CHAPTER 22

DECIDUOUS TREE AND VINE FRUIT

THE most obvious losses from marketing fruit crops are caused by mechanical injury, decay, and aging. Losses in moisture, vitamins, and sugars are less obvious, but they adversely affect quality and nutrition. Rough handling and holding at undesirably high or low temperatures increase loss. Loss can be substantially reduced by greater care in handling and by following recommended storage practices.

FRUIT STORAGE AND HANDLING CONSIDERATIONS

Quality and Maturity

Maximum storage life can be obtained only by storing high-quality commodities soon after harvest. Different lots of fruit may vary greatly in storage behavior because of variety, climate, soil and cultural conditions, maturity, and handling practices. When fruit is transported from a distance, is grown under unfavorable conditions, or is deteriorated, proper storage allowance should be made.

Fresh fruit for storage should be as free as possible from skin breaks, bruises, and decay. These defects reduce the value of the product and may cause rapid deterioration not only of the damaged fruit, but also of fruit stored nearby. Damaged fruit often produces more ethylene, which can cause rapid ripening of many types of climacteric fruit. For the same reason, it is unwise to store fruit or vegetables having different storage characteristics together; some may emit ethylene, causing a more sensitive crop to ripen prematurely. Natural cooling in well-ventilated storage slows down or halts these processes.

The amount of incipient decay infection, which influences storage potential of grapes and apples, can be predicted early. Only lots with good storage potential should be held for late-season marketing.

Fruit maturity at harvest time determines its refrigerated storage life and quality. For any given produce, there is a maturity best suited for refrigerated storage. Undermature produce will not ripen or develop good quality during or after refrigerated storage. For many crops, excessively overmature produce deteriorates quickly during storage, although there are some exceptions for late-harvested fruit (in particular, late-harvested kiwifruit). Determination of maturity can be a complex problem. A number of measurements are used, depending on the crop; these include penetromer firmness, color, degree-days since flowering or fruit set, soluble solids, or other physical, chemical, or biological tests. In critical cases, a combination of tests may be used.

Handling and Harvesting

Rising handling costs have encouraged the use of bulk handling and large storage bins for many kinds of fruit. Moving, loading, and stacking bins by forklift trucks must be done carefully to maintain proper ventilation and refrigeration of the product. Bins should not be so deep that excessive weight damages the produce near the bottom.

Mechanical harvesters for fruit frequently cause some bruising. This damage can materially reduce the quality of the produce.

Storage and Transportation

As in storage, losses from deterioration during distribution are affected by temperature, moisture, diseases, and mechanical damage. Gradual aging and deterioration are continuous after harvest. Time in transit may represent a large portion of postharvest life for some commodities, such as cherries and strawberries. Thus, the environment during this period largely determines produce salability when it reaches the consumer.

To prevent undue warming and condensation of moisture, which promote decay and deterioration, fruit-handling systems must be well-designed to minimize rewarming and moisture condensation on the product. For example, fruit should not be removed from cool storage and left unattended for significant periods of time before loading and transport in refrigerated vehicles. When the product is removed from cool storage, it should be consumed as quickly as possible or retained at low temperature.

Details on storage and handling of common fruit are given in the following sections. For more information on storage requirements and physical properties of specific commodities, see Table 1 in Chapter 11. Table 1 in this chapter shows recommended controlled-atmosphere (CA) and modified-atmosphere (MA) conditions for fruit other than apples and pears (Kader 2001). Also see Table 1 in Chapter 24 for guidelines on mixing produce in storage and transportation.

This chapter describes proper postharvest handling guidelines for selected fruits. Additional information on these and many other fruits can be found at postharvest.ucdavis.edu and www.ba.ars.usda.gov/hb66/contents.html.

APPLES

Apples are not only the most important fruit stored on a tonnage basis, but their average storage period is considerably greater than that of any other fruit. Storage may be short for early varieties and those going into processing, but cold storage is critical to proper handling and marketing.

Recommended storage temperature depends on the cultivar. For most varieties, cool storage at 32 to 34°F is recommended. Specific recommendations for each commercial cultivar are usually available from marketing organizations [or see Kader et al. (2002)].

Storage life depends on harvest maturity, elapsed time and temperature between harvest and storage, cooling rate in storage, and sometimes cultural factors. The best storage potential is usually in apples that are mature but have not yet attained their peak of respiration when harvested. However, the grower is inclined to sacrifice

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storage quality for the better color often gained in red varieties by holding them longer on the tree. Even if harvesting begins at the proper time, fruit picked last may be at an advanced stage of maturity. Such late-harvested apples do not have good storage characteristics; neither do those harvested on the immature side, but this is seldom a problem with apples intended for storage before marketing. Harvest at proper maturity, careful handling, and prompt storage after harvest are conducive to long storage life.

Chilling injury is the term commonly applied to disorders that occur at low storage temperatures where freezing is not a factor. The exact mutual relationship of the many types of chilling injury is unknown. The principal disorders classed as chilling injuries in apples are (1) soft scald, (2) soggy breakdown, (3) brown core, and (4) internal browning. Varieties susceptible to one or more of these disorders are Rome Beauty, Braeburn, Jonathan, Golden Delicious, Empire, Grimes Golden, McIntosh, Rhode Island Greening, and Yellow Newtown. In addition to variable susceptibility by variety, there are also yearly variations related to climate, fruit size, and cultural factors.

The following practices affect the condition of apples held for both conventional and controlled atmosphere storage:

Maturity. Because there is no reliable maturity index, growers must use personal experience of the variety, area, or orchard to decide when the crop is mature. Availability of labor, size of operation and crop, weather, storage facilities, and intended length of storage also affect the time of harvest.

Handling to Storage. For optimum storage, apples should be cooled within one or two days of harvest because they can deteriorate as much during one day at field temperatures as during one week at proper storage temperature. If other factors prevent final packaging, fruit can be cooled and stored in field bins. In this case, no grading will have been done to remove substandard product. Subsequent grading may increase the level of bruising, especially if the fruit is still cold when handled.

Normally, apples are placed in storage and cooled by the room refrigeration equipment to about 32°F in 1 to 3 days. Hydrocooling is sometimes used, but requires careful disease control. It also interferes with scald inhibitors, which must be applied to warm fruit.

Table 1 Summary of Controlled Atmosphere Requirements and Recommendations for Fruits Other Than Apples and Pears

Commodity	Temperature Range,[a] °F	Controlled Atmosphere[b] % Oxygen	% Carbon Dioxide	Commercial Use as of June 2001
Apricot	32 to 41	2 to 3	2 to 3	
Asian pear	32 to 41	2 to 4	0 to 1	Limited use on some cultivars
Avocado	41 to 55	2 to 5	3 to 10	During marine transport
Banana	54 to 61	2 to 5	2 to 5	During marine transport
Blackberry	32 to 41	5 to 10	15 to 20	Within pallet covers during transport
Blueberry	32 to 41	2 to 5	12 to 20	Limited use during transport
Cactus pear	41 to 50	2 to 3	2 to 5	
Cherimoya and Atemoya	46 to 59	3 to 5	5 to 10	
Cherry, sweet	32 to 41	3 to 10	10 to 15	Within pallet covers or marine containers during transport
Cranberry	36 to 41	1 to 2	0 to 5	
Durian	54 to 68	3 to 5	5 to 15	
Fig	32 to 41	5 to 10	15 to 20	Limited use during transport
Grape	32 to 41	2 to 5	1 to 3	Incompatible with SO_2
	32 to 41	5 to 10	10 to 15	Can be used instead of SO_2 for decay control up to four weeks
Grapefruit	50 to 59	3 to 10	5 to 10	
Guava	41 to 59	2 to 5	0 to 1	
Kiwifruit	32 to 41	1 to 2	3 to 5	Expanding use during transport and storage; C_2H_4 must be maintained below 20 ppb
Lemon	50 to 59	5 to 10	0 to 10	
Lime	50 to 59	5 to 10	0 to 10	
Lychee (litchi)	41 to 54	3 to 5	3 to 5	
Mango	50 to 59	3 to 7	5 to 8	Increasing use during marine transport
Nectarine	32 to 41	1 to 2	3 to 5	Limited use during marine transport
	32 to 41	4 to 6	15 to 17	Reduces chilling injury (internal breakdown) of some cultivars
Olive	41 to 50	2 to 3	0 to 1	Limited use to extend processing season
Orange	41 to 50	5 to 10	0 to 5	
Papaya	50 to 59	2 to 5	5 to 8	
Peach, clingstone	32 to 41	1 to 2	3 to 5	Limited use to extend canning season
Peach, freestone	32 to 41	1 to 2	3 to 5	Limited use during marine transport
	32 to 41	4 to 6	15 to 17	Reduces incidence and severity of internal breakdown (chilling injury) of some cultivars
Persimmon	32 to 41	3 to 5	5 to 8	Limited use of modified atmosphere packaging
Pineapple	46 to 55	2 to 5	5 to 10	Waxing is used to create modified atmosphere and reduce endogenous brown spot
Plum	32 to 41	1 to 2	0 to 5	Limited use for long-term storage of some cultivars
Pomegranate	41 to 50	3 to 5	5 to 10	
Rambutan	46 to 59	3 to 5	7 to 12	
Raspberry	32 to 41	5 to 10	15 to 20	Within pallet covers during transport
Strawberry	32 to 41	5 to 10	15 to 20	Within pallet covers during transport
Sweetsop (custard apple)	54 to 68	3 to 5	5 to 10	

Source: Kader (2001).
[a]Usual or recommended range; 90 to 95% rh is recommended.
[b]Specific CA combination depends on cultivar, temperature, and duration of storage. Recommendations are for transport or storage beyond two weeks. Exposure to lower O_2 or higher CO_2 concentrations for shorter durations may be used to control some physiological disorders, pathogens, or insects.

