Postharvest handling of pome fruits, soft fruits, and grapes

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Manutention des fruits à pépins, des fruits fragiles et des raisins après la récolte

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.** A pesticide should also be recommended by provincial authorities. Because recommendations for use may vary from province to province, your provincial agricultural representative should be consulted for specific advice.

CONTENTS

PREFACE

This publication provides detailed information on current procedures for preventing or minimizing postharvest problems in pome fruits, soft fruits, and grapes, Emphasis is placed on the practical considerations encountered at the packinghouse level.

Because crop quality and disease prevention vary from year to year, it is important to recognize that postharvest treatments will depend on this variability. The handbook is designed to collate information on individual crops and present it in a useful manner. However, there may be occasions when such information is superseded by such circulars as those from B.C. Tree Fruits Limited or the British Columbia Ministry of Agriculture and Food.

Each commodity (e.g., apples, cherries) is described as a separate entity, and there is therefore no need to turn to several sections to find the information needed. The procedures for each commodity appear in the text approximately in the order that they would be encountered in the packinghouse. Thus, for apples, the procedures deal with postharvest dips, washing, waxing, and storage, in that order.

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 others that may be also suitable.

Further information can be obtained by writing to: Agriculture Canada, Pesticides Division, Food Production and Inspection Branch, K.W. Neatby Building, Carling Avenue, Ottawa, Ont. K1A 0C6.

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APPLES

Removal of deposits on apples

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

Acid removal of calcium deposit

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 heeded. 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 color and blackened lenticels. Precautions must also be taken with the soda ash because of its alkalinity (pH 10), which can also cause lenticel injury.

Superficial scald

Control procedures

Both ethoxyquin and diphenylamine (DPA) give excellent control of superficial scald (Plate 1). Suggested levels for both chemicals are as follows:

	Concentration	
Cultivar	DPA (ppm)	ethoxyquin (ppm)
McIntosh	1000	2700
Stayman	1500	2700
Winesap	1000	1800
Delicious	2000	2700

In the Okanagan, 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 ethoxyquin may be washed and waxed as soon as the fruit is dry. However, 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 is 10 ppm for DPA and 3 ppm for ethoxyquin.

Preparation and precautions

The solution should be agitated while it is being prepared in order to obtain a homogeneous product. Concentrations of DPA or ethoxyquin vary with each manufacturer, and it is important that instructions on the label be followed for preparation of the solutions. To calculate the amount needed, one can use the following formula:

$$\frac{\text{strength of solution (ppm)}}{1\,000\,000} \times \frac{\text{size of tank (litres)}}{1} \times \frac{100}{\text{\% formulation on label}}$$

= litres of DPA or ethoxyquin

Thus, for a 1360-L tank to contain 1000 ppm DPA using a 25% commercial DPA concentrate, one requires the following:

$$= \frac{1000}{1\,000\,000} \times \frac{1360}{1} \times \frac{100}{25}$$

$= 1.360 \times 4$

$= 5.44$ L or 5440 mL

Substitute gallons for litres and multiply by 160 to obtain the amount of DPA or ethoxyquin, in fluid ounces, required for the solution if the tank is calibrated in gallons.

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

Detecting scald inhibitors on the fruit

Ethoxyquin fluoresces under ultraviolet light (ultraviolet black light, mineral light, type 3660 lamp), and this characteristic is used to assess coverage of the fruit. The light is directed on the surface of an apple in a dark room, and any iridescent light blue areas indicate the presence of ethoxyquin. Apples should be viewed when dry. Ultraviolet light is harmful to the eyes and one should not look directly into the lamp. Reflected light is safe to view.

Estimating scald inhibitor in a solution

Practical methods are available for the estimation of DPA and for ethoxyquin. More information can be obtained by contacting postharvest personnel at the Summerland Research Station.

Time 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.

Worker sensitivity to scald inhibitors

Some people may be sensitive to ethoxyquin or DPA, especially when the chemical comes in contact with the skin. Dermatitis may develop but readily disappears when the individual is removed from the source of the chemical. Use of protective clothing or gloves is another means of avoiding the reaction.

Combining scald inhibitors with other materials

In British Columbia, there are currently no recommended treatments on apples in which scald inhibitors are combined with other chemicals. Air-stored Spartan apples are dipped into calcium chloride–gum solutions, and neither DPA nor ethoxyquin should be added to this solution to accommodate early deliveries of Delicious apples, because severe skin injury will occur (Plate 2). Again, it must be emphasized that scald inhibitors should not be combined with calcium chloride or gums in a dip for apples. Appendix C consists of a compatibility chart for various scald-inhibiting agents.

Research personnel at the Summerland Research Station should be consulted on the efficacy and hazards associated with multiformulated solutions.

Internal breakdown of Spartan apples

Nature of the disorder

Spartan apples with flesh calcium levels of less than 225 ppm (dry weight) or 30 ppm (fresh weight) are susceptible to internal breakdown (Plate 3) 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.

Control of Spartan breakdown

Breakdown is virtually eliminated in controlled-atmosphere (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 the Okanagan. 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 is 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.

Preparation of calcium chloride–gum solutions

Because most gums do not dissolve readily in water, it is useful to disperse the gum in alcohol (ethyl or isopropyl) before adding it to the water. If the powdered gum is added directly to the water, lumps may form, which are very difficult to disperse. Vigorous agitation is necessary during addition of the gum, either moistened in alcohol or used dry. Dry gum must be added slowly to the water and must be finely dispersed to avoid the formation of lumps. The calcium salt is added *after* the gum is dissolved. Inclusion of a surfactant is optional, but evidence does suggest a slightly higher

