, may become infected as the fruit ripens or during storage and marketing if the fungus becomes active again. Decay also may emanate from wounds in the fruit skin caused by insects, physiological forces such as suture cracks, or weather related injuries such as those caused by hail. Levels of infection increase sharply when there is frequent wet weather close to or during harvest and spore levels are high in the orchard.

Control of brown rot depends on orchard sanitation, a protective fungicide spray program, careful handling at harvest to avoid injuries, and rapid cooling of fruit. Protective fungicides are applied at blossom, during fruit ripening, and immediately before harvest. Decay can be prevented during the growing season with timely fungicide sprays alternated with or used in combination with fungicides having different modes of action. Fungicide resistance is an important consideration and measures should be taken to manage it before it becomes a problem.

Prompt cooling is achieved by hydro-cooling. Hydro-cooling water should be chlorinated to prevent contamination of the fruit with decay-causing fungi. Fludioxonil and dichloran are registered for postharvest decay control of brown rot.<sup>60</sup>

## Rhizopus rot (*Rhizopus stolonifer*)

Rhizopus rot often accompanies brown rot in peaches and nectarines. Circular brown water soaked areas appear on the fruit, and the skin is easily detached from the infected area. Affected fruit are soft, watery and often covered with a whisker-like growth. The fungus quickly spreads to nearby fruit resulting in clusters of infected fruit.

Fruit is contaminated during harvest by spores of this fungus. Inoculum often comes from cull fruit on the orchard floor that are infected with *R. stolonifer*, decay and release millions of spores into the air.

Infection takes place via injuries made during harvesting the fruit. This disease occurs regardless of weather conditions and can be particularly damaging in peaches held by canneries for ripening.

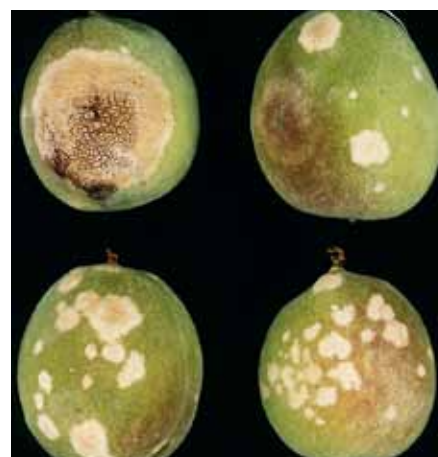
Rhizopus rot is effectively controlled by storing fruit at 4°C because the fungus does not grow at temperatures below 4.4°C. During storage spores of *R. stolonifer* die, reducing the chance of infection later during marketing of the fruit. Effective chemical control of Rhizopus rot is provided by dichloran and fludioxonil. Because dichloran is incompatible with flotation salts, it should be applied on-line after the rinse operations. The spray bar should be mounted 30 cm above the seventh brush, and spray should be directed so that the peaches are drenched at the fifth brush. Six nozzles spaced 15 cm apart are adequate. Dipping the fruit in dichloran upon arrival at the packinghouse is essential for peaches held for the cannery. Iprodione is also effective against *R. stolonifer* especially if combined with oil.<sup>61</sup>

## Powdery Mildew (*Sphaerotheca pannosa*)

Powdery mildew and rusty spot, a disease associated with mildew fungi, are rare in BC peach orchards. The first symptoms of infection are white circular spots which may coalesce to cover most of the fruit. On older peach fruit the infected areas are scabby and brown, but on nectarines they remain green.

The fungus over winters as mycelium in the inner bud scales of peach. Spores are carried by wind and rain to fruit. Peach fruit are susceptible to powdery mildew from the early stages of growth until pit-hardening. The disease is most severe during mild wet weather.

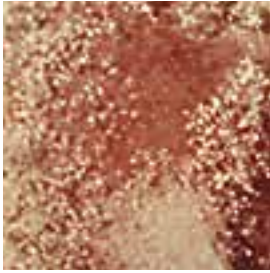
Most peach cultivars grown in BC are resistant to powdery mildew. Rio-Oso-Gem, Redskin and Bailey, used for peach rootstocks, are susceptible. Fungicide sprays of sulphur or myclobutanil initiated at petal fall and continued every 10-14 days until pit hardening will control the disease.<sup>62</sup>



Powdery mildew



Rhizopus rot of peaches



# Diseases of Plums and Prunes

- Overview
- Brown rot (*Monilinia* spp.)



## Overview

Plums and prunes are relatively resistant to postharvest decay. They can be preserved for several days if they are immediately placed in cold storage at less than 10°C immediately after harvest. They also may be dried to prevent spoilage for several weeks.<sup>63</sup>

blighted blossoms or mummified fruit from nearby stone fruit such as apricots and peaches. Spores are deposited on fruit by wind, rain, or insects. Orchard sprays to control brown rot have not been necessary in British Columbia. If brown rot were to become a problem, a similar spray program as used in peaches would be justified.<sup>64</sup>

## Brown rot (*Monilinia* species)

Brown rot is the only important disease of plums and prunes in commercial orchards in the interior of British Columbia. Early symptoms of brown rot are spots with discolouration and softening of the skin. The infection develops overnight into a powdery, brown spore mass.

Brown rot is favoured by rains near harvest during fruit ripening. The inoculum may come from spores produced on



*Brown rot (Italian prune)*



# Plum and Prune Storage Conditions



Taking representative fruit samples and following changes in fruit firmness and soluble solids will allow the grower to determine the time of optimum harvest. Defects such as off-color interior tissue, end cracks, scab, embedded dirt, insect and mold damage should be avoided if possible by effective orchard management. Prunes are dehydrated and then rehydrated in order to handle the fruit and prevent them from spoiling. Most plums and prunes can only be stored for 2-3 weeks at 0°C without drying, but Italian prunes can be stored for a month. <sup>65</sup>



# Table Grape Disorders



## Sulfur dioxide injury

No postharvest treatments are recommended for table grapes to control postharvest rots other than the use of sulfur dioxide pads. The pads generate sulphur dioxide within the carton from the humidity that is present and thus controls the pathogen. Sulphur dioxide gas is effective but cannot kill the fungus in established infections.

There is a fine margin between the concentration of sulphur dioxide required for mold suppression and the concentration that will injure the grape. The stem-end of the grape berry becomes bleached and most berries in a bunch show partial discolouration extending a few millimetres from the stem-end. As well as bleaching the skin, sulphur dioxide can produce a disagreeable taste in the grape flesh.