Controlled-Atmosphere Storage

Controlled-atmosphere (CA) storage is important in extending the market life of certain apple varieties. Chilling injury is eliminated in some varieties by elevating the storage temperature to about 40°F and altering the composition of the atmosphere.

Only apples of good quality and high storage potential should be placed in CA storage. Harvest maturity and handling practices are crucial; only fruit harvested at proper maturity should be considered. In any one district, this limits the number of apples suitable for CA storage to only a few days' harvest. Immature apples or those retained on the tree to gain better color, as is often done with Delicious and McIntosh, are equally undesirable.

Table 2 lists optimum levels of O_2, CO_2, and temperature for CA storage of apples. It also indicates storage life and whether the specific variety is susceptible to storage scald. This information was obtained from a worldwide survey of postharvest scientists who work on pome fruits.

Chapter 14 discusses systems and methods for achieving specific CA conditions as well as construction techniques and details for the rooms and spaces.

Storage Diseases and Deterioration

Storage problems in apples may be caused either by invading microorganisms or by the fruit's own physiological processes. Physiological disorders, although sometimes resembling rots, are related to biochemical processes within the fruit. Susceptibility to such disorders is often a variety characteristic, but it may be influenced by cultural and climatic factors and storage temperature.

Alternaria Rot. Dark brown to black, firm, fairly dry to dry storage decay centering at wounds, in skin cracks, in core area, or in scald patches; one of the blackest of storage decays. *Control*: Cultural practices that produce apples of good finish and prevent skin diseases and injuries that open the way for infection.

Table 2 Optimum Levels for Controlled Atmosphere Storage of Apples

Cultivar	Country	Region	Optimum O_2, %	Optimum CO_2, %	Optimum Temperature, °F	Storage Life, months
Alwa	Poland	Skierniewice	1.5	1.5	32 to 37	7
Ampion	Poland	Skierniewice	1.5	1.5	32 to 37	7
Arlet	Poland	Skierniewice	3	5	32 to 37	8*
Bancroft	Poland	Skierniewice	1.5	1.5	32	9
Bellena Roma	Spain	Lleida	3	2.5	32	*
Blanquilla	Spain	Lleida	3	3	32	6 to 7
Bonza	Australia	Victoria	1.5 to 1.8	1	32	*
Boskoop	Belgium	Heverlee	2	0.7	37 to 38	6*
Braeburn	Australia	Victoria	1.5 to 1.8	0.8 to 1	34	*
	Belgium	Heverlee	2	1	34	6
	France	St. Remy	1.5	0.8 to 1.2	33 to 34	6*
	Italy	Milan	1	1	33 to 34	8 to 9*
	New Zealand	New Zealand	3	1	33	6
	South Africa	Stellenbosch	1.5	1.5	31	8 to 9
	United States	Washington	2	<0.5	35	*
Bramley's Seedling	United Kingdom	Kent	1	5	39	11*
Cortland	Canada	Nova Scotia	2.5	4.5	37	8 to 10*
	United States	New York	2 to 3	2 to 3% one month, then 5%	36	4 to 6*
Cox's Orange	Belgium	Heverlee	2	0.7	37 to 38	5
Pippin	New Zealand	New Zealand	2	2	37	4 to 5
	Netherlands	Wageningen	1.2 to 1.4	<1	39	6.5
	United Kingdom	Kent	1.3	4	38	7
Elstar	Belgium	Heverlee	2	1	34	7
	Canada	Nova Scotia	2.5	4.5	32 to 33	No data
	Netherlands	Wageningen	1.2	2.5	35	7
Empire	Canada	Nova Scotia	2.5	0.5 to 1	34 to 36	No data
	United States	Michigan	1.5	2.5	37	9
		New York	2 to 3	2 to 3	34 to 36	5 to 10
Fiesta	New Zealand	New Zealand	2	2	33	6
	Poland	Skierniewice	1.5	1.5	32 to 37	7
Firmgold	Australia	Victoria	1.5 to 1.8	2 to 2.5	32	No data
Fuji	Australia	S. Australia	2	1	32	8*
		Victoria	2 to 2.5	2	32	*
	Canada	British Columbia	1.2	1	32	9*
			0.7	2	32	9*
	France	St. Remy	2 to 2.5	1 to 2	32 to 34	7 to 8*
	Italy	Milan	1	1	32	*
	United States	Washington	1	1	34	9*
			1	1	34	11*
		California	1.5	<0.5	32 to 34	7 to 9*
Gala	Australia	Victoria	1.5 to 2	1	32	*
	Canada	British Columbia	1.2	1	32	6
	France	St. Remy	1.5	2	32 to 34	4 to 5
	Italy	Milan	3	2	34 to 36	6
	New Zealand	New Zealand	2	2	33	No data
	Poland	Skierniewice	1.5	1.5	37	7

*Indicates variety of cultivars is subject to storage scald.

Table 2 Optimum Levels for Controlled Atmosphere Storage of Apples (*Continued*)

Cultivar	Country	Region	Optimum O_2, %	Optimum CO_2, %	Optimum Temperature, °F	Storage Life, months
Gala (*continued*)	Spain	Lleida	2	2	36	2 to 9
	United States	Washington	1	1	34	4
	Netherlands	Wageningen	1.2	2	34	5.5
Gala-Mondiel	United Kingdom	Kent	1	5	35	7*
Galaxy	Australia	Victoria	1.5 to 2	1	32	No data
Gloster	Netherlands	Wageningen	1.2	3	34	7.5
	Austria	Austria	2.25	3	35	10
	Canada	Nova Scotia	2.5	4.5	32 to 33	10
	Poland	Skierniewice	1.5	2	32 to 37	7 to 8
Golden Delicious	Australia	South Australia	2	1	32	7
		Victoria	1.5 to 2	1	32	*
	Austria	Austria	2 to 3	3	35	9 to 10
	Belgium	Heverlee	2	2	33	10*
	Canada	Nova Scotia	2.5	3	32 to 35	10
		British Columbia	1	1.5	32	11
	France	St. Remy	1 to 1.5	2 to 3	34 to 36	7 to 9*
	Israel	Israel	1.2	2	32	No data
			1 to 1.5	2	32	No data
	Italy	Milan	1	1.5	32 to 34	8 to 9
	New Zealand	New Zealand	2	2	33	6
	South Africa	Stellenbosch	1.5	3	31	9*
	Spain	Lleida	2.5	2.5	33	9*
		Murcia	2 to 3	4	33	7 to 8*
	Netherlands	Wageningen	1.1	4	34	8
	United States	Washington	1	2 to 3	34	9
		West Virginia	1	0	32	7 to 9
		Michigan	1.5	3	32 to 34	9
		New York	2 to 2.5	2 to 3	32	8 to 10*
Granny Smith	Australia	South Australia	2	1	32	8*
		Victoria	1.5 to 1.8	1	34	*
	France	St. Remy	0.8 to 1.2	0.8 to 1	32 to 36	7 to 8*
	Israel	Israel	1.2	3.5	32	No data
			0.8 to 1.5	2 to 5	32	No data
	South Africa	Stellenbosch	1.5	0 to 1	31 to 33	No data
	Spain	Lleida	2.5	4	36	7 to 8*
	United States	Washington	1	1	34	11*
		California	1.2	1	33	8*
Gravenstein	Canada	Nova Scotia	2.5	2.5	37	4*
Idared	Austria	Austria	2	2 to 2.5	36 to 37	No data
	Belgium	Heverlee	2	1.5	34	7
	Canada	Nova Scotia	2.5	0.5 to 1.5	32 to 37	10*
	France	St. Remy	3	3	36 to 39	7 to 8
	United Kingdom	Kent	1.3	4	39	4*
	United States	Michigan	1.5	3	32	9
		New York	2 to 2.5	2 to 3	34	7 to 9*
Jester	Poland	Skierniewice	1.5	1.5	32 to 37	6*
Jonagold	Australia	Victoria	1.5 to 1.8	1	32	*
	Austria	Austria	2	2	36	10
	Belgium	Heverlee	1	2.5	33	9*
	Canada	Nova Scotia	2.5	4.5	32 to 33	10
		British Columbia	1.2	1.5	32	9
	Poland	Skierniewice	1.5	2	37	9
	Spain	Lleida	2	3	33	5 to 8*
	Netherlands	Wageningen	1 to 1.2	4	34	9*
	United Kingdom	Kent	1.3	4	35	6*
	United States	New York	2 to 2.5	2 to 3	32	5 to 7*
Jonagold Red	Australia	Victoria	1.5 to 1.8	1	32	*
Jonamac	United States	New York	2 to 3	2 to 3% one month, then 5%	36	3*
			2 to 3	2 to 3	32	3*
			2 to 3	2 to 3	32	3*
Jonathan	Australia	South Australia	2	1	32	8*
		Victoria	1.5 to 1.8	1	34	*
	Poland	Skierniewice	3	5	32	7
	United States	Michigan	1.5	3	32	6
Lady Williams	Australia	Victoria	1.5 to 1.8	1	34	*
		South Australia	2	1	32	8*

*Indicates variety of cultivars is subject to storage scald.