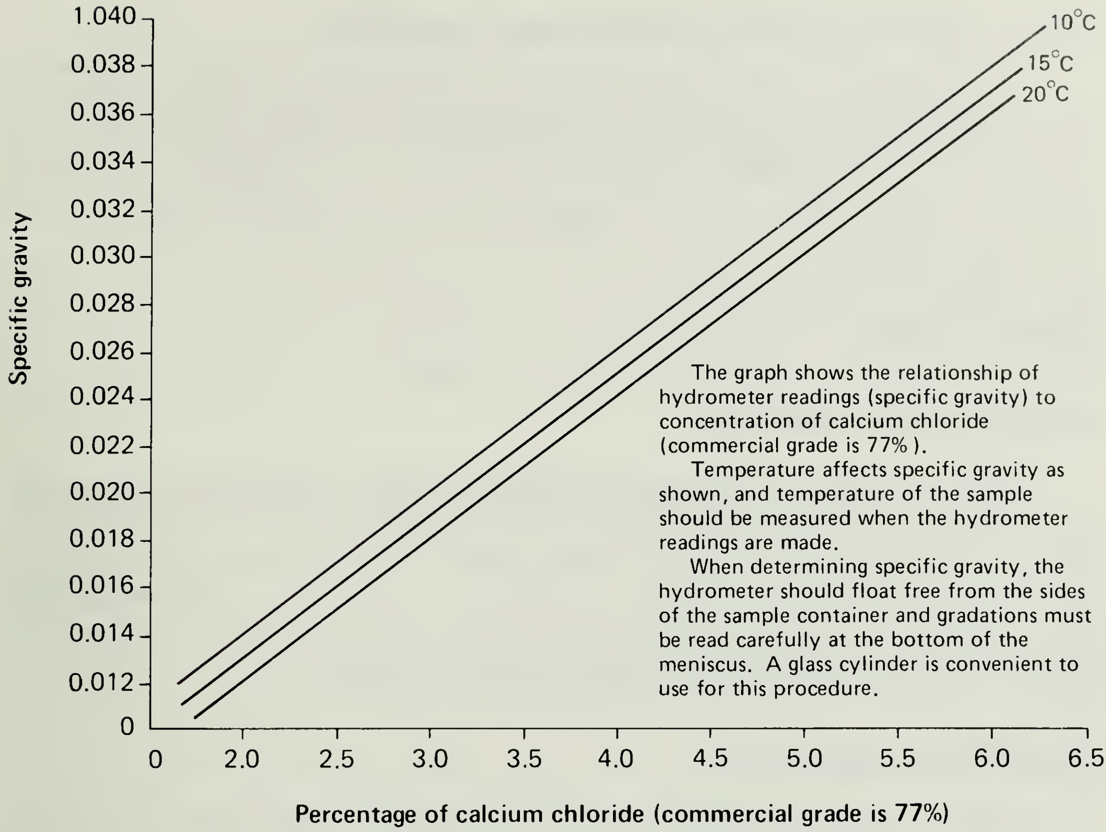

Fig. 1 Standard curve for calcium chloride concentration.
Courtesy of S.W. Porritt, Agriculture Canada, Research Station, Summerland, B.C.

uptake of calcium when it is present. The use of a 0.05–0.10% concentration of a nonionic surfactant is recommended if it is to be included in the solution.

The concentration of calcium chloride can be estimated from the specific gravity of the solution. Hydrometer readings are compared with the standard curve shown in Fig. 1.

A sample calculation for a 4% calcium chloride and 0.15% gum solution in a 1360-L tank would be as follows:

1 L	= 1000 mL
4% calcium chloride	= 40 g per 1000 mL of water
4% calcium chloride in 1360 L	= 54.4 kg
0.15% gum	= 1.5 g per 1000 mL
0.15% gum in 1360 L	= 1.5 × 1360
	= 2.04 kg

If the tank is calibrated in gallons, one would use the following calculations:

4% calcium chloride	= 0.4 lb per gallon of water
0.15% gum	= 0.015 lb per gallon of water

Injury from calcium chloride–gum solutions

The only injury reported with the dip is the occasional split in the calyx basin. Solution remaining in an inverted apple may cause small breaks in the skin that become more prominent with desiccation. However, the occurrence of this problem is minor compared with the volume of fruit treated with the solution.

Water core

Nature of the disorder

Delicious apples are more susceptible to water core (Plate 4) than are the other cultivars commercially grown in the Okanagan. 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. Incidence of the disorder increases with advanced maturity, and cool nights during harvest tend to precipitate the disorder.

Control of water core

Harvest of Delicious apples at the proper maturity is probably the best means of avoiding water core. Grower 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.

Detecting and segregating apples with water core

Portable instruments are available for the detection of water core in apples, and personnel at the Summerland Research Station can be contacted for more information on such instruments.

A commercial method of segregating apples with moderate to severe water core was developed by Porritt et al. (1964), 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.

Bruising

Rough harvesting and handling, and mechanical impact on the packing line, produce bruises in apples. Golden Delicious apples are particularly vulnerable to bruising, and special care must be taken with this cultivar. Light-colored or yellow fruit is more apt to bruise and to retain the bruise than is green fruit. McIntosh are sensitive to bruising, particularly when firmness values drop below 5 kg.

Studies at Washington State University indicated greater susceptibility of Golden Delicious to bruising as storage time increased. 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.

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. Packinghouse personnel content that the delay after opening reduces the level and severity of bruising.

The relationship of bruising to increased incidence of decay is covered in a later section.

Decay problems and their control

Introduction

Spores of decay-causing fungi are always present in orchards and packinghouses because these fungi are generally saprophytes, which survive on dead organic material. The spores fall on the fruit and can initiate decay in the orchard or during storage. Losses of up to 10% are possible in storage, and a knowledge of the fungi and their control is important. An excellent source for the identification of most fungal problems is a publication entitled *Market Diseases of Apples, Pears, and Quinces*, Agricultural Handbook No. 376, United States Department of Agriculture. Many of the fungal organisms exhibit a variety of symptoms that depend on local conditions, and a trained postharvest pathologist should be consulted if there is any doubt about the identity of a particular fungal disorder.

Packinghouse contamination

Sources

It is important to maintain good sanitary conditions in all packinghouse areas to eliminate sources of spore production. Any organic matter (leaves, apples, soil) can act as a substrate for fungi and can support the production of spores. A predominant fungus is *Penicillium expansum*, which can colonize wood and other surfaces in the cold-storage area.

Control of fungi in the flumes

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 100–150 ppm of active chlorine provides excellent fungicidal activity. Although chlorine effectively kills spores in water, it does not protect wounded tissue against subsequent infection from spores lodged in the wound. Organic matter in the water inactivates chlo-

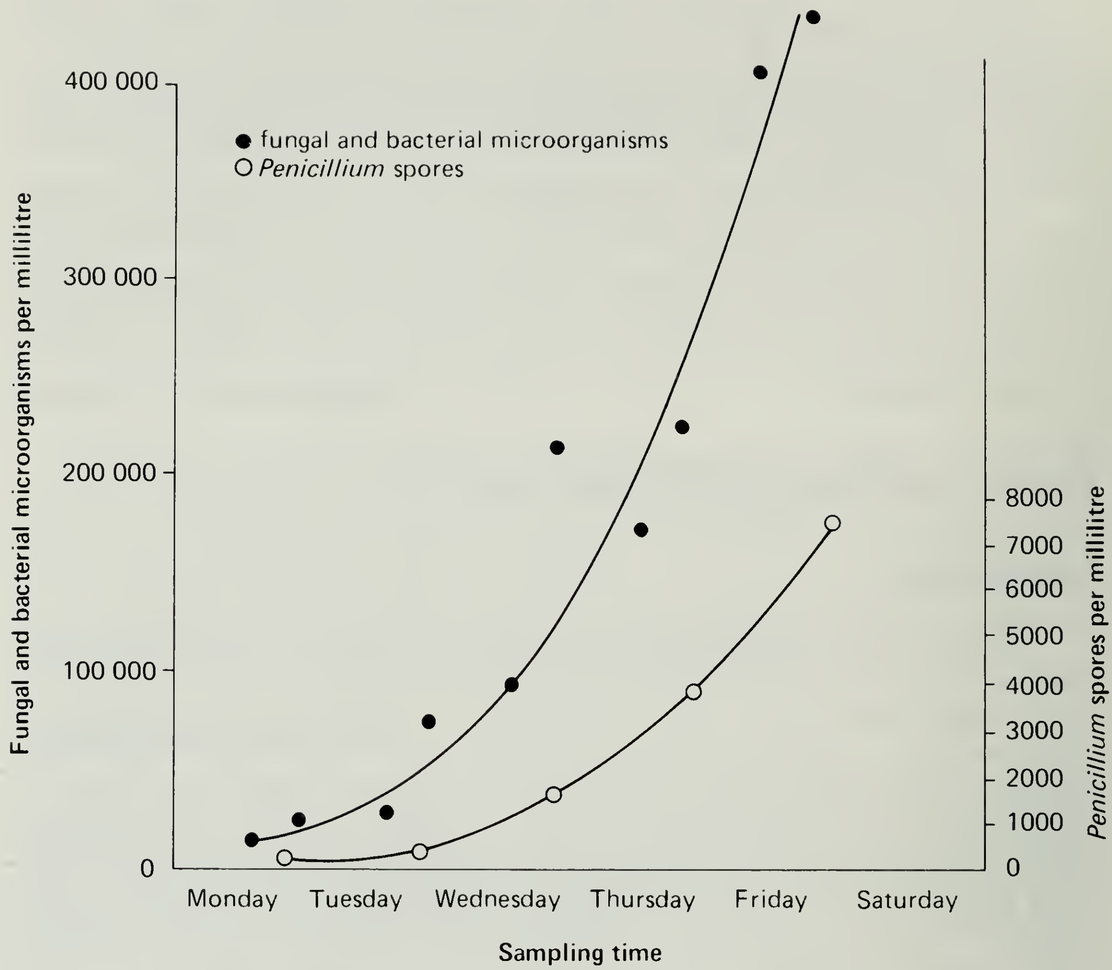

Fig. 2 Microbial population in the flumes during a 1-week period.