To reduce the risk of injury, grapes should be cooled before being packed so sulphur dioxide will be released slowly at first, prolonging the usefulness of the fumigant. Another tactic is to use two stage pad generators so that one generator releases sulphur dioxide immediately and the other emits the gas during the later stages of storage.<sup>66</sup>



# Table Grape Diseases

- Overview
- Botrytis rot or Bunch rot (*Botrytis cinerea*)
- Penicillium rot (*Penicillium* spp.)



## Overview

Postharvest diseases of grapes are suppressed by immediately cooling the fruit to less than 10°C. Information on grape pest management is available in the grape production guide available from agricultural suppliers or:

BC Wine Institute  
 1737 Pandosy Street  
 Kelowna BC V1Y 1R2  
 Phone: 250 762-9744  
 Toll-free: 1 800 661-2294  
 E-mail: [dgeoffrey@bcwi.bc.ca](mailto:dgeoffrey@bcwi.bc.ca).

The most important postharvest diseases of table grapes are listed below. <sup>67</sup>

## Botrytis rot or Bunch rot (*Botrytis cinerea*)

Botrytis rot, also known as gray mold rot, is the most important postharvest disease of grapes. In the vineyard it is known as bunch rot. In its early stages the skin of the berry becomes

loose and is easily detached. This is followed by brown discoloration and the production of gray-brown spores. Sometimes a whitish mold growth occurs without spores under humid conditions.



Bunch rot

Infection may occur anytime from blossom until harvest. If the infection occurs early in the season the fungus remains quiescent until the berries mature. Harvest infections are favoured by wet weather.

The disease is controlled by well timed fungicide sprays initiated during the pre-bloom phase of berry development. Fungicides such as iprodione, captan, cyprodinil, fenheximid, and benomyl have been effective in preventing bunch rot in the vineyard. They must be alternated so *B. cinerea* does not quickly develop resistance to them. Resistance by *B. cinerea* to benomyl has been documented in several grape growing areas and is known to occur in British Columbia. Postharvest measures to prevent Botrytis rot are careful handling to avoid injuries, rapid cooling, and the use of sulfur dioxide to prevent the spread of *B. cinerea* to healthy berries. Acetic acid has been used in place of sulfur dioxide in controlled experiments conducted at the Pacific Agri-Food Research Centre, Summerland, B.C. with the same effectiveness and could be an important alternative where sulfite residues are a concern. However this will require registration of acetic acid for this use. <sup>68</sup>

## Penicillium rot (*Penicillium* spp.)

Penicillium rot, also called blue mold rot, develops in cold storage on table grapes. Injuries on grape berries become covered with a white growth that gives rise to greenish-blue powdery spores. The decayed berries are soft and watery with a moldy odour. Spores of the fungus are present in cold storage unless every precaution has been taken to prevent their presence. Careful handling of the grapes to prevent injuries and strict sanitation of containers and room surfaces are extremely important. Generally, species of *Penicillium* infect grape berries at the wound site and continue to grow at cold storage temperatures. The mold will spread through the bunch in cold storage. A common species of *Penicillium* that infects grapes in storage is *P. expansum* which produces a toxin called patulin. Therefore it is important not to allow growth of *P. expansum* on grapes destined for human consumption.

Penicillium rot is controlled by minimizing injury to grapes at all stages of production and handling. The rot is prevented by the use of cold storage and fumigation with sulfur dioxide. Acetic acid fumigation and irradiation were effective in research trials. <sup>69</sup>



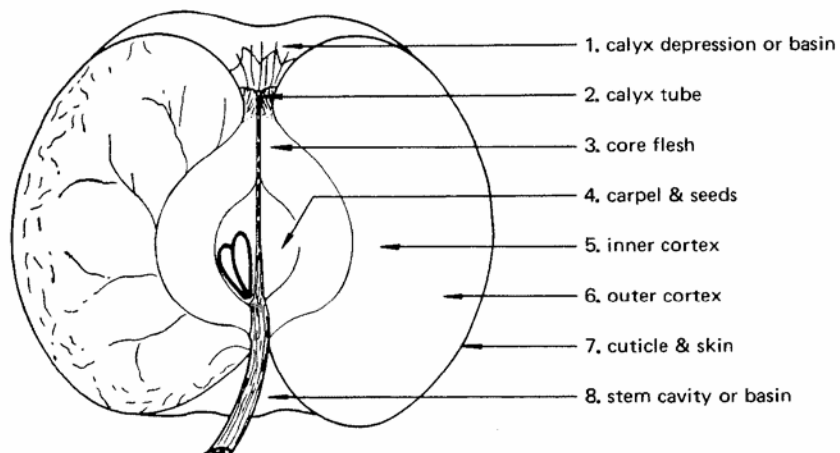
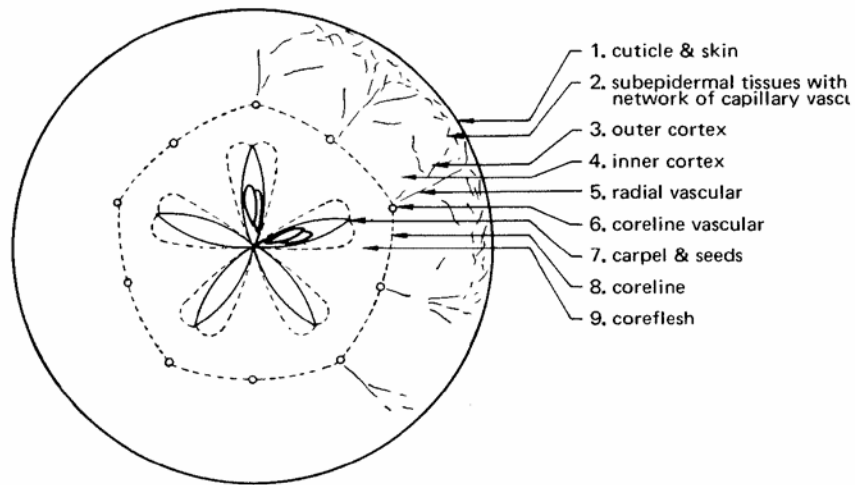
## Table Grape Storage Conditions

Storage at 0°C will keep most cultivars for several weeks. If polyliners are used, a precooling period of 24 hours with the liner open is recommended to reduce moisture accumulation in the carton.