Table 2 Optimum Levels for Controlled Atmosphere Storage of Apples (*Continued*)

Cultivar	Country	Region	Optimum O_2, %	Optimum CO_2, %	Optimum Temperature, °F	Storage Life, months
Law Rome	United States	Michigan	1.5	3	32	9*
		New York	2 to 2.5	2	32	7 to 9*
Ligol	Poland	Skierniewice	1.5	1.5	32	7.5*
Lobo	Canada	Nova Scotia	2.5	4.5	37 to 38	No data
Lodel	Poland	Skierniewice	3	5	32	6
Macfree	Canada	Nova Scotia	2.5	4.5	32 to 33	4
McIntosh	Canada	Nova Scotia	1.5	1.2	37	8
			2.5	5	35 to 37	8
	Poland	Skierniewice	1.5	1	36	8
	United States	Michigan	1.5	3	37	6*
		New York	3	2 to 3% one month, then 5%	36	5 to 7*
McIntosh (not Marshall)	Canada	British Columbia	2.5	4.5	37	8 to 10
McIntosh-Marshall	Canada	British Columbia	2.5	4.5	37	8 to 10
	United States	New York	4 to 4.5	2 to 3% one month, then 5%	36	No data
Melrose	France	St. Remy	2 to 3	3 to 5	32 to 37	4 to 6*
	Poland	Skierniewice	3	5	32	8
Moira	Canada	Nova Scotia	2.5	4.5	32 to 33	<2
Mutsu	Australia	Victoria	1.5 to 1.8	1	34	*
	United States	Michigan	1.5	3	32	9*
		New York	2 to 2.5	2 to 3	32	6 to 8*
Nashi (Nijisseki)	Australia	Victoria	1.5 to 1.8	1	34	*
		South Australia	2	1	32	5
Northern Spy	Canada	Nova Scotia	2.5	2	32 to 33	No data
	United States	Michigan	1.5	3	32	12
Nova Easygro	Canada	Nova Scotia	2.5	4.5	32 to 33	4
Novamac	Canada	Nova Scotia	2.5	4.5	37 to 38	4
Novaspy	Canada	Nova Scotia	2.5	4.5	32 to 33	10
Pink Lady	Australia	South Australia	2	1	32	9
			1.5 to 1.8	1	32	*
Prima	Canada	Nova Scotia	2.5	4.5	32 to 33	<2
Priscilla	Canada	Nova Scotia	2.5	4.5	32 to 33	<2
Boskoop	Netherlands	Wageningen	1.2	0.7	40 to 41	5.5*
Red Delicious	Australia	South Australia	1.8 to 2	2 to 2.5	32	*
	Canada	Nova Scotia	2.5	4.5	32 to 33	10*
		British Columbia	1.2	1	32 to 34	11*
			0.7	1	32 to 34	11*
	Israel	Israel	1.5	2	32	6 to 9*
	Italy	Milan	0.8	1	32 to 34	8
	Japan	Aomori	2	1.5	32	9*
	New Zealand	New Zealand	1.5	1.5	33	6*
	United States	West Virginia	1	0	32	7 to 9*
		Michigan	1.5	3	32	9*
		New York	2 to 2.5	2	32	8 to 10*
		Washington	1	3	34	9*
Red Delicious-Early Red One	Spain	Lleida	2.5	3	32	8*
Red Delicious-Hi Early	Australia	Victoria	2	1	32	8*
Red Delicious-Starking	South Africa	Stellenbosch	1.5	1.5	31	9*
	Spain	Lleida	2.5	2	32	8*
Red Delicious-Top Red	France	St. Remy	1.5	1.8 to 2.2	32 to 34	6 to 7*
	South Africa	Stellenbosch	1	1	31	9*
Rome	United States	West Virginia	1	0	32	7 to 9*
Royal Gala	Australia	South Australia	2	1	32	5
	South Africa	Stellenbosch	1	1	31	8
	United States	California	1.5	1.5	32	6
Rubin	Poland	Skierniewice	1.5	1.5	32	7
Runkel	United States	Michigan	1.5	3	32	9
Spartan	Canada	Nova Scotia	2.5	2.5	32 to 33	10
		British Columbia	1.2	1.5	32	11
	United States	New York	2 to 2.5	2 to 3	32	6 to 8*
Splendor	Canada	Nova Scotia	2.5	4.5	32 to 33	No data
Sturmer Pippin	New Zealand	New Zealand	2	2	36	4 to 5
Sundowner	Australia	South Australia	2	1	32	9
		Victoria	1.5 to 2	1	32	*
York	United States	West Virginia	1	0	32	7 to 9*

Source: Mitcham (1997).

*Indicates variety of cultivars is subject to storage scald.

Ammonia Gas Discoloration. Circular spots centering at lenticels; dull green on unblushed side and brown to black on blushed side. Injury may disappear from slightly affected fruit. *Control*: Ventilate as soon as possible. Examine fruit for injury at various points in the room because some sections may escape damage.

Bitter Pit. Many small, sunken bruise-like spots, usually on the calyx half of the fruit. Masses of brown, spongy tissue occur adjacent to surface pits, or may be found deeper in the flesh. In storage, spongy tissue near surface loses moisture and tends to become hollow. New areas may appear and develop in storage. *Control*: Apply boron and calcium, as recommended, in the orchard. Follow cultural practices that promote regular bearing and stabilize moisture. Store fruit of proper maturity and cool promptly to 32°F. Keep humidity high enough to prevent moisture loss.

Blue Mold Rot (*Penicillium*). Spots of various sizes with decayed tissue that is soft and watery and can be readily scooped out of the surrounding healthy flesh. Rot is usually as deep as it is wide. Advanced stages have white tufts of mold that turn bluish-green, because spores are produced under moist conditions. Affected tissue has moldy or musty flavor and odor. This is the most prevalent type of storage decay of apples. *Control*: Handle carefully to prevent skin breaks. Cool promptly to 32°F. Use fungicides in wash treatments. Keep picking boxes, packing house, and storage room sanitary. Whitewash walls and ceiling.

Brown Core. No external symptoms. It first appears as slight browning or discoloration of core tissue between seed cavities. Later, part or all of the flesh between seed cavities and the core line may become brown. This is serious in McIntosh and other susceptible varieties stored for long periods at 30°F. *Control*: Pick at proper stage of maturity. Use CA storage at 36 to 38°F. A disorder with similar symptoms results from exposure to excessive concentrations of CO_2.

Freezing Injury. Water-soaked, rubbery condition of large areas or of entire apple. Vasculars (water-conducting strands) are brown. Bruised areas in frozen apples are large, with wrinkled gray to light brown surface. Moisture is lost rapidly from affected areas. In refrigerator cars, it is most prevalent on floor and at doorways; in storage rooms, most injury is in bottom layer boxes, near coils, or against walls next to freezer storage. *Control*: Heat car during freezing weather. Prevent cold pockets in storage rooms by adequate air circulation. Minimize handling of fruit while frozen. Thaw at 40 to 50°F. Move thawed fruit into trade channels promptly; do not allow it to become overripe.

Internal Breakdown. Mealy breakdown of internal tissue in overripe fruit. Flesh is soft. Surface is often duller and darker than normal. It is hastened by too high storage temperature, freezing, bruising, or presence of water core, which it often follows. *Control*: Pick before overmature. Cool promptly at temperatures as near 32°F as possible for varieties that tolerate that temperature. Watch ripening rate, particularly of fruit with water core.

Internal Browning. No abnormal skin appearance. Sometimes it appears only around core; the apple's outer fleshy portion remains normal in appearance. Occasionally, only outer flesh is involved, but is usually accompanied by browning around the core. Disease develops uniformly throughout tissue, and occurs in firm, sound apples. *Control*: Use CA at 38°F for Empire and other susceptible varieties.

Jonathan Spot. Slate-brown to black, entirely superficial or very slightly sunken, skin-deep spots in color-bearing cells of skin. In some varieties, spots center at lenticels. *Control*: Refrigerate promptly, because this disease is greatly aggravated by delayed storage. Use CA storage.

Lenticel Rots. Bullseye rot (*Neofabrabraea*): most common of group; important only in apples from Northwest; spots fairly firm, pale centers, decay mealy, may penetrate nearly as deep as wide. Fisheye rot (*Corticum*): tough leathery spot, often follows scab; decayed tissue stringy. Side rots (*Phialophora*): spots shallow with tender skin, decayed tissue wet, slippery. *Control*: Harvest at prime maturity; store and cool promptly; use forecasting technique for bullseye rot to determine potential keeping quality.

Scab (*Venturia*). Occasionally, active scab spots on fruit at time of storage enlarge. Fruit may be infected in orchard but show no disease at the time of storage. Disease may subsequently develop in storage as small brown or jet black spots in peel, often without breaking cuticle of fruit. *Control*: Follow recommended orchard spray schedule.

Scald. Diffuse browning and killing of skin of fruit stored for several months. Ordinarily most prevalent on immature fruit or on green portions of fruit. *Control*: Pick apples when well matured. Treat with scald-inhibiting chemicals. Scald develops less on fruit in controlled atmospheres.

Soft Scald. Sharply defined or slightly sunken ribbon-like areas in the skin. Affected tissue is shallow and rubbery. It is most severe on Jonathan, Golden Delicious, and Wealthy. *Control*: Store promptly. Use recommended controlled atmospheres, temperatures, and lengths in storage for each variety.

Soggy Breakdown. Light brown, moist, rubbery, definitely delimited areas in cortex of apple; not visible on surface. It is worst in Grimes Golden, Wealthy, and Golden Delicious. *Control*: Same as for soft scald.

Water Core. Hard, glassy, water-soaked regions in flesh of apple at core or under skin. Extent decreases during storage but predisposes fruit to internal breakdown. *Control*: Pick as soon as mature. Watch fruit in storage and move before it becomes overripe.