rine, and levels of chlorine should be monitored on a regular basis.[1] 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.

Chlorine may be added as sodium or calcium hypochlorite[2] or in the gaseous[3] form.

Because chlorine is an element that is corrosive to metal, regular inspections 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. The rapid growth of bacteria in a local packinghouse flume system is shown in Fig. 2. Also shown in Fig. 2 is the concomitant growth of *Penicillium* species.

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[1] Test kits are available for monitoring chlorine levels.

[2] To prepare a chlorine solution containing 100–150 ppm of active chlorine with a 23 000-L flume system, add the following: 11.8 L of 12% sodium hypochlorite OR 143 g of 65% calcium hypochlorite.

[3] Systems are available that add gaseous chlorine to the system and that automatically monitor and control pH and chlorine levels.

Control of fungi in storage rooms

It was stated earlier that *Penicillium* grows on surfaces contaminated with fruit pulp or juice, but even apparently clean surfaces are not completely immune to this fungus (Plate 5). The most effective method of controlling fungal growth on storage walls is to paint the walls with a fungicidal paint. Copper-8-quinolinolate is recommended by the Canadian Standards Association and is registered for this use. Information on the registered products that contain this chemical is available, in microfiche form, in the *Compendium of Pest Control Products Registered in Canada*, Agriculture Canada Publ. 1654 RP, 1983.

A chlorine wash is effective for surface 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 136 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.

Fruit susceptibility to decay

Bruises, wounds, and punctures

Studies indicate that bruising and skin punctures substantially increase the susceptibility of fruit to decay, especially to *Penicillium*. 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

Overmature fruit and fruit with mineral imbalances are more susceptible to infection. Infectivity is further compounded by punctures and bruises in such fruit. Careful handling, proper sanitation, and rapid cooling are important control measures for decay.

Specific decay problems of apples

When fungicide treatments are necessary, it is important to realize that fungicides can be stripped from the tank by continuous use. The recharging procedure for a dip tank containing benomyl is given in Table 1.

If more solution is needed in the dipping tank, then benomyl at the initial concentration should be added to this quantity of water. When the solution becomes dirty, it should be discarded, the tank washed, and a new solution prepared.

Table 1 Recharging benomyl dip solutions*

Tank size (litres)	Recharge after treatment (bins)	Recharge rate† (grams)
455	30	60
910	60	90
1365	90	120
1820	120	150
2275	150	180
4550	300	360

*Contains an initial concentration of benomyl at an a.i. rate of 0.3 kg/500 L of water.
†A recharge rate of 15% of the initial concentration of benomyl was used, and values have been rounded off to the nearest figure for convenience of measurement.

Contents of the table are courtesy of C. Pierson, United States Department of Agriculture, Tree Fruit Research Laboratory, Wenatchee, WA.

Superficial mold development on the stem and calyx surface

Stem and calyx mold on apples can be common in cold storage, but the molds are superficial and nonpathogenic; although they in no way damage the fruit, they do affect appearance. *Alternaria* is one such mold that commonly grows on the stem and calyx, but control of this fungus is very difficult.

Other superficial molds can 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 (Plate 6). The apples can be cleaned up with a soap wash and may be run, packed, and handled in the normal manner.

Blue mold (*Penicillium expansum* and other *Penicillium* species)

Blue mold (Plate 7) is the most prevalent of the postharvest rots in apples. It causes a soft rot characterized by a light brown discoloration during the early stage. The decayed tissue is completely mushy and can be separated from healthy tissue by flushing with water. Lenticels on any part of the apple may become infected. 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. It must be stressed that damaged apples should not be left in the packing operation (i.e., caught in belts or gears).

Several species of *Penicillium* are associated with penicillium rot of Okanagan grown apples. Some of these species appear to be resistant to fungicides, and for this reason inadequate control of rots caused by *Penicillium* may be a problem. Extension personnel at the British Columbia Ministry of Agriculture and Food should be contacted immediately if resistance is suspected.

Benomyl controls blue mold at an active ingredient (a.i.) rate of 185–250 g/1000 L of water. The fruit should be treated for 30–60 seconds by means of spray nozzles above the packing line or immersion of bins in a dip. Constant agitation of the benomyl solution is necessary because the fungicide is not soluble in water.

Sodium orthophenylphenate (SOPP, or SOP) is also registered for postharvest control of *Penicillium expansum.* The product label calls for a 0.2% (a.i.,vol/vol) solution in water to be applied as a spray immediately after the fruit is removed from the immersion tank. The fruit should be in contact with the spray for 30 seconds.

The fungicide is highly alkaline and is most effective at pH 11–12. Chemical injury will occur if the fruit is exposed to the solution for several minutes or if the water rinse is omitted. Lenticels or breaks in the skin turn brown or black and may become sunken as the injured cells become desiccated. The calyx area is sensitive to SOPP, and excessive exposure or improper rinsing may cause shrinking or cracking of the skin. These lesions become dark brown or black.

Fruit in the SOPP treatment area should be removed and rinsed when failures in the packing line occur.

Thiabendazole is also registered for postharvest application for the control of penicillium rots (dip, flood, or spray with a suspension at an a.i. rate of 1.1 kg/1000 L).

Gray mold (*Botrytis cinerea*)

Gray mold (Plate 8) usually develops in the stem or calyx end of the apple. 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. Points of infection are pale brown. As the rot progresses, a mass of gray spores may form on the surface, which produce the typical gray coloration (Plate 9).

A number of morphologically different isolates of *Botrytis* have been found in Okanagan apples. One atypical isolate liquefies apple tissue, and rots caused by this isolate are soft and watery. Rot symptoms caused by *Penicillium* are similar in nature to this atypical *Botrytis* symptom, and only a trained person would be able to differentiate between the two molds.

Bull's-eye rot (*Gloeosporium perennans*)

Bull's-eye rot (Plates 10 and 11) appears on apples after a storage period of 4–5 months. Spots vary with the 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 the surrounding healthy tissue. Late season infections may occur at harvest if prolonged wet weather occurs just before or during harvest.

Postharvest treatments have met with variable success because fungicides are unable to reach spores nestled in skin pores (i.e., lenticels).