# Appendixes

## DIAGRAM OF APPLE ANATOMY

Diagrammatic sections of an apple, *Malus pumila*. Drawing shows anatomical terms used this publication. Terms also apply to pears. (Reproduced from Carne 1948.)





# Guide for Identifying Pome Fruit Disorders



## Apples

### External Symptoms

#### Carbon dioxide injury

Similar to superficial scald with rough, depressed affected areas.

#### Chemical injury

Injury is associated with exposure to phytotoxic chemicals in soluble or volatile form. Small dark areas of skin develop and larger circular areas may develop if liquid is retained between adjacent fruit.

#### Friction marking

Diffuse, poorly defined areas of brown skin occurring prominently at high points on the fruit surface associated with rough handling.

#### Heat injury

This disorder associated with the hot-water wash during packing resembles superficial scald but develops within 2 to 3 weeks after exposure to hot water.

#### Jonathan spot

This disorder appears as brown, circular spots 2-4 mm in diameter on the fruit surface. The spots appear black on red apples and lighter in colour on green or yellow apples.

#### Low-oxygen (alcohol) injury

This injury resembles soft scald producing dark-brown, water-soaked lesions.

#### Russet

Solid patches of cork tissue on the fruit surface.

#### Soft scald

This disorder causes well-defined areas of brown irregular shaped areas on the fruit surface.

#### Sun scald

This disorder causes bleached or brown areas on the side of the fruit exposed to the sun often becoming darker after removal from storage.

#### Superficial scald

This disorder causes a diffuse brown discolouration of the skin after several months in cold storage and becomes more extensive after the fruit is moved to warmer.

### Internal Symptoms

#### Core browning

This disorder appears as diffuse brown tissue in the core area after several months of cold storage.

#### Flesh browning

This disorder appears as brown flesh in the cortex evident in a transverse section at the junction of the stem and core.

#### Internal carbon dioxide injury

This disorder causes brown, fairly defined areas in cortex or core tissue. In time lesions become light brown, dry, and develop cavities.



### Low-temperature breakdown

This disorder appears as diffuse browning of outer cortex tissue but does not affect core tissue.

### Senescent breakdown

This disorder appears as softening and browning areas of cortex tissue that is dry and poorly defined.

### Vascular breakdown

This disorder is characterized by browning of the main vascular bundles and some adjacent tissue.

### Water core

This disorder appears as liquid-infused tissue around the vascular bundles or additional tissue within or outside the core area.

## External and Internal Symptoms

### Bitter pit

This disorder causes small brown necrotic zones frequently toward the calyx of the fruit that are sometimes visible through the skin as dark green or brown depressions.

### Freezing injury

This injury appears as a brown discoloration of the skin with water-soaked areas. The cortex tissue is brown and cavities may form due to dehydration of frozen tissue.

### Stem cavity browning

This disorder occurs in McIntosh as brown skin underlying the stem cavity.

## Pears

### External Symptoms

#### Alfalfa greening

This disorder occurs on Anjou pear as dark green specks, blotches, or streaks on the fruit skin.

#### Chemical injury

Injury is associated with exposure to phytotoxic chemicals in soluble or volatile form. Small depressions caused by dehydration occur and larger circular areas may develop if liquid is retained between adjacent fruit.

#### Friction marking

This injury is seen as a brown discoloration particularly at high points on the fruit surface.

#### Russet

Russet that appears on pears is a genetic trait.

#### Senescent scald

This disorder affects Bartlett, Bosc, Sierra, and Howell. Dark-brown skin discoloration turns yellow in storage and the fruit does not ripen normally.

#### Superficial scald

This disorder affects Anjou, Packham's Triumph, and Winter Nelis and is characterized by brown skin discoloration after storage and during ripening.

## Internal Symptoms

### Carbon dioxide injury

This injury causes brown, fairly defined areas in cortex or core tissue. In time lesions become light brown, dry, and develop cavities. Carbon dioxide does not cause injury to the skin of pears.

### Core breakdown

This disorder appears as soft brown watery tissue around the core during or after ripening.

### Low-oxygen injury

Late-harvested Bosc pears stored in 1% oxygen may develop this condition indicated by core browning.

### Freezing injury

This injury appears as translucent, water-soaked tissue that may become light brown, with a greenish water-soaked zone in the outer cortex with cavities.

## External and Internal Symptoms

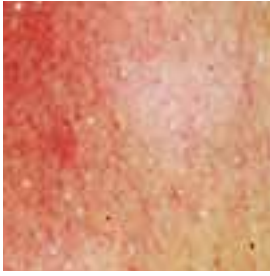
### Bitter pit (Anjou pit)

This disorder occurs often in Anjou and Packham's Triumph where brown, corky lesions appear in the flesh usually near the calyx end. An uneven surface with dark coloured depressions indicates pitted tissue.

### Black end

This disorder appears as cortical tissue at the calyx end that becomes hard and gritty and often turns black.

### Pink end or premature ripening



# Nutritional Disorders

- Overview
- Boron deficiency
- Boron excess
- Calcium deficiency
- Iron deficiency
- Magnesium deficiency
- Nitrogen deficiency
- Nitrogen excess
- Potassium deficiency
- Zinc deficiency

## Overview

Mineral deficiencies and excesses can result in fruit symptoms that may be confused with symptoms induced by fungi or bacteria. Further information on these disorders for grapes can be found in the in the grape production guide available from agricultural suppliers or:

BC Wine Institute  
1737 Pandosy Street  
Kelowna BC V1Y 1R2  
Phone: 250 762-9744  
Toll-free: 1 800 661-2294  
E-mail: [dgeoffrey@bcwi.bc.ca](mailto:dgeoffrey@bcwi.bc.ca)

Information on disorders for tree fruits can be found in the Integrated Fruit Production Guide available from agricultural suppliers or:

BC Fruit Growers Association  
1473 Water Street  
Kelowna, BC, V1Y 1J6  
Telephone: 250 762-5226  
Fax: 250 861-9089  
E-mail: [info@bcfga.com](mailto:info@bcfga.com)

## Boron deficiency

Boron deficiency leads to small, misshapen fruit, drought spot, cracking, premature ripening, and preharvest drop. Boron deficiency in stone fruits is rare. In plums and apricots it has been responsible for necrotic tissue penetrating through the flesh to the endocarp. Fruit trees grown in the BC interior often require applications of boron. Soil and leaf analysis can be used to determine if boron is needed. Boron should be applied to the soil in August at recommended rates. Boron may also be applied as a foliar spray combined with sprays of chelated zinc, magnesium, manganese, and urea. See Chapter 10 of the Integrated Fruit Production Guide for recommended rates available from agricultural suppliers and from the BC Fruit Growers Association.