PEARS

Bartlett is the most important pear variety, exceeding the total of all others by a wide margin. Other Pacific Coast varieties are Hardy, Comice, Anjou, Bosc, and Winter Nelis. The eastern states have limited varieties because of the severe problem of fire blight, and primarily grow the Kieffer variety. Although most Bartlett and Hardy and many Winter Nelis pears are canned, cold storage before ripening for canning is the usual procedure. A 10 day to 2 week cold storage period for Bartlett pears is commonly used by canners because it improves ripening uniformity. Substantial quantities may also be stored for periods approaching maximum storage life of the variety to better use processing facilities.

Maturity at harvest strongly affects subsequent storage life, as it does for apples. However, unlike apples, pears do not ripen on the tree, nor do most varieties ripen at cold storage temperatures. If harvested too early, they are subject to excessive water loss in storage. If allowed to become overmature on the tree, their storage life is shortened, and they may be highly susceptible to scald and core breakdown. Flesh firmness, as measured by a pressure tester, is perhaps the best measure of potential storage life of pears from any single orchard. For the Bartlett variety, a firmness of 19 to 17 lb, measured with a Magnus-Taylor pressure tester or similar device using a 0.31 in. diameter plunger head, indicates best storage quality. If average firmness is as low as 15 lb, storage for any prolonged period is likely to produce poor-quality fruit. Pressure-test information for each lot of pears going into storage can be very helpful to both the fruit owner and the cold storage operator in determining the storage program.

Careful harvesting and handling are essential to good storage quality. Bruises and skin breaks are likely sites for infection by microorganisms. Varieties such as Winter Nelis and Bosc are highly susceptible to punctures caused by stems broken during harvesting. Comice is also easily damaged because of its very tender skin. Pears are harvested into pallet bins holding about 1000 lb of fruit. Care in dumping fruit from a picking container is important in keeping mechanical damage to a minimum.

For best storage quality, rapid cooling after harvest is essential. Pears ripen rapidly at elevated temperatures but do not soften or change color in the early ripening stages. Therefore, a considerable part of the storage life may be used up without a visible change in the fruit. If cold-storage rooms do not have adequate refrigeration and air circulation capacity for rapidly cooling fruit, consider pre-cooling in special rooms (or hydrocooling) before placing in the storage room. When warm fruit is placed in a room with cold fruit, the loading arrangements should be such that the temperature of the cold fruit is not elevated.

Pears are very sensitive to temperature and should be stored at 30°F and 90 to 95% rh. Recommendations as low as 29°F have been made, but the risk of freezing injury is great unless the temperature in all parts of the room can be controlled precisely. Pears are not subject to chilling injury as some apple varieties are, so elevated storage temperatures are not required. The stacking arrangement recommended for apples in the cold storage room also applies for pears.

Because pears lose water more readily than most apple varieties, good humidity conditions in the storage room must be maintained. For long storage, 90 to 95% rh is recommended. Perforated film box liners are excellent for moisture loss control.

The approximate storage life of pears at 30°F is shown in Table 3. These values assume an additional time for transportation and marketing. If Bartlett pears for canning are harvested at the best stage of maturity and quickly cooled to 30°F, their safe storage life may be as long as 4 months, because marketing involves only ripening for processing. However, quality deteriorates during storage, particularly as the maximum storage life is approached.

After removal from storage, best dessert quality (for both canning and fresh use) is attained if pears are ripened in a controlled temperature range of about 60 to 70°F. For cannery fruit, ripening at 68 to 72°F is more practical than at lower temperatures because the shorter time involved reduces overhead costs with no measurable difference in quality.

Controlled-Atmosphere Storage

The storage life of Bartlett pears can be extended to 5 to 6 months at 30°F for fruit of desirable maturity (17 to 20 lb firmness) in controlled-atmosphere storage. Bartlett pears of advanced maturity are intolerant to elevated CO_2 and develop core and flesh browning within a few weeks. They are tolerant of low O_2, but have less storage potential than pears of desirable maturity. Chronological age and pressure test (under 16 lb firmness) are evidence of advanced maturity.

Commercial CA storage of pears has not been considered as necessary as it is in the apple industry. Because no low-temperature disorders have been recognized, there has not been a need for further extension of the storage life.

Table 3 lists optimum levels of O_2 and CO_2, storage time, and CA disorders for pear varieties at 30 to 32°F. This information was obtained through a worldwide survey of postharvest scientists who work on pome fruits.

Many pears from western states, when packed for storage before marketing, have perforated polyethylene liners in the container. Although these liners give excellent protection against water loss, there is no agreement about their value in modifying the atmosphere in the container.

Table 3 Commercial Controlled Atmosphere Conditions for Pear Varieties[a]

Variety	O_2, %	CO_2, %	Storage, months	CA Disorders[b]
Abate Fetel	1	1	5 to 6	IB
Alejandrina	3	2	4 to 5	IB
Anjou, d'Anjou	1 to 2.5	0 to 0.5	7 to 8	IB, PBC, Cav
Bartlett, (= William's Bon Chretien)	1 to 2	0 to 0.5	3 to 5	CF, PBC
Blanquilla, (= Blanca de Aranjuez)	3	3	6 to 7	
Bosc, Kaiser	1 to 2.5	0.5 to 1.5	4 to 8	PBC, Cav
Buena Luisa (= Buona Luisa)	3	2	6	IB, CF
Clapp's Favorite	2	<0.7	3 to 4	IB, PBC
Comice (= Doyenne du Comice, Comizio)	1.5 to 4	0.5 to 4	5 to 6	IB (overmature)
Conference	1 to 2.5	0.6 to 1.5	6 to 8	BH, IB, Cav
Coscia	1.5	2 to 3	6 to 7	CF
Flor d'Hivern (= Inverno)	3	3	4 to 5	IB
Forelle	1.5	0 to 1.5	6 to 7	
General Leclerc	2 to 3	2 to 3	3 to 5	
Grand Champion	3	2 to 2.5	4	
Hardy	2 to 3	3 to 5	4 to 6	
Josephine	1 to 2	1 to 2	8	
Krystalli	2	1 to 2	3 to 5	
Limonera, Llimonera	3	3	3 to 4	
Packham's Triumph	1.5 to 1.8	1.5 to 2.5	7 to 9	CB
Passe Crassane (= Passa Crassane)	3	4 to 5	5 to 8	IB
Rocha	2	2	8	
Spadona	1.5 to 2.5	1.5 to 3.5	8 to 9	IB
Nashi, Asian pears				
Chojuro	2	1 to 2	3 to 4	
Kosui	1 to 2	0 to 2	3 to 4	
Nijiseiki (= 20th Century)	0.5 to 3	0 to 1	5	
Tsu Li	1 to 2	0 to 3	3 to 5	IB
Ya Li[c]	4 to 5	0 to 4	3 to 4	IB, Cav, CI?

Source: Richardson and Kupferman (1997).
[a]Optimum storage temperature is 30 to 32°F, unless otherwise indicated.
[b]CA disorder abbreviations are as follows:
IB = internal breakdown or browning
BH = brown heart
PBC = pithy brown core
CF = core flush
Cav = cavity, usually lens-shaped
CI = chilling injury
[c]Ya Li may show a type of chill injury at <41°F

Storage Diseases and Deterioration

The principal storage disorders in pears are (1) core breakdown, (2) scald and failure to ripen, and (3) fungus rots.

Core Breakdown. Often accompanies scald. Soft, brown breakdown in core area has an acrid, disagreeable odor of acetaldehyde. *Control*: Do not allow pears to become overmature on tree. Cool promptly. Store at 30°F. Ripen between 65 and 75°F.

Core breakdown is associated with overmaturity at harvest. This problem has become more important because of growth regulator sprays used to keep pears from dropping during the harvest season. Pressure-test information on late-harvested fruit is helpful in locating lots susceptible to core breakdown. Records of the time lapse between harvest and storage are important, because pressure-test information may not be a true measure of relative storage quality when storage is delayed. Pear color, particularly in California Bartletts, is a very poor measure of potential storage life because of great variability among pears from different districts.

Scald. Brown to black softening of large areas of skin and tissues immediately beneath skin; often accompanies core breakdown. Affected areas slough off readily. Acetaldehyde odor and flavor are prominent. *Control*: Pick before overmature. Cool promptly. Store only for proper period. Oiled paper wraps do not control scald.

Pear scald is associated with overlong storage and lost ripening capacity. It is not related to apple scald and cannot be controlled by any supplemental treatments. The problem develops progressively earlier as the temperature is raised above 30°F. Yellowing of the fruit is the principal storage symptom; Bartlett and Bosc are the two most susceptible varieties. Anjou and Comice may not develop scald but do lose their capacity to ripen. Periodic inspection is desirable to ensure that green pear varieties are removed from storage before yellowing progresses to the danger point. Yellow pears may show no scald in storage but may develop scald on removal to a ripening temperature. If pear scald does show in storage, the pears have been kept too long and may be worthless.

Anjou Scald. Anjou pears are often affected with a surface browning more superficial than common scald and distinct from it, resembling apple scald. Anjou scald is controlled by oiled paper wraps and scald-inhibiting chemicals.

Gray Mold Rot (*Botrytis*). Extensive, firm, dull brown, water-soaked decay with bleached border. Dirty white to gray extensive mycelia form nests of decayed fruit. *Control*: Wrap fruit in copper-impregnated paper. Use fungicide in spray or wax on packing line. Cool promptly to 30°F.

Gray mold rot caused by *Botrytis cinerea* grows at cold storage temperatures and can be a serious threat to long-stored winter varieties such as Anjou and Winter Nelis. Without control measures, the disease may spread from one fruit to another by contact.