Coprinus rot (*Coprinus* species)

Symptoms of coprinus rot (Plates 12 and 13) have been found to be quite variable. The mold affects Golden Delicious and McIntosh apples and to a lesser extent, Spartan, Newton, and Red Delicious. Early symptoms are similar to Bull's-eye rot, and the two can be differentiated only by culture media. Coprinus rot grows well at 10°C, but Bull's-eye rot does not. In its advanced stages, coprinus rot produces a mass of white mycelia that cover the surface of the infected apple and surrounding apples.

Pinpoint scab and storage scab (*Venturia inaequalis*)

Although pinpoint scab and storage scab (Plate 14) 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. Postharvest treatments are ineffective. The preharvest fungicidal sprays recommended for growers in British Columbia are described in the *British Columbia Tree Fruit Production Guide* (published annually by the British Columbia Ministry of Agriculture and Food).

Storage conditions and problems

Regular cold storage

Apples are stored at −1°C to 0°C in regular storage. McIntosh and Newtown are susceptible to internal disorders at lower storage temperatures and are often stored at temperatures above 0°C.

Controlled-atmosphere (CA) storage

The CA storage conditions recommended for British Columbia-grown apples are presented in Table 2.

Effect and detection of ammonia

Almost all the refrigeration systems in Okanagan storage facilities use ammonia as the refrigerant. The presence of the gas in the storage room can result in injury to fruit in the room. The extent of injury depends on length of exposure and concentration of ammonia in the atmosphere. Brief exposures cause lenticel discoloration, and thorough ventilation or removal of

Table 2 CA storage conditions for apples grown in British Columbia

Cultivar	Storage temperature (°C)	Oxygen level (%)	Carbon dioxide level (%)
McIntosh	1.7	1.5 ± 0.2	1.5 ± 0.2
Golden Delicious	−0.5	1.7 ± 0.2	1.5 ± 0.2
Spartan	−0.5	1.7 ± 0.2	1.5 ± 0.2
Delicious	0	1.7 ± 0.2	1.0 ± 0.2

Reprinted with permission from *Manual for CA Storage Operations in British Columbia*, compiled by B.C. Tree Fruits Limited, Kelowna, B.C., May 1981.

the fruit from the ammonia contamination is sufficient to reverse the discoloration in red cultivars. Golden Delicious apples are likely to suffer some permanent injury. Long 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 or by a filter-paper method devised by Porritt and Lidster (1979). The paper is dipped into a solution sensitive to ammonia, dried, and exposed to the storage atmosphere. The paper turns blue in the presence of ammonia. The lower limit of detection for the two methods is 25 and 50 ppm, respectively, concentrations that one may not be able to smell.

Heat injury of apples

Brief exposure of apples to hot air or hot water can cause injury in the fruit (Plates 15 and 16). Scaldlike 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.

Waxing of apples

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.

Coverage by apple waxes

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 and dryness of fruit 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.

Waxing and drying of 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 L 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 scaldlike 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.

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 discoloration.

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 this wax. More on this aspect is found under the section entitled ‘‘Cleaning the fruit’’.

Maturity of fruit and 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’’).

Whitening of apples waxed with shellac-based waxes

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, translucent 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.

Waxing of stored apples

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.

Effect of palletizing on cooling rates

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 pears to a core temperature of 0°C varies from 2 to 90 days. Delayed cooling in palletized apples can result in accelerated softening of the fruit.

Plate 1 Superficial scald (Red Delicious)

Plate 2 Injury from solutions containing ethoxyquin, calcium chloride, and gum (Red Delicious)

Plate 3 Breakdown (Spartan)

Plate 4 Water core (Red Delicious)

Plate 5 Fungi growing on storage room walls

Plate 6 Superficial mold (Golden Delicious)

Plate 7 Blue mold (Spartan)

Plate 8 Gray mold (Golden Delicious)

Plate 9 Gray mold, showing spore mass (Red Delicious)

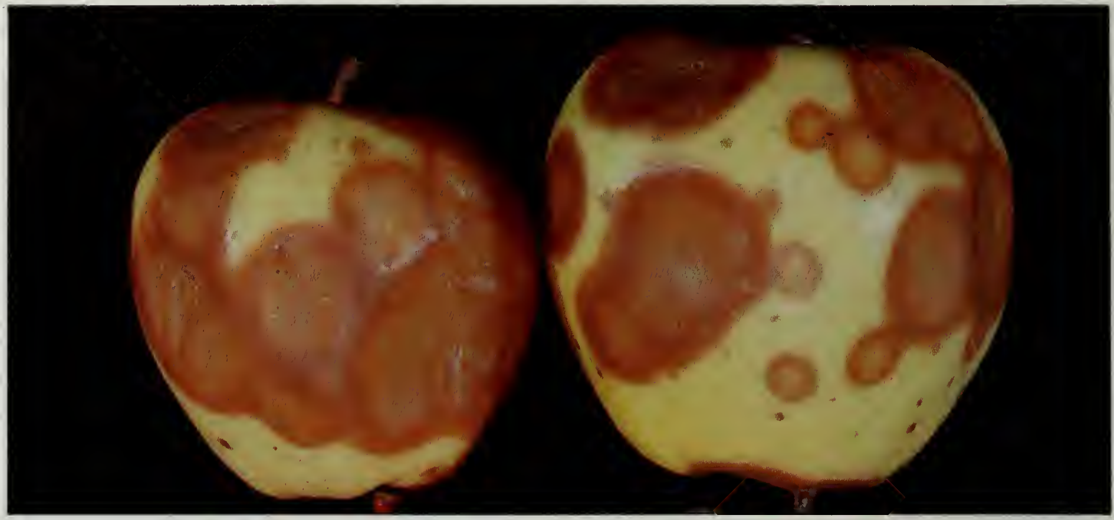


Plate 10 Bull's-eye rot (Golden Delicious)

Plate 11 Bull's-eye rot, advanced stage (Golden Delicious)

Plate 12 Coprinus rot, typical white mycelia (Newtown)

Plate 13 Coprinus rot, variability in symptoms (Golden Delicious)

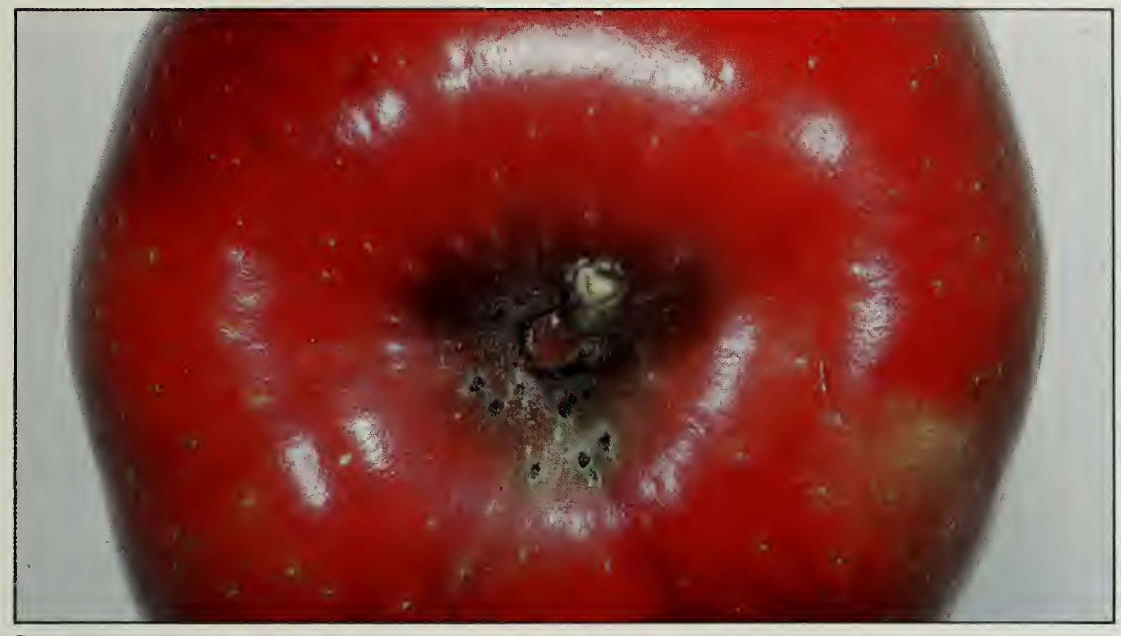


Plate 14 Pinpoint scab (Spartan)