## Boron excess

Excess boron in apples may lead to premature ripening and the fruit may fall prematurely. It also will reduce the length of time the fruit can be stored and still maintain its quality.

Excess boron in stone fruits leads to cracked, shrivelled, and malformed fruit. See Chapter 10 of the Integrated Fruit Production Guide for recommended rates available from agricultural suppliers and from the BC Fruit Growers Association.

## Calcium deficiency

There are several calcium-related disorders of apple and pear. Those particular disorders that affect the fruit are cork spot, water core, bitter pit, Jonathan spot, deep cracking, and raised lenticels. In pear, cork spot (bitter pit), black end and alfalfa greening are the result of calcium deficiency. Alfalfa greening, also known as green stain, is confined to Anjou pears.

Bitter pit is minimized by annual bearing, moderate tree vigour and fruit size, and by harvesting mature fruit. Nitrogen and magnesium sprays should not be applied in summer. Irrigation should be scheduled to avoid excessive fluctuations in soil moisture. Summer pruning can reduce competition for calcium between the fruit and vigorous new growth. Apply lime when soil pH is low. In addition to these orchard practices calcium chloride sprays can be applied. Application of calcium chloride usually only causes slight burning of leaf edges but severe leaf and fruit injury is possible under some conditions. To reduce the chance of severe injury do not exceed recommended rates and apply during the coolest part of the day.<sup>70</sup>



*External bitter pit (Newtown)*



*Bitter pit, internal (Anjou)*

## Iron deficiency

Iron deficiency occurs when there is insufficient iron in the soil, the iron is not available to the plant because of high pH, or iron is not properly utilized by the tree because of poor drainage or over-irrigation. In stone fruits iron deficiency causes fruit skins to become pale and dull. It also leads to smaller fruit.

## Magnesium deficiency

Apple fruit require considerable amounts of magnesium. Magnesium deficiency is often the result of high potassium in the tree rather than low magnesium in the soil. The condition may lead to reduced fruit size.

## Nitrogen deficiency

Fruit colour is enhanced under low nitrogen conditions because anthocyanin production is encouraged. Stone fruit ripen earlier and are highly coloured. In apples the fruit size is reduced and the crop is smaller than normal.

## Nitrogen excess

A high concentration of nitrogen in apple fruit is conducive to several types of breakdown. The ratio of nitrogen to calcium in apple flesh is very important because a ratio of 10 is free of disorders and a ratio of 30 always leads to disorders. Thus nitrogen must be used very judiciously if calcium-related disorders such as bitter pit are to be kept under control.

Excess nitrogen in fruits delays fruit maturity and promotes diseases. In pears and apples high rates of nitrogen will lead to a higher risk of fire blight and in stone fruit leads to more fruit brown rot.

## Potassium deficiency

Apple leaves may be free of symptoms when the fruit is affected by potassium deficiency. Fruit will not attain its normal size or develop colour normally. Red apples are often a dirty brown colour. Stone fruits require considerable amounts of potassium so that deficiency leads to smaller fruit. In prunes it has been reported that potassium deficiency leads to sunburned fruits that drop prematurely.

## Zinc deficiency

Zinc deficiency will reduce the crop size. In stone fruit small, poorly coloured fruit are produced. It is also responsible for misshapen fruit that can be confused with symptoms produced by other causes. In cherries zinc deficiency can be mistaken for X-disease.



*Calcium chloride injury*



# Harvesting Guidelines

- Overview
- Apples, early season cultivars
- Apples, mid season cultivars
- Apples, late season cultivars
- Pears
- Apricots
- Cherries
- Peaches and nectarines
- Plums and prunes
- Freezing points of some fruits



## Overview

The guidelines that follow indicate general criteria that may be used to determine when fruit is ready for harvest. Specific criteria have been developed for many crops and must be used if selling the fruit to a packinghouse or winery. These criteria should be obtained from an industry representative at the beginning of the growing season well in advance of harvest. Information on new varieties and harvest times for these for tree fruits can be found in the Integrated Fruit Production Guide available from agricultural suppliers and from:

BC Fruit Growers Association  
1473 Water Street  
Kelowna, BC, V1Y 1J6  
Telephone: 250 762-5226  
Fax: 250 861-9089  
E-mail: [info@bcfga.com](mailto:info@bcfga.com)

At the packinghouse apples are graded for the following defects: bruises, punctures, russet, codler, budmoth, leaf roller, campylocoma, pansy spot, scale, scab (black), scab (pinpoint), sunscald, limb rub, bitter pit, cork spot, hail, cracked calyx, insect stings or spray burn, aphid residue (dirty bowls), torn or missing stem, storage scald, dip scald, frost scald, and CO<sub>2</sub> injury. Apples are graded extra fancy, fancy or comm. (packable) based on amount of defect.<sup>71</sup>

## Apples, Early Season Cultivars

### Sunrise

Harvest when fruit has a ripe eating taste and background colour changes from green to cream/yellow.

### Gingergold

Harvest when skin colour changes from green to yellow and 25 to 50% of the seeds change colour.

### Silken

Harvest when fruit has a ripe eating taste and skin colour changes from green to cream.

### Tydemans Red

Flesh colour is the determining factor; harvest when flesh changes from green to white.

### McIntosh

Seed colour is the determining factor; harvest when seeds are 80% brown.

### Golden Delicious

Skin colour is the determining factor; harvest when skin colour changes from green to white or silver. Harvest by starch conversion. Skin colour is highly dependent on nitrogen content. High levels of nitrogen

cause green skin and flesh, which tend to persist. Soluble solids should be 12% or more at proper harvest maturity. Starch conversion charts are available.

### Gala

Harvest is based on starch conversion and ground colour change from green to creamy-white. Gala is a multiple pick variety; 3-5 harvests are necessary depending upon strains and conditions. Starch charts are available.