Alternaria Rot. Dark brown to black surface. Decayed tissue is gray to black, dry in center, gelatinous at edge, easily removable as core from surrounding flesh. It is found late in storage season, usually at punctures. *Control*: Prevent skin breaks. Remove from storage at first appearance of trouble.

Brown Core. Various degrees of pithy brown core and desiccated air pockets in Anjou and Bartlett pears stored in sealed, polyethylene-lined boxes with inadequate permeability. Prolonged storage in concentrations of 4% or more CO_2 often produces brown core, particularly when pears are harvested at advanced maturity or are cooled slowly after packing. *Control*: Harvest at proper maturity. Cool promptly. Store at 30°F. Use perforated film liners to maintain CO_2 level at 0 to 0.5%.

Freezing Injury. Glassy, water-soaked external appearance with tan pithy area around core in Bartlett and Anjou pears exposed for 4 to 6 weeks just below their freezing point. Pears frozen sharply may break down completely or show abruptly sunken large pits where slightly bruised while frozen. *Control*: Keep transit and storage temperature above 30°F.

GRAPES

Grapes are widely grown in the United States, but over 90% are grown in California, which produces the *Vitis vinifera* species almost exclusively. This species can withstand the rigors of handling, transport, and storage required of table grapes for wide distribution over a long marketing period. Almost all of this fruit is precooled and much of it stored for varying periods before consumption. On the other hand, for fresh use, fruit of the species *Vitis labrusca* (Eastern type) is largely limited to local market distribution.

Grapes grow relatively slowly and should be mature before harvest because all of their ripening occurs on the vine. *Mature* here means the stage of physiological development when the fruit appears pleasing to the eye and can be eaten with satisfaction. However, grapes should not be overripe, because this predisposes them to two serious postharvest disorders: (1) weakening of stem attachment in some varieties, such as Thompson seedless, which causes the berries to separate from the pedicel attachment; and (2) progressively greater susceptibility to invading decay organisms. Danger of fruit decay is increased with exposure to rain or excessively damp weather before harvest (conditions favorable for field infections by *Botrytis cinerea Pers*).

Cooling and Storage

Grapes are vulnerable to the drying effect of air because of their relatively large surface-to-volume ratio, especially that of the stems. Stem condition is an important quality factor and an excellent indicator of the past treatment of the fruit. Stems should be maintained in a fresh green condition not only for appearance but because they become brittle when dry and are apt to break. The stem of a grape cluster, unlike that of other fruit, is the handle by which the fruit is carried; if breakage (shatter) occurs, the fruit is lost for all practical purposes even though the shattered berries may still be in excellent condition. Therefore, careful attention should be paid to operations that minimize moisture loss.

The rate of water loss is especially high before and during precooling, because grapes are normally harvested under hot, dry conditions. Field heat should be removed promptly after the fruit is picked to minimize the grapes' exposure to low-vapor-pressure conditions. Volume and temperature of precooling air, its velocity past or through the containers (lugs), and accessibility of the fruit to this air are significant factors in the rate of heat removal. These factors are drastically influenced by the location and amount of venting of the containers, alignment of the containers (air channels), and packing materials such as curtains, cluster wraps, and pads.

Table grapes are initially cooled with a forced-air cooling system. A pressure gradient is set up so that there is a positive flow of cold air through the fruit from one vented side of the container to the other. The containers are arranged so that the air must pass *through* the containers before returning to the refrigeration surface. Precooling time is usually 3 to 12 h, depending on packaging system and airflow.

The recommended storage temperature for *Vitis vinifera* (European or California-type) grapes is 30°F. The relative humidity should be 90 to 95%. Although temperatures as low as 29°F have not been injurious to well-matured fruit of some varieties, other varieties with low sugar content have been damaged by exposure to 31°F. Grape storage plants in California should provide uniform air circulation in the rooms. Fruit should be forced-air-cooled to less than 39°F before storage. During initial storage, a well-distributed airflow of 100 cfm per ton of grapes is needed to finish the cooling. After the fruit has been precooled, air velocity should be reduced to a rate that maintains uniform temperatures throughout the room (no more than 10 to 20 fpm in the channels between the lugs).

The greatest change that occurs in stored grapes is water loss. The first noticeable effect is drying and browning of stems and pedicels. This becomes evident with a loss of only 1 to 2% of the mass of the fruit. When loss reaches 3 to 5%, the fruit loses its turgidity and softens.

Maintaining 90 to 95% rh in grape storage is often a problem, especially at the beginning of the storage season when the rooms are being filled with dry lugs. Each lug absorbs 0.33 to 0.67 lb of water over a month, and, unless moisture is supplied to the room, this water must come from the fruit. Spray humidification is effective at minimizing shrinkage. With proper balance of water and air pressure and the correct type of nozzle, a fine spray can be obtained that will vaporize readily even at 31°F.

Fumigation

Vinifera grapes must be fumigated with sulfur dioxide (SO_2) after they are packed to prevent or retard the spread of decay. The treatment surface-sterilizes the fruit, particularly wounds made during handling.

Fumigation with SO_2 in storage prevents new infections of the fruit but does not control infections that have already occurred in the vineyard. Frequently, these have not developed far enough to be detected at harvest and consequently are the primary cause of decay in storage. Harvey (1955, 1984) describes a method of measuring field infection to forecast decay during storage; the forecast indicates lots that are sound and can be safely stored, and those that are likely to decay and should be marketed early.

Common practice during initial cooling is to fumigate the fruit in the evening. In this way, precooling is not delayed, and fumigation can be done after most of the working crew has left. This initial treatment often becomes the responsibility of the refrigeration personnel.

Amount of Sulfur Dioxide. Other commodities should not be treated along with the grapes or even held where the fumigant can reach them, because most of them are very easily injured by the gas. Because grapes also can be injured, they should be exposed to the minimum quantity of SO_2 required, which depends on the following:

- Decay potential and condition of the fruit
- Amount of fruit to be treated
- Type of containers and packing materials
- Air velocity and uniformity of air distribution
- Size of the room
- Losses from leakage and sorption on walls

Much of the following information on sulfur dioxide fumigation methods of table grapes is from *Bulletin* 1932, University of California Division of Agriculture and Natural Resources, 1992.

The amount of SO_2 for effective control of *Botrytis* varies with the length of time that grapes are exposed to the gas. The dosage of SO_2 to kill *Botrytis* spores or mycelia during fumigation is 100 ppm·h.

Fumigation Methods. The following two methods are currently used for fumigation. Both give adequate decay control but differ in the quantity of SO_2 used and the application method.

Traditional fumigation may be used for initial fumigation when grapes are received at a facility, and for weekly fumigation during long-term storage. Relatively high SO_2 concentrations are added for 20 to 30 min, then the remaining gas is scrubbed or vented from the room.

Traditional initial fumigation can use either circulating-air or forced-air fumigation. Each is used either in combination with initial cooling or as a separate operation. In **circulating-air fumigation**, air flows past, but not through, palletized boxes. Penetration of SO_2 into the innermost boxes depends on the speed of air past the pallets and the types of box and packing materials. A minimum airspeed of 140 fpm is required for maximum penetration.

Airflow systems for **forced-air fumigation** are the same as systems used for forced-air cooling. Sulfur dioxide gas is introduced into the room air and forced through the boxes, resulting in rapid and thorough penetration, even for bagged or tissue-wrapped fruit.

Airflow for many forced-air fumigation rooms is typical of forced-air coolers (about 1 cfm per lb of product stored); however, good SO_2 penetration has been observed even with lower airflow (0.5 cfm/lb) and slower cooling times.

The maximum permitted SO_2 concentration for initial fumigation is 10,000 ppm. Although a few operators regularly use this level in small circulating-air fumigation chambers, many operators use 5000 ppm for initial fumigation. Levels used for a particular facility must be determined by using SO_2 dosimeter tubes to measure actual SO_2 penetration into boxes.

The amount of SO_2 needed for a traditional fumigation can be calculated by

$$W_s = \frac{AVC}{10^6}$$

where

W_s = quantity of SO_2 required, lb
A = 1.67 lb SO_2/ft^3 at 70°F and 1.82 lb SO_2/ft^3 at 32°F
V = room volume, ft^3
C = desired SO_2 concentration, ppm

Sulfur dioxide concentration may also be expressed in terms of the percentage of SO_2 in the room atmosphere (1% equals 10,000 ppm; 0.5% equals 5000 ppm).

New fumigation facilities may be restricted from releasing any SO_2 into the outside atmosphere. Water scrubbing can remove SO_2 from the room atmosphere without venting. The most effective systems route refrigeration return air through a water spray or pad assembly. Water can absorb SO_2 at a rate of 10 lb SO_2 per 1400 gal H_2O, if the water is at 32°F and becomes completely saturated with the fumigant. At 70°F, water will absorb only half as much SO_2.

Because absorption efficiency drops as water nears saturation with SO_2, the actual amount of water used in practice will be several times the theoretical amount. This water cannot be reused, and must be disposed of. Sodium hydroxide or potassium hydroxide can be added to the scrubber water to increase the amount of SO_2 it can absorb. For large storage rooms, portable scrubbers used by some operators often require long periods of operation to yield adequate fumigant level reductions. If not maintained, their efficiency can be reduced dramatically by sulfite salts (plugged nozzles are a common problem).

Traditional storage room fumigation is done weekly to prevent the spread of decay from *Botrytis*-infected fruit. In cold-storage rooms, it is similar to traditional circulating-air initial fumigation. The maximum permitted SO_2 concentration for storage fumigation is 5000 ppm (CFR 2005), although many operators use 2500 ppm to fumigate filled storage rooms, and lower levels for partially filled rooms.