Plate 15 Hot air injury (Spartan)

Plate 16 Hot water injury (Red Delicious)

Plate 17 Anjou scald

Plate 18 Senescent scald (Bartlett)

Plate 19 Pink end (Bartlett)

Plate 20 Blue mold (Bartlett)

Plate 21 Coprinus rot (Anjou)

Plate 22 Gray mold (Anjou)

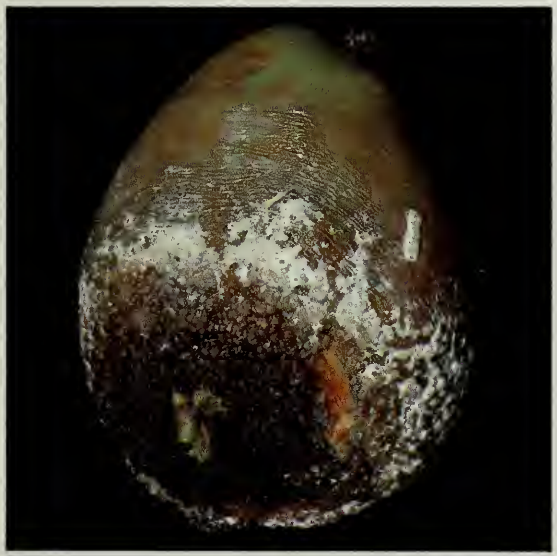


Plate 23 Gray mold, showing sclerotia (Anjou)

Plate 24 Freezing injury (Bartlett)

Plate 25 Differential ripening caused by improper cooling (Bartlett)

Plate 26 Brown rot on apricots

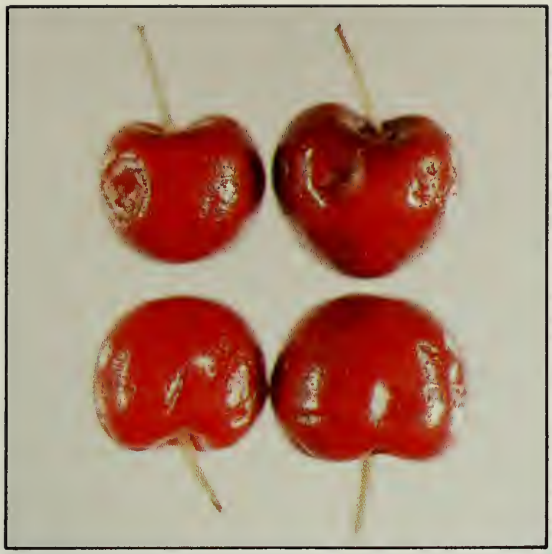


Plate 27 Surface pitting (Van)


Plate 28 Brown rot on cherries


Plate 29 Rhizopus rot on cherries


Plate 30 Alternaria rot on cherries


Plate 31 Penicillium rot on cherries

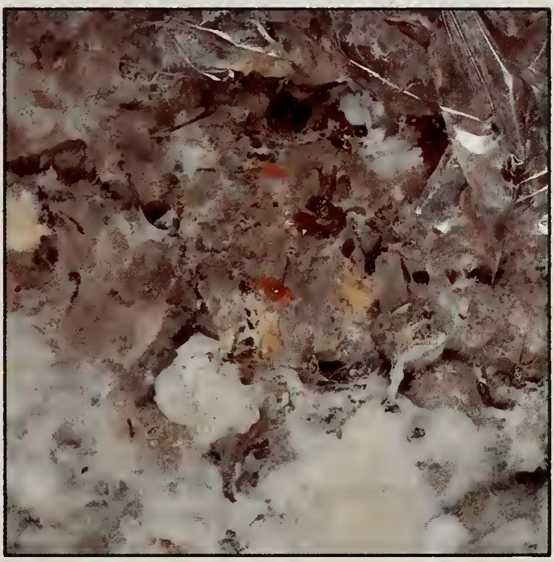


Plate 32 Gray mold on cherries

Plate 33 Brown rot on peaches

Plate 34 Rhizopus rot on peaches

Plate 35 Brown rot on Italian prunes

Plate 36 Rot on grapes

Plate 37 Color comparators used for cherry harvesting

PEARS

Prevention of physiological problems

Anjou scald

Anjou scald (Plate 17) develops on Anjou pears during storage and is similar to superficial scald in apples. An ethoxyquin dip at 2700 ppm controls the problem.

Senescent scald in Bartlett pears

Senescent scald (Plate 18) develops in Bartlett pears that are stored beyond their normal period. 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 not stored beyond 90 days, are cooled promptly at harvest, and are kept at −0.5°C during storage.

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 aureole around the calyx button (Plate 19). 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.

Decay problems and their control

Blue mold (*Penicillium expansum*)

As with apples, blue mold rot in pears (Plate 20) is soft and watery and is easily separated from the healthy tissue. Infection occurs on the cheek of the pear, where cuts, abrasions, or punctures are found. Neck rot is a form of the disease that develops from stem infections in such varieties as Anjou. The high humidity that prevails in polyethylene box liners favors the development of white to bluish green fungal masses of spores on the surface of the fruit.

Anjou pears should not be stored for long periods (not longer than 5–6 months) without a protective fungicide treatment.

Thiabendazole, at an a.i. rate of 1.1 kg/1000 L of water, is registered for postharvest application on pears. This fungicide 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 benomyl and thiabendazole.

Coprinus rot (*Coprinus* species)

In British Columbia coprinus rot in pears (Plate 21) is being observed more frequently, especially in Anjou pears stored for extended periods. Infected areas are dark brown, variable in size, slightly sunken, and often have a tuft of white mycelia in the center of each lesion. Severe rot results in extensive mycelial growth on the surface of the fruit and on the cardboard trays holding the fruit.

Development of coprinus rot is dependent on temperature and moisture. Growth of the rot is slow, and infected lots can be repacked for the retail market provided they are sold fairly promptly. Low relative humidity during repacking and storage helps to reduce subsequent infection of the repacked fruit. There are no fungicides registered for control of coprinus rot.

Gray mold (*Botrytis cinerea*)

Gray mold (Plates 22 and 23) is common in pears stored for long periods. The rot that develops in storage from incipient infections present at harvest occurs principally at the stem or calyx end. Gray mold rot is firm on unripened fruit and not easily separated from healthy tissue. The appearance of the mold is influenced by cultivar, degree of ripeness, and storage temperature. Identification should be based on isolation of the organism in pure culture on a potato dextrose agar. As the fruit ripens, the rot becomes softer but is never as soft and translucent as that of blue mold. The gray mold rot of pears has a pleasantly fermented odor that distinguishes it from other storage rots.