### Honeycrisp

Harvest based on skin colour, fruit pressure and starch conversion.

## Apples, Mid Season Cultivars

### Red Delicious

Harvest based on starch conversion and red over-colour. Flesh colour is the determining factor; harvest when green colour has disappeared from vascular bundles and flesh is white. Green pigmentation may persist in some spur types but does not necessarily imply a later maturity period.

### Ambrosia

Harvest by starch conversion only. Ambrosia starch conversion charts are available. Do not use colour as a harvest indicator. Ambrosia has a short harvest window so care must be taken not to harvest overmature fruit.

### Aurora Golden Gala

Harvest by starch taste, change in skin colour to yellow and by starch conversion.

### Jonagold

The fruit is at harvest maturity in late September to early October. Colour charts are used to provide consistency of pack. Starch index is a commonly used maturity indicator. Jonagold requires at least 3 harvests.

### Spartan

The fruit matures in mid September just before Red Delicious. Skin and flesh colour are the determining factors; harvest when skin is bright red into the calyx end and skin also has a white bloom, flesh colour is white, and vascular bundles are no longer green.

### Pinova

Harvest is based on ripe eating taste, ground colour change, and starch conversion.

### Newtown

The starch-iodine test is used to determine readiness. Colour charts for this test are available.

## Apples, Late Season Cultivars

### Braeburn

Harvest based on starch conversion and red over-colour. Maturity depends on the strain. Some strains mature with Granny Smith and Fuji and experience suggests it matures with Fuji. Multiple harvests are required.

### Nicola

Harvest is based on starch conversion and background colour change.

### Fuji

This apple matures very late, similar to Granny Smith. Harvest is based on starch conversion, taste, and red over-colour.

### Granny Smith

Granny Smith matures in early to mid October in the South Okanagan and Similkameen areas. Harvest criteria is based on starch conversion, taste and market availability.

### Pink Lady

Harvest is based on pink/red over-colour.

### Winesap

Maturity is determined by the number of days from full bloom to harvest. It should be harvested at about 160 days from full bloom or before water core appears.

### Rome Beauty

Maturity is similar to that of Winesap, but frost damage should be avoided in late picking.



# Pears

Firmness is the accepted index of maturity for pears.

Table 4. Acceptable firmness for harvesting six pear varieties

Variety	Firmness (kg)	Harvest date (relative to Barlett)
Dr. Jules Guyot	8.2-9.1	1 week earlier
Barlett	8.2-9.1	---
Flemish Beauty	5.0-5.5	2 weeks later
Bosc	5.5-6.4	3 weeks later
Anjou	5.5-6.4	5 weeks later
Winter Nelis	5.5-6.4	7 weeks later

for the following defects: bruises, shape, hail, limb rub mark, pear psylla, russetting, scab spots, scale, skin punctures, stony pit, freckle pit, insect injury, sunscald-sprayburn, drought spot, scuffing, frost injury, russet ring, spray residue dirt, and green staining. Pears are graded Canada Fancy, Canada Cee or Canada No.1, and Canada Domestic based on the level of tolerance to these defects.

# Apricots

The harvesting of apricots depends on their use. Skin colour exclusive of any blush colour is the recommended index for maturity.

Table 5. Apricot maturity factors

Variety	Colour	Shipping	Harvest Time
Wenatchee Moorpark	Yellow	Okay	
Titon	Pale yellow	Okay	7 days after Moorpark
Skaha	Orange	Okay	5 days before Moorpark
Goldrich	Orange yellow	Good	10 days before Moorpark
Tomcot	Creamy/yellow	Poor	3 to 4 days before Goldstrike
Goldbar	Orange with red		1 to 2 days before Goldstrike
Goldstrike	Orange with red		
Rival	yellow/rosy		7 Days after
Perfection	Yellow	Good	Matures after Moorpark
Pui Sha Sin		Poor	Requires 4 to 5 harvests

At the packing house pears are graded

# Cherries

Skin colour is the most reliable index for cherry maturity.

## Size Requirements

For red varieties, the picking range is light to medium mahogany. Colour comparator charts are available to assist with this determination. For Lapins, skin colour is a poor guide to maturity. It is mature when the flesh is completely red, the area around the pit dark mahogany and the skin almost black.

## Early Season Varieties

Cristalina is a dark red cherry that ripens 5 days before Van.

Celeste is a dark red cherry that ripens 5 to 7 days before Van.

Sandra Rose is a dark red cherry that ripens 3 days after Van.

Bing is very susceptible to rain splitting.

Van is prone to pitting.

## Mid Season Varieties

Summit is a large cherry that matures 5 to 10 days before Lambert.

Sylvia is a medium dark red cherry that ripens 4 to 5 days before Lambert.

Sonata is a textured, black, very large cherry that matures 7 days after Van.

Stella Lambert

## Late Season Varieties

Lapins is a dark red, large cherry that ripens 2 days after Lambert.

Skeena is a black, large cherry that ripens 3 to 4 days after Lambert.

Sweetheart is a good quality cherry that ripens 5 to 10 days after Stella Lambert.

# Peaches and Nectarines

The uneven ripening of peaches may require up to three harvests in the same block of trees. Growth, not skin colour, is the recommended index for maturity; touch and sight are also good indicators. Mature peaches yield under moderate pressure, lack a prominent suture, are full and smooth, and are less fuzzy than those not ready to harvest.

Table 6. Peach and nectarine maturity factors

Variety	Colour	Harvest time
<b>Peach</b>		
Early Redhaven	Red skin	
Redhaven	Red skin	
Giohaven	Dark red skin	10 days after Redhaven
Cresthaven		Last week in August
<b>Nectarine</b>		
Crimson Gold	Not highly coloured	Mid August
Early Sungrand	Overall red skin	Mid August
Firebrite	Cherry red skin	
Redgold	Red skin	Too late for some locations

# Plums and Prunes

Skin colour (exclusive of any blush colour present) is used as an index of maturity.