Traditional storage fumigation has a number of disadvantages. Large rooms are required, and poorly designed airflow systems and/or nonuniform placement of grape pallets can cause even lower levels of SO_2 penetration and greater variations than in initial fumigation. The short fumigation time results in high SO_2 levels in room air at the end of fumigation; excess fumigant must be vented or scrubbed before the room is safe for reentry.

In **total utilization fumigation**, the amount of SO_2 applied is balanced with the amount absorbed by fruit, boxes, and the room itself. Because fumigation is prolonged and the quantity of fumigant is calculated so closely, nearly all of the SO_2 is absorbed by fruit, packaging materials, and room surfaces. At the end of fumigation, the SO_2 concentration in the room air is usually less than 2 ppm.

Total utilization initial fumigation can *only* be used with precooling. For complete gas absorption, the gas must be kept in contact with the product and room surfaces for at least a few hours. Without precooling, the grapes would be exposed to warm air, which would desiccate the stems. Waiting several hours for a drop in SO_2 concentration would also unnecessarily delay cooling. With simultaneous fumigation and precooling, the fruit is quickly cooled and effectively fumigated. Forced-air total utilization initial fumigation may use 75% less SO_2 than traditional fumigation, and consistently provides an in-box **CT** (the SO_2 concentration in ppm times exposure time in hours) in excess of 100 ppm·h in all package types. Airflow considerations for traditional initial fumigation also apply to total utilization initial fumigation with circulating air.

The quantity of SO_2 required for effective decay control can be calculated using the following equation and the factors listed in Table 4.

$$W_s = \frac{BQR}{10{,}000}$$

where

W_s = quantity of SO_2 required, lb
B = SO_2 factor from Table 4 (lb of SO_2 per 10,000 boxes)
Q = quantity of boxes in room
R = ratio of actual box count to maximum box count in room (R should equal 0.5 if box count drops below 50% of room capacity)

Each box stored occupies 2.5 to 3.5 ft^3 of room volume. Calculations are based on a box occupying 3 ft^3 of room volume (10,000 boxes in a 30,000 ft^3 room).

Because polystyrene does not absorb sulfur dioxide as readily as wood and fiberboard materials, expanded polystyrene (EPS) boxes have lower SO_2 factors than wood-paper laminated (TKV) boxes. Although there are no reliable industry data on which to base factors for fiberboard boxes, laboratory studies show that they absorb more

Table 4 Factors for Determining Amount of SO_2 Needed for Forced-Air Fumigation Using Total Utilization System

	SO_2 Factor, lb/10,000 boxes[a]	
Box Type[b]	Good SO_2 Penetration	Poor SO_2 Penetration
EPS	1.5	3.0
TKV	3.7	6.3

Source: University of California (1992)
[a]Factor is based on boxes that weigh 20 to 25 lb gross.
[b]Fiberboard boxes should probably be fumigated using TKV factors, although there are no industry data available to make a reliable recommendation.

Table 5 Factors for Determining Amount of SO_2 Needed for Storage Room Fumigation

	SO_2 Factor, lb/10,000 boxes[a]	
Box Type[b]	Good SO_2 Penetration	Poor SO_2 Penetration
EPS	3.0	7.5
TKV	6.3	14.0

Source: University of California (1992)
[a]Factor is based on boxes that weigh 20 to 25 lb gross.
[b]Fiberboard boxes should probably be fumigated using TKV factors, although there are no industry data available to make a reliable recommendation.

SO_2 and would have higher factors than TKV boxes (Harvey et al. 1988). The higher factors ("poor SO_2 penetration" in Table 4) should be used for boxes that have low SO_2 penetration rates because of poor venting or packing materials that reduce gas movement into the box. Grapes with a high potential for decay may also require high SO_2 levels.

As rooms are emptied of grapes, the minimum amount of SO_2 needed is influenced by the absorption by room surfaces and coils and the amount of air leakage. The amount of SO_2 used should not be less than that required for a half-full room. Because initial fumigation rooms may differ in construction and operation, each room must be calibrated to determine the SO_2 quantity needed for a CT of 100 ppm·h in packed boxes.

The procedure for total utilization storage-room fumigation is similar to that for total utilization initial forced-air fumigation: SO_2 flows past the outside surfaces of palletized boxes rather than being forced through the boxes. Lanes are usually stacked two to three pallets high with 4 to 6 in. between lanes.

The amount of SO_2 required for effective decay control is calculated by the same methods as for total utilization forced-air fumigation. However, SO_2 penetration into boxes can be much poorer in a storage room than in an initial fumigation room, so the SO_2 factors are greater (Table 5). The amount of SO_2 should never be below that required for a half-full room. Higher factors should be used for boxes with poor SO_2 penetration characteristics because of poor venting, overpacking with fruit, or packing with materials that reduce air movement through the box.

EPS and TKV boxes should be stored in separate rooms, as should wrapped, plain-pack, and bagged grapes. Even so, because of the great variability in SO_2 penetration among boxes of the same type, there is still potential for differences in decay control and residue levels in a room filled with similar boxes.

Fans should always be on high speed during the first 1 to 2 h of fumigation, and airspeeds past all pallets should be greater than 140 fpm. Pallets should be stacked neatly with a 4 to 6 in. gap between lanes so that airflow is not blocked.

Calibration. All storage rooms should be monitored to determine the effectiveness of the fumigation program by conducting CT, residue, and *Botrytis*-control tests as follows:

- **CT.** A CT of at least 100 ppm·h should be indicated by dosimeter tubes placed among the grapes in boxes located in the hardest-to-fumigate positions in the room (typically, center boxes in pallets in areas with the least airflow). Dosimeter tubes should be placed in the boxes immediately before fumigating and removed and read at completion. Excessive SO_2 use is indicated if all dosimeter tubes have a color change along their entire length.
- **Residues.** Residue analyses should be conducted on grapes removed from the easiest-to-penetrate positions. High-residue areas (typically top corner boxes in the highest-airflow areas) can be located by using dosimeter tubes. Because of the variability of residue analysis, residues over 3 ppm SO_2 should be viewed with concern.
- ***Botrytis* control.** Grapes stored for a prolonged period should be inspected for the number of *Botrytis*-infected berries. Initial fumigation kills spores of this fungus. Fumigated rooms are nearly sterile; living *Botrytis* spores are not present in the atmosphere in these rooms. Infected berries found later during storage result from field infections. Inadequate fumigation and temperatures above 35°F during cold storage after initial fumigation allow mycelial development, and berry-to-berry spread (nesting).

Frequency of Storage-Room Fumigation. Storage rooms should be fumigated regularly and frequently enough to control mycelia from infected berries before they can spread to adjacent berries. The speed of mycelium growth varies with temperature. Berry temperature during storage should be as close as possible to 31°F. Industry experience and test results indicate that a maximum fumigation interval of 7 days is adequate to prevent *Botrytis* spread. Lengthening the fumigation interval may lead to a greater amount or spread of decay.

Precautions. Sulfur dioxide has certain properties that demand care in its use as a fumigant in cold-storage plants. Concentrations recommended for grape fumigation in storage can cause respiratory spasms and death if the victim cannot escape the fumes. When working in even weak concentrations of SO_2, goggles to protect against eye injury and a gas mask fitted with canister for acid gases (not the usual canister for ammonia gas) should be worn. Concentrations as low as 30 to 40 ppm can be detected by smell. It requires several times these concentrations to cause discomfort.

Because a small segment of the population may experience severe allergic reactions to sulfites, the U.S. Environmental Protection Agency allows a 10 ppm tolerance for sulfite residues in table grapes (CFR 2005; Harvey et al. 1988). Fruit with residues exceeding the tolerance cannot be marketed.

Another precaution about SO_2 that cannot be overemphasized is its injurious effects on other produce. For this reason, care must be taken that only grapes are stored in the room that is to be fumigated and that there are no leaks through walls or halls to adjacent rooms storing other produce.

Periodic fruit inspection is recommended to check whether the SO_2 gas is reaching the center of the stacks or whether some grapes are being overtreated. If the pedicels and stems retain a yellow or green color and broken berries show no mold and appear to be dried or seared, the gas has reached the fruit in question and is having the desired effect. Serious bleaching on unbroken grapes means too high a concentration or too long an exposure; there should be better distribution of the gas, lower concentration, or shorter fumigation periods.

Diseases

Blue Mold Rot (*Penicillium*). Watery, mushy condition, with early production of typical bluish green spores on berries and stems. There is moldy odor and flavor. *Control*: Prevent deterioration by careful handling and prompt refrigeration, preferably to 32°F. Fumigate with SO_2 in storage.

Cladosporium Rot. Black, firm, shallow decay that produces an olive green surface mold. It is common on stored grapes harvested early in the season. Infections occur on small growth cracks at the blossom end and sides of the grape. *Control*: Precool and store grapes promptly at 32°F. After harvest, fumigate with SO_2 to reduce spread.

Gray Mold Rot (*Botrytis*). Early stage: slip skin with no mold growth. Later: nest of fairly firm decay covered with abundant fine gray mold and grayish brown, velvety spore masses. *Control*: Cull decay when packing. Fumigate grapes with SO_2. For storage, cool rapidly to 30°F. Use forecasting to determine safe storage periods. Use short storage for grapes harvested in rainy periods or after slight freezes.

Rhizopus Rot. Soft, mushy, leaky decay causing staining of lugs. Coarse, extensive mycelia and black sporangia develop under moist conditions. *Control*: Prevent skin breaks. Cool promptly to below 50°F.