Under humid conditions, surface mycelia and conidia form to give a characteristic gray appearance. Small hard black resting bodies of the fungus (sclerotia) may appear on rotted surfaces of fruits in the advanced stages of decay (Plate 23).

Botrytis cinerea is a widely distributed orchard saprophyte. Cool moist weather at harvest time favors spore production in the orchard and thus increases the possibility of infection. Several isolates have been found in Okanagan pears, but it is not known whether they differ in their response to the fungicides used for control of the fungus. This fungus grows slowly at $-1°C$.

Control is difficult, especially in cases where prolonged storage is necessary. Thiabendazole is registered and may be used at an a.i. rate of 1.1 kg/1000 L of water. Fruit may be dipped, sprayed, drenched, or flooded with the solution.

Procedures and problems in packing of pears

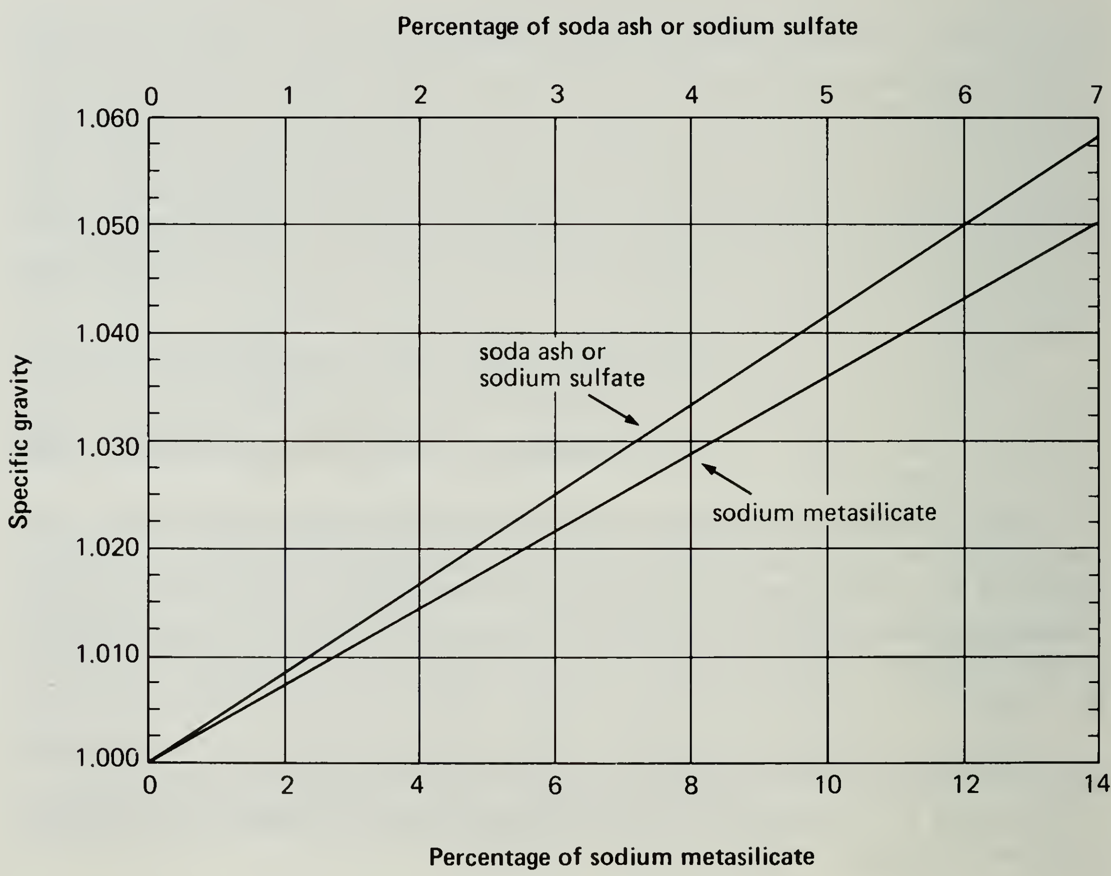
Flotation of pears

Pears do not float because their density is slightly higher than that of water, and it is necessary to add salts to elevate the water density. Sodium sulfate, sodium silicate, or soda ash can be used. The first salt produces a neutral solution and the latter two give an alkaline solution of pH 10. 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 Fig. 3.

Pears left for an extended time in alkaline solutions may develop discoloration 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 reports less scuffing when sodium silicate is used as the salt in the flume system.

Fig. 3 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.



Skin abrasion and scuffing

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

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 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.

Storage conditions and problems

Storage conditions

Temperatures of −1°C to −0.5°C are recommended. Conditions for CA storage are 2.2 ± 0.2% oxygen and 0.7 ± 0.3% carbon dioxide. Approximate storage periods for Bartlett and Anjou in regular storage are 90 and 150 days, respectively.

Effect of cooling rate on pears

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°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°C followed by 7 days at 20°C.

Freezing injury

Pears have an average freezing point of $-2.2°C$, and in years when the soluble-solids content is low, freezing is a distinct possibility (Plate 24). Bartlett pears with soluble solids of 8% may have a freezing point of $-1.7°C$ or higher. Particularly vulnerable to freezing are pears in the top bins opposite the refrigeration coil and in the bottom bins, where cold air may stratify if bins have been stacked incorrectly.

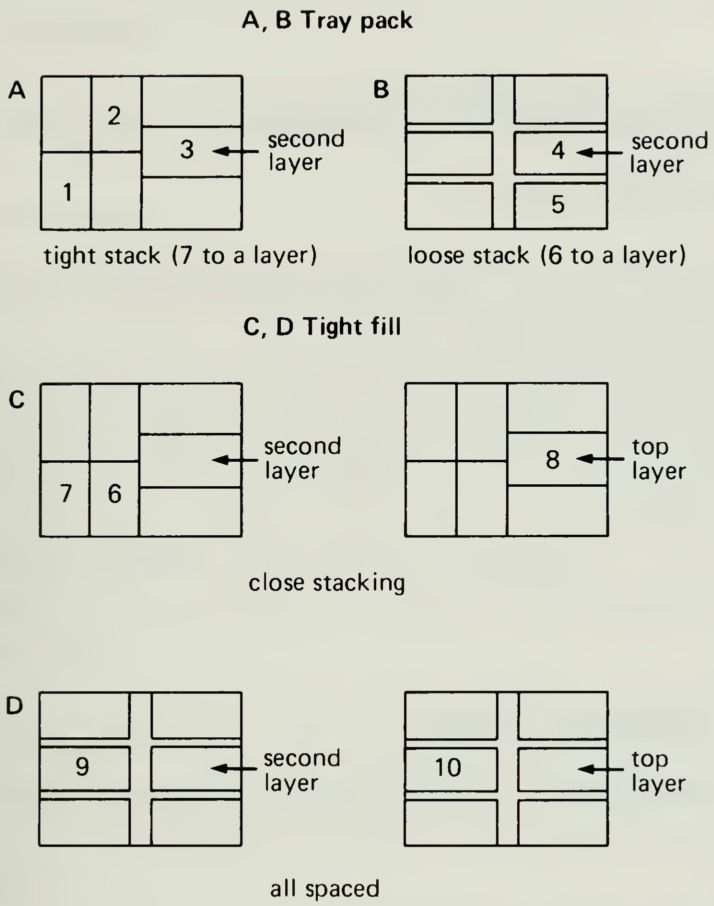
Frozen tissue has a glassy appearance and can be thawed without permanent injury; however, prolonged freezing results in desiccation and the formation of internal cavities.