Table 7. Plum maturity factors

Variety	Minimum colour requirement	Min. size (cm)
English Damson	100% dark characteristic colour	---
Gold Plum	well-developed yellow	3.8
June Blood	red blush	3.5
Peach plum	fully developed ground colour (yellow)	3.8
Bradshaw	35% red or light purple	3.5
Elephant Heart	50% tinge of red colour	4.1
English Greengage	(fully developed fruit is index used)	2.5
Abundance	tinge of yellow	3.5
Burbank	tinge of yellow	3.5
Stanley	95% dark colour	3.5
Damson	100% characteristic colour	---
Sugar	65% characteristic colour	3.2
President	80% maroon to purple	3.5
Santa Rosa	minimum colour not established; Canada Agricultural Products Standards Act applies	

# Prunes

Sugar content should be 17% or more for regular Italian prunes; skin colour should be 50% light purple for early strains and 75% dark purple for regular Italian prunes; flesh colour should be light yellow, not green.

## Freezing Points of Some Fruits

Table 8. Average freezing point of some fruit

Fruit	Temp (°C)	Highest freezing point found*
Apples	-2	-1.7
Cherries	-4	-1.8
Grapes (Labrusca)	-2.4	-1.3
Grapes (Vinifera)	-4	-1.3
Peaches	-1.4	-0.9
Pears	-2.3	-1.6
Plums	-2.2	-1.3

\* Information obtained from Porritt, S.W. 1974. Commercial storage of fruits and vegetables. Agric. Can. Publ. 1532

# References

1. Curry, E. A., Schrader, L., Hanrahan, I., and Lötze, E. Lenticel Related Disorders Guide. Postharvest Information Network. 1 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
2. Meheriuk, M. 1985. Low-Oxygen Atmospheres to Control Superficial Scald in Red Delicious Apples. Postharvest Information Network. 3 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
McPhee, W.J. 1999. Proper Management of Your DPA Program Can Save You Money and Headaches! Postharvest Information Network. 6 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Kuferman, E. 2001. Storage Scald of Apples. Postharvest Information Network. 7 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Mattheis, J., Fan, X., and Argenta, L. 2002. Factors Influencing Successful Use of 1-MCP. Postharvest Information Network. 3 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
DeEll, J.R., and Murr, D.P. 2005. Ontario Experience with 1-MCP (Smartfresh™) on apples. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
3. Meheriuk, M., Prange, R.K., Lidster, P.D., and Porritt, S.W. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E. 67 pp.
4. Jones, W., Brunner, J., Kupferman, E., and Xiao, C. 2007. Quick Identification Guide to Apple Postharvest Defects & Disorders. Copyright © 2007 Washington State University, Tree Fruit Research & Extension Center, Wenatchee, WA 98801. Available as card sets from [www.goodfruit.com](http://www.goodfruit.com).  
Mitcham, B. 2002. Fruit Physiological Disorders: Apples, Watercore. Postharvest Technology Research Information Center, University of California, Davis, Calif. Available electronically at <http://postharvest.ucdavis.edu/Produce/Disorders/apple/pdapsun.shtml>.  
Schrader, L., Sun, J., Zhang, J., Seo, J-H., Jedlow, L., and Felicetti, D. 2004. Fruit skin disorders.. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
5. Argenta, L., Fan, X., and Mattheis, J. 2001. Development of Internal Browning in Fuji Apples During Storage. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Kupferman, E. 2001. Controlled Atmosphere Storage of Apples and Pears. Postharvest Information Network. 8 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
6. Jones, W., Brunner, J., Kupferman, E., and Xiao, C. 2007. Quick Identification Guide to Apple Postharvest Defects & Disorders. Copyright © 2007 Washington State University, Tree Fruit Research & Extension Center, Wenatchee, WA 98801. Available as card sets from [www.goodfruit.com](http://www.goodfruit.com).
7. Meheriuk, M., Prange, R.K., Lidster, P.D., and Porritt, S.W. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E. 67 pp.  
Mitcham, B. 2002. Fruit Physiological Disorders: Apples, Watercore. Postharvest Technology Research Information Center, University of California, Davis, Calif. Available electronically at <http://postharvest.ucdavis.edu/Produce/Disorders/apple/pdapwater.shtml>.
8. Kuferman, E. 2006. Minimizing Bruising in Apples. Postharvest Information Network. 3 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
9. Jones, W., Brunner, J., Kupferman, E., and Xiao, C. 2007. Quick Identification Guide to Apple Postharvest Defects & Disorders. Copyright © 2007 Washington State University, Tree Fruit Research & Extension Center, Wenatchee, WA 98801. Available as card sets from [www.goodfruit.com](http://www.goodfruit.com).
10. Curry, E. 2003. Factors Associated with Apple Lenticel Breakdown. Postharvest Information Network. 9 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Kupferman, E. 2004. Lenticel Breakdown in Gala Apples (September 2004). Postharvest Information Network. 11 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Kupferman, E. 2005. Latest Research on Lenticel Breakdown of Apples. Postharvest Information Network. 3 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

11. Pierson, C.F., Ceponis, M.J., and McColloch, L.P. 1971. Market Diseases of Apples, Pears, and Quinces (this book is currently out of print). Agriculture Handbook No. 376, USDA, ARS. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Swindeman, A. M. 2002. Fruit Packing and Storage Loss Prevention Guidelines. Postharvest Information Network. 9 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
12. Kupferman, E. 1984. Using Chlorine in the Packinghouse. Postharvest Information Network. 6 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Rosenberger, D.A. 1990. Postharvest Integrated Pest Management. Postharvest Information Network. 8 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Sholberg, P.L. 2004. Bin and Storage Room Sanitation. Postharvest Information Network. 8 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Spotts, R.A., and Serdani, M. 2005. New High-Tech Methods to Solve Old Decay Problems. Postharvest Information Network. 3 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
13. Bedford, K. 2000. Preventing Decay. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
14. McPhee, W. 1999. Field management of postharvest rots reviewed. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
15. Tedford, E.C. 2004. Scholar-a new Broad-Spectrum Postharvest Fungicide for Pome Fruits. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Xiao, C-L, and Kim, Y-K. 2004. Decay Control with New Tools. Postharvest Information Network. 7 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
16. Sholberg, P. 1999. Dry Eye Rot (Blossom End Rot) of apple in British Columbia. Canadian Plant Disease Survey 79:139-140.  
Rosenberger, D.A. 1990. Gray Mold. In: Compendium of Apple and Pear Disease, Edited by A.L. Jones and H. S. Aldwinckle, pp. 55-56. APS Press, St. Paul, MN.
17. Xiao, C.L. 2005. Sphaeropsis Rot. Tree Fruit Research and Extension Center. Washington State University, Wenatchee, WA. Available electronically at <http://decay.tfrec.wsu.edu/displayPage.php?id=pathlab&pn=60>.
18. Dugan, F. 1993. Anthracnose, Perennial Canker and Bull's-eye Rot of Apple and Pear. Postharvest Information Network. 3 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Tedford, E.C. 2004. Scholar-a new Broad-Spectrum Postharvest Fungicide for Pome Fruits. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Xiao, C-L, and Kim, Y-K. 2004. Decay Control with New Tools. Postharvest Information Network. 7 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
19. Spotts, R.A. 1990. Coprinous Rot. In: Compendium of Apple and Pear Disease, Edited by A.L. Jones and H. S. Aldwinckle, pp. 55-56. APS Press, St. Paul, MN.
20. Carisse, O., and Jobin, T. 2006. Apple Scab: Improving Understanding for Better Management. Agriculture and Agri-Food Canada, Publication 10203E.
21. Burr, T.J. 1990. Blister Spot. Dans : Compendium of Apple and Pear Disease, publié par A.L. Jones et H. S. Aldwinckle, p. 55-56. APS Press, St. Paul, MN.  
Sholberg, P.L. et K.E. Bedford. 1997. Characterization of blister spot [*Pseudomonas syringae* pv *papulans*] in British Columbia and its potential for spread to new apple cultivars. *Revue canadienne de phytopathologie* 19:347-351.
22. Thompson, P.E. 2006. Requirements for successful forced-air cooling. Postharvest Information Network. 2 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
23. Lau, O.L. 1985. Storage Factors Influencing the Quality of Apples. Postharvest Information Network. 6 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Waelti, H. 1983. Energy Conservation in Apple Storages. Postharvest Information Network. 6 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
24. Meheriuk, M., Prange, R.K., Lidster, P.D., and Porritt, S.W. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E. 67 pp.



Houston, S. 1998. Ammonia Leak Detection in CA Storage. Postharvest Information Network. 6 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

25. Kupferman, E. 2001. Controlled Atmosphere Storage of Apples and Pears December 2001. Postharvest Information Network. 8 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

26. Kupferman, E. 2001. Controlled Atmosphere Storage of Apples and Pears December 2001. Postharvest Information Network. 8 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

27. Jones, W., Brunner, J., Kupferman, E., and Xiao, C. 2007. Quick Identification Guide to Apple Postharvest Defects & Disorders. Copyright © 2007 Washington State University, Tree Fruit Research & Extension Center, Wenatchee, WA 98801. Available as card sets from [www.goodfruit.com](http://www.goodfruit.com).

28. Meheriuk, M., Prange, R.K., Lidster, P.D., and Porritt, S.W. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E. 67 pp.

29. Kolattukudy, P.E. 2003. Natural Waxes on Fruits. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Curry, E. 2001. Lenticel and Cuticle Disorders: A Survey. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

30. Chen, P.M. and Varga, D.M. 1997. CA Regimes for Control of Superficial Scald of d'Anjou Pear. Postharvest

Information Network. 18 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

Kupferman, E. and Gutzwiller, J. 2003. Use of Diphenylamine, Ethoxyquin and Semperfresh on Anjou Pears. Postharvest Information Network. 15 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

31. Meheriuk, M., Prange, R.K., Lidster, P.D., and Porritt, S.W. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E. 67 pp.

32.

33. Sugar, D. 2006. Advances in Integrated Management of Pear Postharvest Decay. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

Tedford, E.C. 2004. Scholar-a new Broad-Spectrum Postharvest Fungicide for Pome Fruits. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

34. Lennox, C., and Spotts, R. 1997. Botrytis Gray Mold as a Postharvest Pathogen in D'Anjou Pear. Postharvest Information Network. 6 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

Tedford, E.C. 2004. Scholar-a new Broad-Spectrum Postharvest Fungicide for Pome Fruits. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.  
Sholberg, P.L., Bedford, K., and Stokes, S. 2005. Sensitivity of *Penicillium* spp. and *Botrytis cinerea* to pyrimethanil and its control of blue and gray mold of stored apples. *Crop Protection* 24: 127-134.

35. Xiao, C.L. 2005. Phacidiopycnis Rot. Tree Fruit Research and Extension Center. Washington State University, Wenatchee, WA. Available electronically at [http://decay.tfrec.wsu.edu/display\\_Page.php?id=pathlab&pn=30](http://decay.tfrec.wsu.edu/display_Page.php?id=pathlab&pn=30).

36. Spotts, R.A. 1990. Mucor Rot. In: *Compendium of Apple and Pear Disease*, Edited by A.L. Jones and H. S. Aldwinckle, pp. 57-58. APS Press, St. Paul, MN.

37. Spotts, R.A. 1990. Mucor Rot. In: *Compendium of Apple and Pear Disease*, Edited by A.L. Jones and H. S. Aldwinckle, pp. 59. APS Press, St. Paul, MN.

38. Sugar, D. 1989. Flotation Materials for Pear. Postharvest Information Network. 5 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.

39. Meheriuk, M., Prange, R.K., Lidster, P.D., and Porritt, S.W. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E. 67 pp.

40. Meheriuk, M., Prange, R.K., Lidster, P.D., and Porritt, S.W. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E. 67 pp.

41. Meheriuk, M., Prange, R.K., Lidster, P.D., and Porritt, S.W. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E. 67 pp.

42. Meheriuk, M., Prange, R.K., Lidster, P.D., and Porritt, S.W. 1994. Postharvest disorders of apples and pears. Agriculture Canada Publication 1737/E. 67 pp.

42. Thompson, P.E. 2006. Requirements for Successful Forced-Air Cooling. Postharvest Information Network. 2 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
43. Ogawa, J.M., and English, H. 1995. Shot Hole. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp. 1-3, APS Press, St. Paul, MN.
44. Ogawa, J.M., and Zehr, E.I. 1995. Brown rot. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp. 17-18, APS Press, St. Paul, MN.
45. Ogawa, J.M. 1995. Rhizopus rot. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp. 16, APS Press, St. Paul, MN.
46. Patterson, M.E. 1987. Factors of Loss and The Role of Heat Removal for Maximum Preservation of Sweet Cherries. Postharvest Information Network. 7 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>. Thompson, J., Grant, J., Kupferman, G., Knutson, J., and Miller, K. 1995. Reducing Cherry Damage in Packinghouse Operations-Packinghouse Evaluations. Postharvest Information Network. 11 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>. Schick, J.L. and Toivonen, M.A. 2000. Optimizing Cherry Stem Quality. Postharvest Information Network. 7 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
47. Ryugo, K. 1995. Cracking of Sweet Cherry. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp. 86-87, APS Press, St. Paul, MN.
48. Patten, K.D., Patterson, M.E., and Kupferman, E. 1983. Reduction of Surface Pitting in Sweet Cherries. Postharvest Information Network. 7 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
49. Willett, M., Kupferman, G., Roberts, R., Spotts, R., Sugar, D., Apel, G., Ewart, H.W., and Bryant, B. 1989. Postharvest Diseases of Cherries. Postharvest Information Network. 3 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>. Rener, P.R., and Southwick, S.M. 1995. Sweet Cherry. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp. 4-5, APS Press, St. Paul, MN.
50. Willett, M., Kupferman, G., Roberts, R., Spotts, R., Sugar, D., Apel, G., Ewart, H.W., and Bryant, B. 1989. Postharvest Diseases of Cherries. Postharvest Information Network. 3 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>. Kupferman, E. 1993. Postharvest Diseases of Cherries. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
51. Kupferman, E. 1993. Postharvest Diseases of Cherries. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
52. Kupferman, E. 1993. Postharvest Diseases of Cherries. Postharvest Information Network. 4 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
53. Ogawa, J.M., and English, H. 1995. Shot Hole. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp. 1-3, APS Press, St. Paul, MN.
54. Patterson, M.E. and Kupferman, E. 1983. CA Storage of Bing Cherries. Postharvest Information Network. 8 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.
55. Feliciano, A.J. 1995. Peach and Nectarine. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp. 2-3, APS Press, St. Paul, MN. Anon. 2007. Post-Harvest Diseases. Government of British Columbia. Ministry of Agriculture and Lands. Available electronically at <http://www.al.gov.bc.ca/cropprot/tfipm/postharvest.htm#stonefruit>.
56. Ogawa, J.M., Zehr, E.I., and A.R. Biggs. 1995. Brown rot. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp. 7-10, APS Press, St. Paul, MN. Anon. 2007. Brown rot of stone fruit. Government of British Columbia. Ministry of Agriculture and Lands. Available electronically at <http://www.al.gov.bc.ca/cropprot/tfipm/brownrot.htm>.

- 57.** Ogawa, J.M. 1995. Rhizopus rot. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp. 16, APS Press, St. Paul, MN.
- Anon. 2007. Post-Harvest Diseases. Government of British Columbia. Ministry of Agriculture and Lands. Available electronically at <http://www.agf.gov.bc.ca/cropprot/tfipm/postharvest.htm#stonefruit>.
- 58.** Grove, G.G. 1995. Powdery Mildew. In: Compendium of Stone Fruit Diseases, Edited by J.M. Ogawa, E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu, and J.K. Uyemoto, pp.12-14, APS Press, St. Paul, MN.
- Anon. 2007. Powdery Mildew – Tree Fruit. Government of British Columbia. Ministry of Agriculture and Lands. Available electronically at <http://www.al.gov.bc.ca/cropprot/tfipm/mildew.htm>.
- 59.** Sholberg, P.L., Ogawa, J.M., and Manji, B.T. 1981. Diseases of Prune Blossoms, Fruits, and Leaves. In: Prune Orchard Management, Edited by David E. Ramos, pp. 121-125, Special Publication 3269, Agricultural Sciences Publications, University of California, Berkeley, Calif.
- Anon. 2007. Brown rot of stone fruit. Government of British Columbia. Ministry of Agriculture and Lands. Available electronically at <http://www.agf.gov.bc.ca/cropprot/tfipm/brownrot.htm>.
- 60.** Miller, M.W. 1981. Fruit Maturation in Prunes: When to Harvest. In: Prune Orchard Management, Edited by David E. Ramos, pp. 142-146, Special Publication 3269, Agricultural Sciences Publications, University of California, Berkeley, Calif.
- Kader, A.A. 1981. Qualit Evaluation and Sizing of Fresh Prunes. In: Prune Orchard Management, Edited by David E. Ramos, pp. 147-150, Special Publication 3269, Agricultural Sciences Publications, University of California, Berkeley, Calif.
- Jackson, H.W. 1981. Prune Processing: The Past and The Present. In: Prune Orchard Management, Edited by David E. Ramos, pp. 153-155, Special Publication 3269, Agricultural Sciences Publications, University of California, Berkeley, Calif.
- 61.** Luvisi, D.A., Shorey, H.H., Smilanick, J.L., Thompson, J.F., Gump, B.H., and Knutson, J. 1992. Sulfur Dioxide Fumigation of Table Grapes. Bulletin 1932, University of California, Oakland, Calif.
- 62.** Sholberg, P.L. 2004. Management of Grape Diseases in Arid Climates. In: Diseases of Fruits and Vegetables-Diagnosis and Management, Volume II, Edited by S.A.M.H. Naqvi, pp. 53-80, Kluwer Academic Publishers, Dordrecht, The Netherlands.
- 63.** Anon. 2007. Botrytis Bunch rot of Grape (*Botrytis cinerea*). Government of British Columbia. Ministry of Agriculture and Lands. Available electronically at <http://www.agf.gov.bc.ca/cropprot/grapeipm/bunchrot.htm>.
- 64.** Sholberg, P.L. 2004. Management of Grape Diseases in Arid Climates. In: Diseases of Fruits and Vegetables-Diagnosis and Management, Volume II, Edited by S.A.M.H. Naqvi, pp. 53-80, Kluwer Academic Publishers, Dordrecht, The Netherlands.
- 65.** Anon. 2007. Calcium Deficiency (bitter pit) in apple. Government of British Columbia. Ministry of Agriculture and Lands. Available electronically at <http://www.agf.gov.bc.ca/cropprot/tfipm/calcium.htm>.
- 66.** Brunner, J.F., Jones, W., Kupferman, E., Xiao, C-L, Faubion, D., and Tangren, G. 2003. Information from the Careful Evaluation of Packingline Culls. Postharvest Information Network. 6 pp. Available electronically at <http://postharvest.tfrec.wsu.edu/>.