Sulfur Dioxide Injury. Bleached sunken areas on berry at skin breaks or cap-stem attachment. Decolorized portions have disagreeable astringent flavor. Full severity does not appear until cool grapes are warmed. *Control*: Apply proper concentration and distribution of gas for recommended period.

Storage Life

The normal storage life of major varieties of California table grapes at 30°F is shown in Table 6. Under exceptional conditions, sound fruit will keep longer than indicated; for example, Emperor grapes have been held in good condition for 7 months, and Thompson seedless for 4 months. The EPA registration label limits the number of legal fumigations permitted for various cultivars. This limit may restrict permissible storage time.

The storage life of grapes is affected most by the attention given to selecting and preparing the fruit. Grapes should be picked at the best maturity for storage, especially Thompson seedless and Ohanez. Stems and pedicels should be well developed, and the fruit should be firm and mature. Soft and weak fruit should not be stored. The display lug is a satisfactory package for storage because it can be cooled and fumigated easily.

Cooling to 40 to 45°F is advised for grapes that are to be in transit a day or two before reaching storage. Take special care during transit so that decay does not start. It is not good practice to delay fumigation until the grapes reach a distant storage plant, because during picking and packing, many berries are injured enough for mold to begin unless the fruit is fumigated promptly.

For *labrusca* (Eastern type) grapes, a storage temperature of 32°F and humidity of 85% are recommended. Care in packing and handling the fruit, minimum delay before storage, and prompt cooling are important for best results with these varieties, as with *vinifera* grapes. Eastern varieties are not fumigated with SO_2 because of their susceptibility to injury from it. Storage life of important commercial varieties at 32°F is shown in Table 7.

Refrigeration System Materials and Practices

SO_2 is corrosive to many materials; the following materials and practices are recommended to provide satisfactory equipment durability and economical operation:

Table 6 Storage Life of California Table Grapes at 32°F

Variety	Storage Life, Months
Emperor, Ohanez, Ribier	3 to 5
Malaga, Red Malaga, Cornichon	2 to 3
Thompson seedless, Tokay	1 to 2.5
Muscat, Cardinal	1 to 1.5

Table 7 Storage Life of *Labrusca* Grapes at 32°F

Variety	Storage Life, Weeks
Catawba	5 to 8
Concord, Delaware	4 to 7
Niagara, Moore	3 to 6
Worden	3 to 5

Evaporators

- Coils: an aluminum alloy resistant to SO_2; also can be coated with a material to prevent chemical attack
- Housing: aluminum sheet metal with 304 stainless steel fasteners
- Fan blades: cast aluminum or mild steel coated with a baked-on food-grade powder coating
- Fan guards: mild steel with baked-on food-grade powder coating
- Fan motors: totally enclosed fan-cooled (TEFC) or totally enclosed air-over (TEAO) with cast-iron or cast-steel housing; specify a high-quality paint job
- Fan motor shafts: coat with nickel-based anti-seize material
- Coil connections: use dielectric connectors between coil connections and external piping

Piping to Evaporators

- Use aluminum or stainless steel pipe of correct weight or schedule for the refrigerant. Use stainless steel pipe hangers and hanger rods.
- Locate hand valves and control valves outside the cold-storage space to minimize corrosion and for easy maintenance.
- Locate evaporators as close to outside walls as practical to minimize length of piping between control valves and evaporators.
- Revert to piping materials normally used when the piping is outside the cold storage environment. Use dielectric connections between dissimilar materials.

Maintenance and Operation

A successful SO_2 fumigation program requires that cold-storage facilities be well operated and maintained. Leaky door seals, inoperative SO_2 input lines or fans, improperly functioning or unsafe refrigeration equipment, or poorly operating and maintained ductwork reduce system and program effectiveness. Safe, efficient operations require that equipment and buildings be kept in good working order.

PLUMS

Plums are not suitable for long storage. Commercial storage life varies from 1 to 8 weeks, depending on variety. The Italian prune can be held for no more than 2 weeks before marketing begins.

Plums intended for storage should be harvested at a high soluble solids level for the variety, although doing so may delay harvest beyond the normal picking date. Harvested fruit should be carefully graded to remove disease, defects, and injuries before packing in the shipping container.

Fruit should be thoroughly cooled before storage. Forced-air or hydrocooling may be done in the 900 to 1000 lb bulk bins that are used for harvest. Shipping containers are normally vented to aid cooling after packing. Although most fruit is air-cooled in conventional room coolers, some shippers use forced air to cool fruit quickly in bulk bins or shipping containers.

Many varieties can usually be stored for 1 month at 30 to 32°F with 90 to 95% rh. Results of storage-life tests have been varied, with some lots in certain seasons remaining in good condition even after 4 to 5 months in storage. Other lots in some seasons have not been held satisfactorily beyond 2 months. Fruit with the highest soluble solids has consistently shown the longest storage life, even when harvested several weeks after the completion of commercial harvest. Some plum varieties benefit from CA storage.

Storage Diseases and Deterioration

Plum deterioration appears as changes in appearance and flavor. A poststorage holding period should be used in judging the condition of stored fruit. Fruit that appears bright and flavorful in storage can show severe deterioration when removed to room temperature for 2 to 3 days.

Some flesh softening and a gradual loss of varietal flavor and tartness occur even at low storage temperatures. The first visual sign of deterioration is the development of translucence, first around the pit, then extending outward through the fruit, followed by progressively more severe flesh browning following the same pattern. The first noticeable loss in flavor is generally associated with the first symptoms of translucence. It is necessary to cut through the fruit to judge condition, because fruit held under good storage conditions may appear sound from the outside while being seriously deteriorated internally. See the section on Sweet Cherries for diseases. See the section on Diseases under Peaches and Nectarines for information on cold-storage and sulfur dioxide injuries.

SWEET CHERRIES

Harvesting Techniques

Sweet cherries for storage must be harvested with stems attached.

Cooling

Rapid cooling to 30°F is essential if the fruit is to be stored. Hydrocooling has been used successfully; wetting is tolerable as long as the fruit remains cold. Fungicidal postharvest sprays or dips are helpful in reducing decay during storage.

Forced-air or pressure cooling can be used to quickly cool the fruit without the problem of wetting. Moisture loss and stem drying can be minimized by rapid movement from the field to the cooler, rapid cooling, and maintaining low temperatures and high humidity during cooling and storage.

Storage

When sweet cherries are stored, they are normally held in shipping containers, often with polyethylene liners. These liners allow increased CO_2 gas around the fruit, which tends to reduce decay rates and increase storage time. Cherries should be stored at 30°F and may be held 2 weeks after harvest and still retain enough quality for shipment to market.

Controlled atmospheres with 10 to 15% CO_2 and 3 to 10% O_2 help maintain firmness and bright, full color during storage. Polyethylene liners can extend market life. The liner must be perforated when removed from storage. Modified-atmosphere bags are now used commercially.

Diseases

Alternaria and Cladosporium Rot. Light brown, dry, firm decay lining skin breaks that can be removed easily from surrounding healthy tissue. Mycelia on the area are fine and white above and dark green below. *Control*: Remove cherries with cracks and other skin breaks at packing. Use fungicide in spray or sizer on packing line.

Blue Mold Rot (*Penicillium*). Circular, flat spots covering conical, soft, mushy decay that can be scooped out cleanly from surrounding healthy flesh. White fungus tufts turning to bluish green develop on surface. Odor and flavor are musty. *Control*: Prevent skin breaks. Use fungicide in spray or sizer on the packing line. Market promptly. Refrigerate promptly to 32°F.

Brown Rot (*Monilinia*). See the section on Diseases under Peaches and Nectarines. *Control*: Follow recommended orchard spray practices. Use fungicide in spray or sizer on packing line. Refrigerate promptly to 32°F. Package cherries in polyethylene bags to reduce desiccation of stem and fruit, preserve color, and reduce decay development.

Gray Mold Rot (*Botrytis*). Light brown, fairly firm, watery decay covered with extensive delicate, dirty-white mycelia. On completely decayed cherries, grayish-brown velvety spores may be found. *Control*: Handle carefully. Use fungicide in spray or sizer on packing line. Refrigerate promptly to 32°F.

Rhizopus Rot. Extensive soft, leaking decay with little change from normal color. Coarse mycelia and black spore heads are prominent under moist conditions. More prevalent in upper-layer packages in refrigerator car. *Control*: Rhizopus develops very slowly at temperatures below 50°F, so storage at recommended temperature keeps decay in check.

PEACHES AND NECTARINES

This discussion relates primarily to peaches but also applies to nectarines in many respects.

Storage Varieties

Peaches do not adapt well to prolonged storage. However, if they are sound and well matured, most freestone varieties can be stored for up to 2 weeks (some freestone and most clingstone for up to 4 weeks) without noticeable deterioration in flavor, texture, or appearance. Storage life appears to depend on harvest season. Early varieties, particularly freestone peaches grown in Florida and early clingstones grown in the Southeast, have an extremely short storage life and should be used as soon as possible after harvest. However, some late-season varieties can be safely stored for up to 6 weeks. In the West, the Rio Oso Gem and several other varieties can be stored for 4 to 6 weeks before being marketed.

Harvest Techniques

Peaches for fresh consumption must be in a condition to survive a postharvest holding period of several days to several weeks. The fruit must be sound and bruise-free and must be handled delicately during harvesting and packing. With widespread use of bulk bins or pallet boxes, hand-picked fruit requires extra-careful handling. Hydrodumpers are generally used for dumping pallet bins. With proper care, pallet boxes cause less bruising than small field boxes.