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 of exposed surface contained fruit that varied from fully green to fully ripe (Plate 25). 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. 4).

Forced-air cooling

Rapid reduction of fruit temperature can be achieved with forced-air cooling. With 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.



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

Fig. 4 Effect of stacking within a pallet on cooling rate of Anjou pears.

APRICOTS

Decay problems and their control

Brown rot (*Monilinia* species)

In years when brown rot (Plate 26) is a serious problem, postharvest treatment of apricots is essential. Rots occur more readily on riper fruit because of the higher sugar content.

Brown rot can be controlled with benomyl. The fungicide is applied as a drench and the fruit is allowed to dry before packing (approximately 24 hours). Benomyl at an a.i. rate of 250 g/1000 L of water controls brown rot. Thorough wetting of the fruit is needed to control the organism. Because the fungicide is insoluble in water, the solution should be agitated continuously.

A means of monitoring coverage is available and is discussed in Appendix B.

Rhizopus rot (*Rhizopus* species)

Rhizopus rot and brown rot fungi often occur together. There are no fungicides available for control of rhizopus rot on apricots.

Packing and storage conditions

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 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.

CHERRIES

Physiological problems and their control

Surface pitting

Considerable surface pitting (Plate 27) has been found in some years 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.

Decay problems and their control

Introduction

There are several species of fungi that cause postharvest rot of cherries and all are present in the orchard. These fungi include *Monilinia, Penicillium, Rhizopus, Botrytis, Alternaria,* and *Cladosporium* and all are abundant in wet seasons. Spores from these fungi are airborne and readily settle on fruit.

Brown rot (*Monilinia* species)

Brown rot spores germinate and infect fruit quickly in the presence of moisture and favorable temperatures of 20–26°C (Plate 28). Lower temperatures reduce but do not prevent the growth of the fungus. The rot is characterized by the presence of a brown powdery growth on the surface of the cherry. The disease spreads quickly to other cherries by contact in packs.

Rhizopus rot (*Rhizopus* species)

Rhizopus rot (Plate 29) contains an abundant 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.

Dichloran (a.i. at a rate of 1.25 kg/1000 L of water) controls rhizopus rot, but it can leave an undesirable yellow residue on the fruit if it is not applied according to the manufacturer's specifications. Chemical control is probably not necessary if the cherries are kept at 0°C.

Alternaria rot (*Alternaria* species)

Alternaria rot (Plate 30) appears as a dark green, feltlike growth that occurs most frequently on the calyx end of the cherry. Several species of *Alternaria* occur in the Okanagan, and symptoms vary slightly among the infecting species. Over the past few years it has become evident that the disease is becoming more prevalent in packed cherries. Careful handling of cherries is imperative, because infection is more likely to occur in fruit with skin breaks.

No chemicals are registered for the control of alternaria rot, either in the field or the packinghouse.

Penicillium rot (*Penicillium* species)

Penicillium rot on cherries (Plate 31) can cause serious problems in packed cherries shipped to distant markets. Storage or transit temperatures of 0–4°C control the fungus.

Gray mold (*Botrytis cinerea*)

Gray mold rot of cherries (Plate 32) can be a serious problem in the Okanagan. The rot causes extensive mycelial growth and sporulation in the packs. It is similar to brown rot and only a trained person can differentiate between the two.

Hydrocooling

Quick removal of field heat in cherries can be obtained with hydrocooling. The water in the apparatus is chlorinated to prevent a buildup of microorganisms in the water and subsequent contamination of the fruit. Active chlorine is maintained at 100–150 ppm and should be monitored so as not to drop below 100 ppm. A chlorine monitoring kit should be used for this purpose.

There is no residual effect with chlorine, and application of fungicides may be needed to prevent subsequent rot problems.

Orchard-pack cherries

Cherries packed in the orchard should be treated for control of rots. A preharvest spray, one day before harvest, is adequate for control of postharvest pathogens.

Storage conditions

Cherries can be stored for 2–3 weeks at 0°C, but longer storage periods result in stem browning and a loss of fruit luster.

Polyliners are recommended to reduce moisture loss.

PEACHES AND NECTARINES

Decay problems and their control

Control procedures listed below apply only to peaches because there are no fungicides registered for postharvest application on nectarines.

Brown rot (*Monilinia* species)

Peaches are highly susceptible to brown rot (Plate 33), especially when they ripen. Levels of infection increase sharply when there is frequent wet weather close to or during harvest and spore levels are high in the orchard.

Brown rot on peaches 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. Wounded or damaged fruit is particularly vulnerable to infection.

Benomyl (a.i. at a rate of 250 g/1000 L of water) is the most effective compound for control of brown rot. Dichloran (a.i. at a rate of 1.2 kg/1000 L of water) is also registered as a postharvest application for control of brown rot.

Rhizopus rot (*Rhizopus* species)

Rhizopus rot (Plate 34) often accompanies brown rot in peaches. Dichloran (a.i. at a rate of 1.25 kg/1000 L of water) effectively controls rhizopus rot. Because dichloran is incompatible with flotation salts, it should be applied on-line after the rinse operations.

This disease occurs regardless of weather conditions and can be particularly damaging in peaches held by canneries for ripening. Dipping the fruit in dichloran upon arrival at the packinghouse is essential for peaches held for the cannery.

Fungicide application with nozzles

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.

Storage conditions

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

PLUMS AND PRUNES

Decay problems and their control

Brown rot (*Monilinia* species)

Early symptoms of brown rot (Plate 35) are spots with discoloration and softening of the skin. The infection develops overnight into a powdery, brown spore mass that infects other fruit. Brown rot has not been as troublesome in prunes and plums, and control treatments have not been required. Recently, however, postharvest brown rot is becoming more common.

Storage conditions

Most plums and prunes can be stored for 2–3 weeks at 0°C, but Italian prunes can be stored for a month.

GRAPES

Decay problems and their control

Botrytis rot (*Botrytis* species) and Penicillium rot (*Penicillium* species)

No postharvest treatments are recommended for table grapes to control botrytis and penicillium rots (Plate 36) other than the use of sulfur dioxide in a commercial pad. The pads generate sulfur dioxide within the carton from the humidity that is present and thus control the pathogens. Grapes are placed in polyliners, the pad is placed on top of the grapes, and the liner is then folded over the pad and the grapes. The pad must be placed with the writing facing away from the grapes; one pad for 5–6 kg of grapes is recommended.

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.

APPENDIX A HARVESTING GUIDELINES

The guidelines that follow indicate the criteria to be used to determine when the fruit is ready for harvest.

Apples

Tydeman Red

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

McIntosh

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

Red Delicious

Flesh color is the determining factor; harvest when green color 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.

Spartan

Skin and flesh color are the determining factors; harvest when skin is bright red into the calyx end and skin also has a white bloom, flesh color is white, and vascular bundles are no longer green.

Golden Delicious

Skin color is the determining factor; harvest when skin color changes from green to white or silver. Skin color, however, 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.

Newtown

The starch–iodine test is used to determine readiness. Color charts for this test are available from the British Columbia Ministry of Agriculture and Food or from packinghouse field personnel.

Winesap

Number of days from full bloom is the determining factor; harvest at about 160 days from full bloom or before water core appears.