Cooling

Cooling peaches to 40°F soon after harvesting is essential to retention of quality and control of decay. Peaches begin to soften and decay in a few hours without proper temperature management. All peaches shipped out of the Southeast are hydrocooled, originally in flood-type hydrocoolers as a final operation after being packed in containers. In the West, most fresh peaches are hydrocooled or forced-air cooled in pressure coolers before packing to remove field heat rapidly for postharvest holding. Forced-air cooling is used after packing to complete the cooling. With forced-air or pressure cooling, peaches or nectarines in two-layer plastic tray packs with 6% side-vented corrugated containers cool 80% in about 6 h with an airflow of 0.2 cfm per pound of fruit.

Storage

Peaches are normally stored in corrugated or tray pack shipping containers.

An environment of 31°F and 90 to 95% rh with very low air movement is best for peaches. Under these conditions, peaches can be held for 2 to 6 weeks, depending on variety.

The same storage conditions may be used for nectarines; however, they are somewhat more susceptible to shrivel than peaches are. Air velocity in the storage room should be as low as possible but still maintain proper storage temperatures. Frequently check fruit at the edge of alleyways, for example, to detect the first signs of shrivel.

Good experimental CA results have been obtained with peaches and nectarines held in 1 to 2% O_2 with 3 to 5% CO_2 at 32°F. Extended storage of 6 to 9 weeks is possible. Fruit ripens or softens with good flavor and is juicy on removal. Low-temperature breakdown, which is usually encountered with lengthy storage, is controlled by CA. Although CA reduces decay, it does not completely control it; thus, a fungicide is needed for extended storage.

Diseases

Brown Rot (*Monilinia*). Extensive firm, brown, unsunken areas turning dark brown to black in the center and generally covered with yellowish gray spore masses. Skin clings tightly to center of old lesions. *Control*: Follow recommended field and postharvest control measures involving use of heat treatments and fungicides. Refrigerate promptly to as near 32°F as feasible.

Cold Storage Injury. Flavor loss, dry and mealy texture. Breakdown starting around pit is grayish brown, water-soaked, or mealy. *Control*: Refrigerate promptly to 32°F. Breakdown appears earlier at 38°F. Store for only 2 to 4 weeks, depending on variety.

Pustular Spot (*Coryneum*). Common on peaches from the West, occasionally on Eastern fruit. Small purplish-red spots grow up to 0.5 in. in diameter, becoming brown, sunken, with white center. *Control*: Treat with orchard sprays. Cool harvested fruit to below 45°F.

Rhizopus Rot. Extensive, fairly firm, watery decay with uniformly brown surface color. Skin slips readily from center of lesions. Coarse mycelia and black spherical sporangia develop. *Control*: Store cannery peaches at 32°F before ripening. Prevent skin breaks. Follow recommended field and postharvest control measures. Refrigerate promptly to as near 32°F as feasible.

Sulfur Dioxide Injury. Bleached and pitted areas on fruit surface. After removal from refrigeration, injured areas of peaches are brown, dry, and collapsed. Skin may slough off. *Control*: Avoid SO_2 contact of peaches (and other stone fruit) in storage or in transit with grapes.

Sour Rot. An unfamiliar postharvest disease in peaches noticed in some packing sheds in southeastern states. First signs of the infection may be peaches that are easily skinned by brushes and belts on the packing line. Affected peaches then develop softened and sunken brown lesions that eventually become covered with a white or creamy exudation. Infected areas generally emit a vinegar-like, sour odor. *Control*: Chlorination of dump tank water, chlorination of hydrocooling water, and careful culling of all overripe, bruised, and damaged fruit. In short, good shed sanitation and quality control are the keys to eliminating sour rot.

APRICOTS

Apricots are not stored for a prolonged time but may be held for 2 or 3 weeks if they are picked while firm enough not to bruise. Unfortunately, this maturity does not yield good dessert-quality fruit. Care must be used in sizing and packing fruit going into storage, because small surface bruises can become infected with disease-producing organisms. Chapter 11 has further details.

Apricots for short-term storage are harvested in much the same way as freestone peaches, precooled, and placed in storage promptly. Storage temperature should be 32°F with 90 to 95% rh.

Diseases and Deterioration

See the section on Peaches and Nectarines.

BERRIES

Blackberries, raspberries, and related berries cannot be stored for more than 2 or 3 days even at 31°F with a relative humidity of 90 to 95%. An atmosphere with 20 to 40% CO_2 increases storage life by 3 or 4 days by inhibiting fungal rots.

As they come from the field, cranberries are stored in field boxes at 36 to 40°F and 90 to 95% rh. They are usually not stored longer than 2 months. Storage at 30 to 32°F causes chilling and physiological breakdown. Modified atmospheres have not extended the storage life of fresh cranberries beyond that attainable in conventional storage.

Diseases

Cladosporium Rot. Surfaces of berries covered with olive to olive green mold. In raspberries, the mold is most abundant on inside or cup of berry. *Control*: Avoid bruising; pack and ship promptly. Refrigerate to 32°F.

Gray Mold Rot. Causes soft, watery rot. Fruit may be covered with dense, dusty gray fungus, which spreads rapidly in package, forming nests. *Control*: Avoid bruising. Refrigerate to 32°F in transit and use modified-atmosphere packaging (MAP).

Anthracnose (*Gloeosporium* sp.). Berries may be completely rotted and show masses of spores glistening in salmon-colored droplets on fruit. *Control*: Refrigerate to 32°F.

Alternaria Rot. Affected berries remain firm and show gray-white woolly fungal growth from injured cap-stem areas. Nesting occurs in tight clusters scattered throughout containers. *Control*: Refrigerate to 32°F.

Chilling Injury. Berries held for 4 or more weeks become tough and rubbery; surfaces are dull in appearance, red throughout. *Control*: Hold fruit at 37°F.

Fungus Rots (Several Fungi). Limited portions or entire berries are brown, soft, or collapsed. Some berries turn into water bags. *Control*: Spray in field. Handle carefully. Reduce temperature to 38°F after harvest.

STRAWBERRIES

Diseases

Gray Mold Rot (*Botrytis*). Brown, fairly firm, fairly dry decay. Dirty-gray mold and grayish-brown velvety spore masses are present. Nesting is common. *Control*: Apply recommended fungicides in field. Handle carefully to prevent skin breaks. Cull out all diseased berries. Cool promptly to 40°F or below.

Leather Rot (*Phytophthora*). Large, slightly discolored tough areas with indefinite purplish margins. Vascular system is browned; flavor is bitter. *Control*: Mulch plants to keep berries from contact with infested soil. Cool promptly to 40°F or below.

Rhizoctonia Rot. Hard dark brown decay on one side of berry, usually small quantities of soil adhering. This develops shortly after harvest. *Control*: Mulch plants to keep berries from contact with infested soil. Cull thoroughly.

Rhizopus Rot. Mushy, leaky collapse of berries associated with coarse black mycelia and sporangia. Extensive red staining of containers from leaking juice. *Control*: Reduce temperature promptly to 40°F or below. Handle carefully to prevent skin breaks.

FIGS

Diseases

Alternaria Spot. White fungal growth on surfaces that soon darkens. As fungus spots enlarge, tissue beneath becomes slightly sunken. *Control*: Cool promptly after harvest, hold at 45°F in transit.

Black Mold Rot (*Aspergillus*). First appears as a dirty white to pink color of skin and pulp. White mold growth develops within fig. Cavities formed in fruit become lined with black spore masses. *Control*: Store fresh figs at 32°F and 85 to 90% rh.

SUPPLEMENTS TO REFRIGERATION

Antiseptic Washes

Many types of fruit are washed before packing to remove dirt and improve appearance. In some cases, hydrocoolers are used to remove field heat. If water is recirculated, it may become heavily contaminated with decay-producing bacteria and fungi. Chlorine can be added at 50 to 100 ppm to control build-up of these organisms. Other fungicides may also be used, but they must be legally registered for the specific application.

Protective Packaging

Proper packaging protects against bruising, moisture loss, and spread of disease. Packaging materials may also contain chemicals to control spoilage. Packages must have good stacking strength for palletizing and perform well under high humidity.

Selective Marketing

The potential storage life of grapes and apples can be predicted within a few weeks after they are stored. Thus, those with a short storage life may be marketed while still in good condition, and longer-lived products can be stored for late-season marketing. Samples taken from each lot placed in storage are kept for a few weeks at temperatures and relative humidities that favor rapid development of decay. Grapes that will not keep long can be detected in about 2 weeks, and apples in about 60 days. Because both kinds of fruit may be stored for several months, knowing their potential storage life can significantly reduce spoilage losses.

Heat Treatment

Heat treatments to reduce decay also kill insects on and microorganisms near the surface of the fruit without leaving a residue. For example, brown rot and rhizopus rot of peaches are reduced by exposing the fruit for 1.5 min in 130°F water or for 3 min in 120°F water.

Fungicides

Fungicides may be applied during cleaning, brushing, or waxing of some fruit. Only fungicides registered for the particular fruit and application may be used.

Irradiation

Gamma radiation effectively controls decay in some products. High dosages can cause discoloration, softening, or flavor loss. Commercial application of gamma radiation is limited because of the cost and size of equipment needed for the treatment and uncertainty about the acceptability of irradiated foods to the consumer (Hardenburg et al. 1986).

Ultraviolet lamps are sometimes used to control bacteria and mold in refrigerated storage. Although ultraviolet light kills bacteria and fungi that are sufficiently exposed to the direct rays, it does not reduce decay of packaged fruit in storage. Even ultraviolet light directed on fruit as it passed over a grader did not control decay.

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