Rome Beauty

Number of days from full bloom is the determining factor; harvest period is similar to that for Winesap, but frost damage should be avoided in late picking.

Pears

Firmness is the accepted index of maturity.

Variety	Firmness (kg)	Harvest date (relative to Bartlett)
Dr. Jules Guyot	8.2–9.1	1 week earlier
Bartlett	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

Apricots

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

Apricots

Variety	Purpose	Stage of maturity	Color	Harvest time*	Size (cm)
Blenheim	canning	firm to firm-ripe	100% pale yellow; green has faded to yellow	2–4 days later	large, 3.8 medium, 3.2
Tilton	canning	firm to firm-ripe	100% pale yellow; green has faded to pale yellow	7 days later	large, 3.8 medium, 3.2
Wenatchee Moorpark	fresh market	firm to firm-ripe	change from green to yellow over entire fruit; no dark green permitted		minimum, 4.1
Wenatchee Moorpark	process	ripe, but able to withstand transportation	95% yellow or more		minimum, 4.1
Ryland	fresh market	firm to firm-ripe	90% pale yellow	2–4 days earlier	minimum, 4.1
Skaha	fresh market	firm to firm-ripe	change from green to pale orange, or orange over entire fruit	5 days earlier	minimum, 4.1
Perfection	process	ripe	95% yellow	5 days earlier	minimum, 4.1
Reliable	process	ripe	95% yellow orange	1–3 days later	minimum, 4.1
Sunglo	process	ripe	90% pale yellow	1–3 days later	minimum, 4.1

*Harvest date is relative to Wenatchee Moorpark.

Cherries

Skin color is the most reliable index for cherry maturity.

Color requirements for fresh market cherries

Minimum: Bing, Lambert, Van, Chinook, Stella, Deacon, Full No. 3[1] color comparator (Plate 37). Vans should approach No. 6 color comparator.

Maximum: Lambert and other black varieties, No. 33 comparator.

Size requirements

Bing, Lambert, Chinook, Van, and Stella, 2.2–1.9 cm in diameter, up to 10% below 2.2–2.1 cm in diameter.

Deacon: 2.1 cm in diameter, up to 10% below 2.1–1.9 cm in diameter.

Size and color must be considered together. A 2.2-cm diameter Van with No. 3 color is not acceptable, and No. 6 or darker is preferable.

Peaches and nectarines

The uneven ripening of peaches may require up to three harvests in the same block of trees. Growth, not skin color, 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.

Variety	Skin color (exclusive of blush color)
Redhaven	100% change from green
Dixie Red	100% change from green
Jubilee	100% change to very pale yellow
Vees	100% change to light yellow; no deep green
Fairhaven	100% change to light yellow; no deep green
Elberta	90% change to yellow
Hale	100% yellow

[1] Color comparators are synthetic models of cherries with specific colors. Information on source and use of the comparators can be obtained from: Okanagan Federated Shippers Association, 1476 Water Street, Kelowna, B.C.

Plums and prunes

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

Plums

Variety	Minimum color requirement	Minimum size (cm)
English Damson	100% dark characteristic color	—
Gold Plum	well-developed yellow	3.8
June Blood	red blush	3.5
Peach Plum	fully developed ground color (yellow)	3.8
Bradshaw	35% red or light purple	3.5
Elephant Heart	50% tinge of red color	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 color	3.5
Damson	100% characteristic color	—
Sugar	65% characteristic color	3.2
President	80% maroon to purple	3.5
Santa Rosa	minimum color not established; *Canada Agricultural Products Standards Act* applies	—

Prunes

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

APPENDIX B BIOASSAY FOR BENOMYL RESIDUE

Benomyl residues can be detected at relatively low levels and the bioassay technique can be used to detect benomyl in pome and stone fruits.

Bioassay technique

Detection of benomyl residues is made possible by the extreme sensitivity of the fungus *Penicillium expansum* to very low levels of the chemical. It has been detected at 0.1 ppm, well below the residue on pears or apples properly treated with benomyl (a.i. at a rate of 190 g/500 L of spray), as described on the label. To detect benomyl residue on fruit surfaces, it is necessary to remove discs or plugs from the fruit; place them skin side down in petri plates seeded with a spore suspension of the fungus; and incubate the plates at room temperature (21–29°C) for 24 hours. When the sample disc has a benomyl residue it is surrounded by a clear zone. If the sample does not contain benomyl the fungus will grow over the entire area. The procedure is outlined as follows:

(1) Prepare potato-dextrose-agar (PDA), sterilize it, and dispense it into sterile petri plates (20 mL per plate). Allow it to cool and solidify on a level surface.

(2) Prepare a heavy suspension of *Penicillium expansum* (blue mold) and flood each plate. Pour off the excess liquid into the next plate and serially inoculate each plate to be used. Inoculated plates should be used within 4 hours after they are seeded. Because of the oily nature of blue mold spores, it is necessary to add one or two drops of liquid surfactant to the inoculum.

(3) Remove plugs from the fruit to be bioassayed and place skin side down on the seeded PDA plate. Plugs can be removed from the fruit with a No. 3 cork borer or with a pliers-type paper punch. If a paper punch is used, carefully peel the skin from the fruit, taking care not to touch the surface to be tested, and punch the discs out directly on the plate. Position the plugs or discs about 2.5 cm apart so that the inhibition zones will not overlap.

(4) Incubate 24–48 hours at 20–30°C. Inhibition zones will be evident in 18–24 hours but will be easily detected in 48 hours as the fungus begins to sporulate. The size of the zone is indicative of the amount of benomyl residue. Standard amounts of benomyl can be applied to a series of plates to quantitate the assay. Any sample that shows a distinct zone of inhibition should have sufficient residue to provide adequate protection against storage decay. The test is intended to determine the presence or absence of benomyl and its distribution on the fruit surface rather than to measure exactly the total benomyl residue.

Experience with postharvest applications indicates that fruit treated by overhead sprays of benomyl should be relatively dry before the benomyl spray is applied and thoroughly brushed or sponge-rolled after spraying to distribute the chemical evenly. One of the most frequent problems encountered is excess water on the fruit as it passes under the spray nozzle. The lack of residue in these cases is probably due to dilution of the spray beyond the level of detection.

APPENDIX C COMPATIBILITY CHART

	Thiabendazole	Benomyl	Dichloran	Calcium chloride	Calcium chloride + guar gum	Diphenylamine	Ethoxyquin	Sodium sulfate	Sodium silicate	Sodium orthophenylphenate
Thiabendazole						C^1				
Benomyl			C		C	C	C			
Dichloran		C						I	I	
Calcium chloride		C				C^1				
Calcium chloride + guar gum		C				C^2	C^2			
Diphenylamine	C^1	C		C^1	C^2					
Ethoxyquin	C	C			C^2					
Sodium sulfate			I							
Sodium silicate			I							
Sodium orthophenylphenate										

I: Incompatible (may be chemical incompatibility).
C: Compatible.
C^1: Compatibility problems may arise with some formulations. Check the label for degree of compatibility.
C^2: Mixture causes skin discoloration on apples; also, some formulations of DPA may not be compatible with calcium chloride and guar gums.
A blank indicates that compatibility is unknown.

APPENDIX D AVERAGE FREEZING POINT OF SOME FRUITS

Fruit	Temperature (°C)	Highest freezing point found* (°C)
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 (1974).

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CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2.5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre