CHAPTER 11

COMMODITY STORAGE REQUIREMENTS

THIS chapter presents information on storage requirements of many perishable foods that enter the market on a commercial scale. Also included is a short discussion on the storage of furs and fabrics. The data are based on the storage of fresh, high-quality commodities that have been properly harvested, handled, and cooled.

Tables 1 and 2 present recommended storage requirements for various products. Some products require a curing period before storage. Other products require different storage conditions, depending on their intended use.

The recommended temperatures are optimum for long storage and are commodity temperatures, not air temperatures. For short storage, higher temperatures are often acceptable. Conversely, products subject to chilling injury can sometimes be held at a lower temperature for a short time without injury. Exceptions include bananas, cranberries, cucumbers, eggplant, melons, okra, pumpkins, squash, white potatoes, sweet potatoes, and tomatoes. The minimum recommended temperature for these products should be strictly followed.

The listed storage lives are based on typical commercial practice. Special treatments can, in certain instances, extend storage life significantly.

Thermal properties of many of these products, including water content, freezing point, specific heat, and latent heat of fusion, are listed in Chapter 9. Also, because fresh fruits and vegetables are living products, they generate heat that should be included as part of the storage refrigeration load. The approximate heat of respiration for various fruits and vegetables is also listed in Chapter 9.

REFRIGERATED STORAGE

Cooling

Because products deteriorate much faster at warm than at low temperatures, rapid removal of field heat by cooling to the storage temperature substantially increases the market life of the product. Chapter 15 describes various cooling methods.

Deterioration

The environment in which harvested produce is placed may greatly influence not only the respiration rate but also other changes and products formed in related chemical reactions. In fruits, these changes are described as ripening. In many fruits, such as bananas and pears, the process of ripening is required to develop the maximum edible quality. However, as ripening continues, deterioration begins and the fruit softens, loses flavor, and eventually undergoes tissue breakdown.

In addition to deterioration after harvest by biochemical changes within the product, desiccation and diseases caused by microorganisms are also important.

Deterioration rate is greatly influenced by temperature and is generally reduced as temperature is lowered. The specific relationships between temperature and deterioration rate vary considerably among commodities and diseases. A generalization, assuming a nominal deterioration rate of 1 for a fruit at 30°F, is as follows:

Approximate Deterioration Rate of Fresh Produce

Temperature, °F	Relative Deterioration Rate
68	8 to 10
50	4 to 5
41	3
37	2
32	1.25
30	1

For example, fruit that remains marketable for 12 days when stored at 30°F may last only 12/3 = 4 days when stored at 41°F. The best temperature to slow down deterioration is often the lowest temperature that can safely be maintained without freezing the commodity, which is 1 to 2°F above the freezing point of the fruit or vegetable.

Some produce will not tolerate low storage temperatures. Severe physiological disorders that develop because of exposure to low but not freezing temperatures are classed as **chilling injury**. The banana is a classic example of a fruit displaying chilling injury symptoms, and storage temperatures must be elevated accordingly. Certain apple varieties exhibit this characteristic, and prolonged storage must be at a temperature well above that usually recommended. An apple variety's degree of susceptibility to chilling may vary with climatic and growing factors. Products susceptible to chilling injury, its symptoms, and the lowest safe temperature are discussed in Chapters 9, 22, 23, and 24.

Desiccation

Water loss, which causes a product to shrivel, is a physical factor related to the evaporative potential of air, and can be expressed as follows:

$$p_D = \frac{p(100 - \phi)}{100}$$

where

p_D = vapor pressure deficit, indicating combined influence of temperature and relative humidity on evaporative potential of air
p = vapor pressure of water at given temperature
ϕ = relative humidity, percent

For example, comparing the evaporative potential of air in storage rooms at 32°F and 50°F db, with 90% rh in each room, the vapor pressure deficit at 32°F is 0.018 in. Hg, whereas at 50°F it is 0.036 in. Hg. Thus, if all other factors are equal, commodities tend to lose water twice as fast at 50°F db as at 32°F at the same relative humidity. For equal water loss at the two temperatures, the rh has to be maintained at 95% at 50°F in comparison to 90% at 32°F. These comparisons are not precise because the water in fruits and vegetables contains a sufficient quantity of dissolved sugars and other chemicals to cause the water to be in equilibrium with water vapor in the air at 98 to 99% rh instead of 100% rh. This property is described by the water activity a_w of the product. Lowering the vapor pressure deficit by lowering the air temperature is an excellent means of reducing water loss during storage.

The preparation of this chapter is assigned to TC 10.5, Refrigerated Distribution and Storage Facilities.

Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons

Common Name (Other Common Name)	Scientific Name	Storage Temp., °F	Relative Humidity, %	Highest Freezing Temp., °F	Ethylene Production Rate[a]	Ethylene Sensitivity[b]	Respiration Rate[c]	Approximate Postharvest Life	Observations and Beneficial CA[d] Conditions
Acerola (Barbados cherry)	*Malpighia glabra*	32	85 to 90	29.5				6 to 8 weeks	
African horned melon (kiwano)	*Cucumis africanus*	55 to 59	90		Low	Moderate		3 to 6 months	
Amaranth (pigweed)	*Amaranthus* spp.	32 to 36	95 to 100		Very low	Moderate		10 to 14 days	
Anise (fennel)	*Foeniculum vulgare*	32 to 36	90 to 95	30.0				2 to 3 weeks	
Apple									
Not chilling sensitive	*Malus pumila*	30	90 to 95	29.3	Very high	High	Low	3 to 6 months	2 to 3% O_2 1 to 2% CO_2
Chilling sensitive	*Malus pumila* cv. Yellow Newton, Grimes golden, McIntosh	40	90 to 95	29.3	Very high	High	Low	1 to 2 months	2 to 3% O_2 1 to 2% CO_2
Apricot	*Prunus armeniaca*	31 to 32	90 to 95	30.0	Moderate	Moderate	Low	1 to 3 weeks	2 to 3% O_2 2 to 3% CO_2
Artichokes									
Chinese	*Stachys affinia*	32	90 to 95		Very low	Very Low		1 to 2 weeks	
Globe	*Cynara acolymus*	32	95 to 100	29.8	Very low	Low	High	2 to 3 weeks	2 to 3% O_2 3 to 5% CO_2
Jerusalem	*Helianthus tuberosus*	31 to 32	90 to 95	27.5	Very low	Low	Low	4 months	
Arugula	*Eruca vesicaria* var. *sativa*	32	95 to 100		Very low	High	Moderate	7 to 10 days	
Asian pear (nashi)	*Pyrus serotina P. pyrifolia*	34	90 to 95	29.1	High	High	Low	4 to 6 months	
Asparagus, green or white	*Asparagus officinalis*	36.5	95 to 100	31.0	Very low	Moderate	Very high	2 to 3 weeks	5 to 12% CO_2
Atemoya	*Annona squamosa* x *A. cherimola*	55	85 to 90		High	High		2 to 4 weeks	3 to 5% O_2 5 to 10% CO_2
Avocado									
Fuchs, Pollock	*Persea americana* cv. Fuchs, Pollock	55	85 to 90	30.4	High	High	Moderate	2 weeks	
Fuerte, Hass	*Persea americana* cv. Fuerte, Hass	37 to 45	85 to 90	29.1	High	High	Moderate	2 to 4 weeks	2 to 5% O_2 3 to 10% CO_2
Lula, Booth	*Persea americana* cv. Lula, Booth	40	90 to 95	30.4	High	High	Moderate	4 to 8 weeks	
Babaco (mountain papaya)	*Carica candamarcensis*	45	85 to 90					1 to 3 weeks	
Banana	*Musa paradisiaca* var. *sapientum*	55 to 59	90 to 95	30.5	Moderate	High	Low	1 to 4 weeks	2 to 5% O_2 2 to 5% CO_2
Barbados cherry	see Acerola								
Beans									
Fava (broad)	*Vicia faba*	32	90 to 95					1 to 2 weeks	
Lima	*Phaseolous lunatus*	41 to 43	95	31.0	Low	Moderate	Moderate	5 to 7 days	
Long (yard-long)	*Vigna sesquipedalis*	40 to 45	90 to 95		Low	Moderate		7 to 10 days	
Snap (wax, green)	*Phaseolus vulgaris*	40 to 45	95	30.7	Low	Moderate	Moderate	7 to 10 days	2 to 3% O_2 4 to 7% CO_2
Winged	*Psophocarpus tetragonolobus*	50	90					4 weeks	
Beet									
Bunched	*Beta vulgaris*	32	98 to 100	31.3	Very low	Low	Low	10 to 14 days	
Topped	*Beta vulgaris*	32	98 to 100	30.4	Very low	Low	Low	4 months	
Berries									
Blackberry	*Rubus* spp.	31 to 32	90 to 95	30.5	Low	Low	Moderate	3 to 6 days	5 to 10% O_2 15 to 20% CO_2

Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons (*Continued*)

Common Name (Other Common Name)	Scientific Name	Storage Temp., °F	Relative Humidity, %	Highest Freezing Temp., °F	Ethylene Production Rate[a]	Ethylene Sensitivity[b]	Respiration Rate[c]	Approximate Postharvest Life	Observations and Beneficial CA[d] Conditions
Blueberry	*Vaccinium corymbosum*	31 to 32	90 to 95	29.7	Low	Low	Low	10 to 18 days	2 to 5% O_2 12 to 20% CO_2
Cranberry	*Vaccinium macrocarpon*	36 to 41	90 to 95	30.4	Low	Low	Low	8 to 16 weeks	1 to 2% O_2 0 to 5% CO_2
Dewberry	*Rubus* spp.	31 to 32	90 to 95	29.7	Low	Low		2 to 3 days	
Elderberry	*Rubus* spp.	31 to 32	90 to 95	30.4	Low	Low		5 to 14 days	
Loganberry	*Rubus* spp.	31 to 32	90 to 95	29.7	Low	Low		2 to 3 days	
Raspberry	*Rubus idaeus*	31 to 32	90 to 95	30.4	Low	Low	Moderate	3 to 6 days	5 to 10% O_2 15 to 20% CO_2
Strawberry	*Fragaria* spp.	32	90 to 95	30.5	Low	Low	Low	7 to 10 days	5 to 10% O_2 15 to 20% CO_2
Bittermelon (bitter gourd)	*Momordica*	50 to 54	85 to 90		Low	Moderate	Moderate	2 to 3 weeks	2 to 3% O_2 5% CO_2
Black salsify (scorzonera)	*Scorzonera hispanica*	32 to 34	95 to 98		Very low	Low		6 months	
Bok choy	*Brassica chinensis*	32	95 to 100		Very low	High		3 weeks	
Breadfruit	*Artocarpus altilis*	55 to 59	85 to 90					2 to 4 weeks	
Broccoli	*Brassica oleracea* var. *Italica*	32	95 to 100	31.0	Very low	High	Moderate	10 to 14 days	1 to 2% O_2 5 to 10% CO_2
Brussels sprouts	*Brassica oleracea* var. *Gemnifera*	32	95 to 100	30.5	Very low	High	Moderate	3 to 5 weeks	1 to 2% O_2 5 to 7% CO_2
Cabbage									
Chinese (Napa)	*Brassica campestris* var. *Pekinensis*	32	95 to 100	30.4	Very low	High	Low	2 to 3 months	1 to 2% O_2 0 to 6% CO_2
Common, early crop	*Brassica oleracea* var. *Capitata*	32	98 to 100	30.4	Very low	High	Low	3 to 6 weeks	
Common, late crop	*Brassica oleracea* var. *Capitata*	32	95 to 100	30.4	Very low	High	Low	5 to 6 months	3 to 5% O_2 3 to 7% CO_2
Cactus leaves (nopalitos)	*Opuntia* spp.	41 to 50	90 to 95		Very low	Moderate		2 to 3 weeks	
Cactus fruit (prickly pear fruit)	*Opuntia* spp.	41	85 to 90	28.7	Very low	Moderate		2 to 6 weeks	
Caimito	see Sapotes								
Calamondin	see Citrus								
Canistel	see Sapotes								
Carambola (starfruit)	*Averrhoa carambola*	48 to 50	85 to 90	29.8			Low	3 to 4 weeks	
Carrot									
Topped	*Daucus carota*	32	98 to 100	29.5	Very low	High	Low	3 to 6 months	No CA benefit
Bunched, immature	*Daucus carota*	32	98 to 100	29.5	Very low	High	Moderate	10 to 14 days	Ethylene causes bitterness
Cashew, apple	*Anacardium occidentale*	32 to 36	85 to 90					5 weeks	
Cassava (yucca, manioc)	*Manihot esculenta*	32 to 41	85 to 90		Very low	Low	Low	1 to 2 months	No CA benefit
Cauliflower	*Brassica oleracea* var. *Botrytis*	32	95 to 98	30.5	Very low	High	Moderate	3 to 4 weeks	2 to 5% O_2 2 to 5% CO_2
Celeriac	*Apium graveolens* var. *Rapaceum*	32	98 to 100	30.4	Very low	Low	Low	6 to 8 months	2 to 4% O_2 2 to 3% CO_2
Celery	*Apium graveolens* var. *Dulce*	32	98 to 100	31.1	Very low	Moderate	Low	1 to 2 months	1 to 4% O_2 3 to 5% CO_2
Chard	*Beta vulgaris* var. *Cida*	32	95 to 100		Very low	High		10 to 14 days	
Chayote	*Sechium edule*	45	85 to 90				Low	4 to 6 weeks	
Cherimoya (custard apple)	*Annona cherimola*	55	90 to 95	28.0	High	High	Very high	2 to 4 weeks	3 to 5% O_2 5 to 10% CO_2
Cherries									
Sour	*Prunus cerasus*	32	90 to 95	28.9			Low	3 to 7 days	3 to 10% O_2 10 to 12% CO_2
Sweet	*Prunus avium*	30 to 32	90 to 95	28.2			Low	2 to 3 weeks	10 to 20% O_2 20 to 25% CO_2
Chicory	see Endive								

Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons (*Continued*)

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Chiles	see Peppers								
Chinese broccoli (gailan)	*Brassica alboglabra*	32	95 to 100		Very low	High		10 to 14 days	
Chives	*Allium schoenoprasum*	32	95 to 100		Very low	High		2 to 3 weeks	
Cilantro (Chinese parsley)	*Coriandrum sativum*	32 to 36	95 to 100		Very low	High	High	2 weeks	
Citrus									
Calamondin orange	*Citrus reticulta* x. *Fortunella* spp.	48 to 50	90	28.4			Low	2 weeks	
Grapefruit									
CA, AZ, dry areas	*Citrus paradisi*	58 to 59	85 to 90	30.0	Very low	Moderate	Low	6 to 8 weeks	3 to 10% O_2 5 to 10% CO_2
FL, humid areas	*Citrus paradisi*	50 to 59	85 to 90	30.0	Very low	Moderate	Low	6 to 8 weeks	3 to 10% O_2 5 to 10% CO_2
Kumquat	*Fortunella japponica*	40	90 to 95				Low	2 to 4 weeks	
Lemon	*Citrus limon*	50 to 55	85 to 90	29.5			Low	1 to 6 months	5 to 10% O_2 0 to 10% CO_2 Store at 32 to 40°F for <1 mo.
Lime (Mexican, Tahitian or Persian)	*Citrus aurantifolia; C. latifolia*	48 to 50	85 to 90	29.1			Low	6 to 8 weeks	5 to 10% O_2 0 to 10% CO_2
Orange									
CA, AZ, dry areas	*Citrus sinensis*	37 to 48	85 to 90	30.5	Very low	Moderate	Low	3 to 8 weeks	5 to 10% O_2 0 to 5% CO_2
FL, humid areas	*Citrus sinensis*	32 to 36	85 to 90	30.5	Very low	Moderate	Low	8 to 12 weeks	5 to 10% O_2 0 to 5% CO_2
Blood orange	*Citrus sinensis*	40 to 45	90 to 95	30.5			Low	3 to 8 weeks	5 to 10% O_2 0 to 5% CO_2
Seville (sour)	*Citrus aurantium*	50	85 to 90	30.5	Low		Low	12 weeks	
Pomelo	*Citrus grandis*	45 to 48	85 to 90	29.1			Low	12 weeks	
Tangelo (minneola)	*Citrus reticulata* x *paradisi*	45 to 50	85 to 95	30.4			Low		
Tangerine (mandarin)	*Citrus reticulata*	40 to 45	90 to 95	30.0	Very low	Moderate	Low	2 to 4 weeks	
Coconut	*Cocos nucifera*	32 to 36	89 to 85	30.4				1 to 2 months	
Collards and kale	*Brassica oleracea* var. *Acephala*	32	95 to 100	31.1	Very low	High	High	10 to 14 days	
Corn, sweet and baby	*Zea mays*	32	95 to 98	31.0	Very low	Low	High	5 to 8 days	2 to 4% O_2 5 to 10% CO_2
Cucumber	*Cucumis sativus*	50 to 54	85 to 90	31.1	Low	High	Low	10 to 14 days	3 to 5% O_2 0 to 5% CO_2
Cucumber, pickling	*Cucumis sativus*	40	95 to 100		Low	High		7 days	3 to 5% O_2 3 to 5% CO_2
Currants	*Ribes sativum; R. nigrum; R. rubrum*	31 to 32	90 to 95	30.2	Low	Low		1 to 4 weeks	
Custard apple	see Cherimoya								
Daikon (Oriental radish)	*Raphanus sativus*	32 to 34	95 to 100		Very low	Low		4 months	
Dasheen	see Taro								
Date	*Phoenix dactylifera*	0 to 32	75	3.7	Very low	Low	Low	6 to 12 months	
Dill	see Herbs								
Durian	*Durio zibethinus*	40 to 43	85 to 90					6 to 8 weeks	3 to 5% O_2 5 to 15% CO_2
Eggplant	*Solanum melongena*	50 to 54	90 to 95	30.5	Low	Moderate	Low	1 to 2 weeks	3 to 5% O_2 0% CO_2
Endive (escarole)	*Cichorium endivia*	32	95 to 100	31.6	Very low	Moderate	High	2 to 4 weeks	

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Belgian endive (Witloof chicory)	*Cichorium intybus*	36 to 37	95 to 98		Very low	Moderate		2 to 4 weeks	Light causes greening; 3 to 4% O_2; 4 to 5% C_2
Feijoa (pineapple guava)	*Feijoa selloiana*	41 to 50	90		Moderate	Low		2 to 3 weeks	
Fennel	see Anise								
Fig, fresh	*Ficus carica*	31 to 32	85 to 90	27.7	Moderate	Low	Low	7 to 10 days	5 to 10% O_2; 15 to 20% CO_2
Garlic	*Allium sativum*	32	65 to 70	30.5	Very low	Low	Low	6 to 7 months	0.5% O_2; 5 to 10% CO_2
Ginger	*Zingiber officinale*	55	65		Very low	Low		6 months	No CA benefit
Gooseberry	*Ribes grossularia*	31 to 32	90 to 95	30.0	Low	Low	Low	3 to 4 weeks	
Granadilla	see Passionfruit								
Grape[e]									
Table grape	*Vitis vinifera*	31 to 32	90 to 95	27.1	Very low	Low	Low	1 to 6 months	2 to 5% O_2; 1 to 3% CO_2; to 4 weeks: 5 to 10% O_2; 10 to 15% CO_2
American grape	*Vitis labrusca*	30 to 31	90 to 95	29.5	Very low	Low	Low	2 to 8 weeks	
Grapefruit	see Citrus						Low		
Guava	*Psidium guajava*	41 to 50	90		Low	Moderate	Moderate	2 to 3 weeks	
Herbs, fresh culinary									5 to 10% O_2; 5 to 10% CO_2
Basil	*Ocimum basilicum*	50	90		Very low	High		7 days	
Chives	*Allium schoenorasum*	32	95 to 100	30.4	Low	Moderate			
Dill	*Anethum graveolens*	32	95 to 100	30.7	Very low	High		1 to 2 weeks	
Epazote	*Chenopodium ambrosioides*	32 to 41	90 to 95		Very low	Moderate		1 to 2 weeks	
Mint	*Mentha* spp.	32	95 to 100		Very low	High		2 to 3 weeks	
Oregano	*Origanum vulgare*	32 to 41	90 to 95		Very low	Moderate		1 to 2 weeks	
Parsley	*Petroselinum crispum*	32	95 to 100	30.0	Very low	High	Very high	1 to 2 months	
Perilla (shiso)	*Perilla frutescens*	50	95		Very low	Moderate		7 days	
Sage	*Salvia officinalis*	32	90 to 95					2 to 3 weeks	
Thyme	*Thymus vulgaris*	32	90 to 95					2 to 3 weeks	
Horseradish	*Amoracia rusticana*	30 to 32	98 to 100	28.7	Very low	Low		10 to 12 months	
Husk tomato	see Tomatillo								
Jaboticaba	*Myrciaria cauliflora = Eugenia cauliflora*	55 to 59	90 to 95					2 to 3 days	
Jackfruit	*Artocarpus heterophyllus*	55	85 to 90		Moderate	Moderate		2 to 4 weeks	
Jerusalem artichoke	see Artichoke								
Jicama (yambean)	*Pachyrrhizus erosus*	55 to 65	85 to 90		Very low	Low	Low	1 to 2 months	
Jujube (Chinese date)	*Ziziphus jujuba*	36.5 to 50	85 to 90	29.1	Low	Moderate		1 month	
Kaki	see Persimmon								
Kale	see Collards and kale								
Kiwano	see African horned melon								
Kiwifruit (Chinese gooseberry)	*Actinidia chinensis*	32	90 to 95	30.4	Low	High	Low	3 to 5 months	1 to 2% O_2; 3 to 5% CO_2
Kohlrabi	*Brassica oleracea* var. *Gongylodes*	32	98 to 100	30.2	Very low	Low	Low	2 to 3 months	
Lo Bok	see Daikon								
Langsat (lanzone)	*Aglaia* sp.; *Lansium* sp.	52 to 58	85 to 90					2 weeks	

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Leafy greens									
Cool-season	various	32	95 to 100	31.0	Very low	High		10 to 14 days	
Warm-season	various	45 to 50	95 to 100	31.0	Very low	High		5 to 7 days	
Leek	*Allium porrum*	32	95 to 100	30.7	Very low	Moderate	Moderate	2 months	1 to 2% O_2 2 to 5% CO_2
Lemon	see Citrus								
Lettuce	*Lactuca sativa*	32	98 to 100	31.7	Very low	High	Low	2 to 3 weeks	2 to 5% O_2 0% CO_2
Lime	see Citrus								
Longan	*Dimocarpus longan* = *Euphoria longan*	34 to 36	90 to 95	27.7				2 to 4 weeks	
Loquat	*Eriobotrya japonica*	32	90	28.6				3 weeks	
Luffa (Chinese okra)	*Luffa* spp.	50 to 54	90 to 95		Low	Moderate		1 to 2 weeks	
Lychee (litchi)	*Litchi chinensis*	34 to 36	90 to 95		Moderate	Moderate	Low	3 to 5 weeks	3 to 5% O_2 3 to 5% CO_2
Malanga (tania, new cocoyam)	*Xanthosoma sagittifolium*	45	70 to 80		Very low	Low		3 months	
Mamey	see Sapotes								
Mandarin	see Citrus								
Mango	*Mangifera indica*	55	85 to 90	29.5	Moderate	Moderate	Moderate	2 to 3 weeks	3 to 5% O_2 5 to 10% CO_2
Mangosteen	*Garcinia mangostana*	55	85 to 90		Moderate	High		2 to 4 weeks	
Melons									
Cantaloupes and other netted melons	*Cucurbita melo* var. *reticulatus*	36 to 41	95	29.8	High	Moderate	Low	2 to 3 weeks	3 to 5% O_2 10 to 15% CO_2
Casaba	*Cucurbita melo*	45 to 50	85 to 90	30.2	Low	Low		3 to 4 weeks	3 to 5% O_2 5 to 10% CO_2
Crenshaw	*Cucurbita melo*	45 to 50	85 to 90	30.0	Moderate	High		2 to 3 weeks	3 to 5% O_2 5 to 10% CO_2
Honeydew, orange-flesh	*Cucurbita melo*	41 to 50	85 to 90	30.0	Moderate	High	Low	3 to 4 weeks	3 to 5% O_2 5 to 10% CO_2
Persian	*Cucurbita melo*	45 to 50	85 to 90	30.5	Moderate	High		2 to 3 weeks	3 to 5% O_2 5 to 10% CO_2
Mint	see Herbs								
Mombin	see Spondias								
Mushrooms	*Agaricus*, other genera	32	90	30.4	Very low	Moderate	High	7 to 14 days	3 to 21% O_2 15 to 15% CO_2
Mustard greens	*Brassica juncea*	32	90 to 95		Very low	High		7 to 14 days	
Nashi	see Asian pear								
Nectarine	*Prunus persica*	31 to 32	90 to 95	30.4	Moderate	Moderate	Low	2 to 4 weeks	1 to 2% O_2 3 to 5% CO_2 Internal breakdown at 37 to 50°F
Okra	*Abelmoschus esculentus*	45 to 50	90 to 95	28.7	Low	Moderate	High	7 to 10 days	Air 4 to 10% CO_2
Olives, fresh	*Olea europea*	41 to 50	85 to 90	29.5	Low	Moderate	Low	4 to 6 weeks	2 to 3% O_2 0 to 1% CO_2
Onion									
Mature bulbs, dry	*Allium cepa*	32	65 to 70	30.5	Very low	Low	Low	1 to 8 months	1 to 3% O_2 5 to 10% CO_2
Green	*Allium cepa*	32	95 to 100	30.4	Low	High	Moderate	3 weeks	2 to 4% O_2 10 to 20% CO_2
Orange	see Citrus								
Papaya	*Carica papaya*	45 to 55	85 to 90	30.4			Low	1 to 3 weeks	2 to 5% O_2 5 to 8% CO_2
Parsley	see Herbs								

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Common Name (Other Common Name)	Scientific Name	Storage Temp., °F	Relative Humidity, %	Highest Freezing Temp., °F	Ethylene Production Rate[a]	Ethylene Sensitivity[b]	Respiration Rate[c]	Approximate Postharvest Life	Observations and Beneficial CA[d] Conditions
Parsnips	*Pastinaca sativa*	32	95 to 100	30.4	Very low	High	Low	4 to 6 months	Ethylene causes bitterness
Passionfruit	*Passiflora* spp.	50	85 to 90		Very high	Moderate	Very high	3 to 4 weeks	
Peach	*Prunus persica*	31 to 32	90 to 95	30.4	High	Moderate	Low	2 to 4 weeks	1 to 2% O_2 3 to 5% CO_2 Internal breakdown at 37 to 50°F
Pear, American[e]	*Pyrus communis*	29 to 31	90 to 95	28.9	High	High	Low	2 to 7 months	Cultivar variations 1 to 3% O_2 0 to 5% CO_2
Peas									
In pods (snow, snap, and sugar peas)	*Pisum sativum*	32 to 34	90 to 98	31.0	Very low	Moderate	Very high	1 to 2 weeks	2 to 3% O_2 2 to 3% CO_2
Southern peas (cowpeas)	*Vigna sinensis* = *V. unguiculata*	40 to 41	95					6 to 8 days	
Pepino (melon pear)	*Solanum muricatum*	41 to 50	95		Low	Moderate		4 weeks	
Peppers									
Bell pepper or paprika	*Capsicum annuum*	45 to 50	95 to 98	30.7	Low	Low	Low	2 to 3 weeks	2 to 5% O_2 2 to 5% CO_2
Hot peppers (chiles)	*Capsicum annuum* and *C. frutescens*	41 to 50	85 to 95	30.7	Low	Moderate		2 to 3 weeks	3 to 5% O_2 5 to 10% CO_2
Persimmon (kaki)	*Dispyros kaki*								3 to 5% O_2 5 to 8% CO_2
Fuyu	*Dispyros kaki* var. *Fuyu*	32	90 to 95	28.0	Low	High	Low	1 to 3 months	
Hachiya	*Dispyros kaki* var. *Hachiya*	32	90 to 95	28.0	Low	High	Low	2 to 3 months	
Pineapple	*Ananas comosus*	45 to 55	85 to 90	30.0	Low	Low	Low	2 to 4 weeks	2 to 5% O_2 5 to 10% CO_2
Plantain	*Musa paradisiaca* var. *paradisiaca*	55 to 59	90 to 95	30.5	Low	High		1 to 5 weeks	
Plums and prunes	*Prunus domestica*	31 to 32	90 to 95	30.5	Moderate	Moderate	Low	2 to 5 weeks	1 to 2% O_2 0 to 5% CO_2
Pomegranate	*Punica granatum*	41	90 to 95	26.6			Low	2 to 3 months	3 to 5% O_2 5 to 10% CO_2
Potato									
Early crop	*Solanum tuberosum*	50 to 59	90 to 95	30.5	Very low	Moderate	Low	10 to 14 days	No CA benefit
Late crop	*Solanum tuberosum*	40 to 54	95 to 98	30.5	Very low	Moderate	Low	5 to 10 months	No CA benefit
Pumpkin	*Cucurbita maxima*	54 to 59	50 to 70	30.5	Very low	Moderate	Low	2 to 3 months	
Quince	*Cydonia oblonga*	31 to 32	90	28.4	Low	High		2 to 3 months	
Raddichio	*Cichorium intybus*	32 to 34	95 to 100					4 to 8 weeks	
Radish	*Raphanus sativus*	32	95 to 100	30.7	Very low	Low	Low	1 to 2 months	1 to 2% O_2 2 to 3% CO_2
Rambutan	*Nephelium lappaceum*	54	90 to 95		High	High		1 to 3 weeks	3 to 5% O_2 7 to 12% CO_2
Rhubarb	*Rheum rhaponticum*	32	95 to 100	30.4	Very low	Low	Low	2 to 4 weeks	
Rutabaga	*Brassica napus* var. *Napobrassica*	32	98 to 100	30.0	Very low	Low	Low	4 to 6 months	
Sage	see Herbs								
Salsify (vegetable oyster)	*Trapopogon porrifolius*	32	95 to 98	30.0	Very low	Low	Low	2 to 4 months	
Sapotes									
Black sapote	*Diospyros ebenaster*	55 to 59	85 to 90	27.8				2 to 3 weeks	
Caimito (star apple)	*Chrysophyllum cainito*	37	90	29.8				3 weeks	
Canistel (eggfruit)	*Pouteria campechiana*	55 to 59	85 to 90	28.7				3 weeks	

Table 1 Storage Requirements of Vegetables, Fresh Fruits, and Melons (*Continued*)

Common Name (Other Common Name)	Scientific Name	Storage Temp., °F	Relative Humid-ity, %	Highest Freezing Temp., °F	Ethylene Production Rate[a]	Ethylene Sensitivity[b]	Respi-ration Rate[c]	Approximate Postharvest Life	Observations and Beneficial CA[d] Conditions
Mamey sapote	*Calocarpum mammosum*	55 to 59	90 to 95		High	High		2 to 3 weeks	
Sapodilla (chicosapote)	*Achras sapota*	59 to 68	85 to 90		High	High		2 weeks	
White sapote	*Casimiroa edulis*	68	85 to 90	28.4				2 to 3 weeks	
Scorzonera	see Black salsify								
Shallot	*Allium cepa* var. *ascalonicum*	32 to 36	65 to70	30.7	Low	Low			
Soursop	*Annona muricata*	55	85 to 90					1 to 2 weeks	
Spinach	*Spinacia oleracea*	32	95 to 100	31.5	Very low	High	Low	10 to 14 days	5 to 10% O_2 5 to 10% CO_2
Spondias (mombin, wi apple, jobo, hogplum)	*Spondias* spp.	55	85 to 90					1 to 2 weeks	
Sprouts from seeds		32	95 to 100					5 to 9 days	
Alfalfa sprouts	*Medicago sativa*	32	95 to 100					7 days	
Bean sprouts	*Phaseolus* sp.	32	95 to 100					7 to 9 days	
Radish sprouts	*Raphanus* sp.	32	95 to 100					5 to 7 days	
Squash									
Summer, soft rind (courgette)	*Cucurbita pepo*	45 to 50	95	31.1	Low	Moderate	Low	1 to 2 weeks	3 to 5% O_2 5 to 10% CO_2
Winter, hard rind (calabash)	*Cucurbita moschata; C. maxima*	54 to 59	50 to 70	30.5	Low	Moderate	Low	2 to 3 months	Large differences among varieties
Star apple	see Sapotes								
Starfruit	see Carambola								
Sweet potato or yam	*Ipomea batatas*	55 to 59	85 to 95	29.7	Very low	Low	Low	4 to 7 months	
Sweetsop (sugar apple, custard apple)	*Annona squamosa; Annona* spp.	45	85 to 90		High	High		4 weeks	3 to 5% O_2 5 to 10% CO_2
Tamarillo (tree tomato)	*Cyphomandra betacea*	37 to 40	85 to 95		Low	Moderate		10 weeks	
Tamarind	*Tamarindus indica*	36 to 45	90 to 95	25.4	Very low	Very Low		3 to 4 weeks	
Taro (cocoyam, eddoe, dasheen)	*Colocasia esculenta*	45 to 50	85 to 90	30.4			Low	4 months	No CA benefit
Thyme	see Herbs								
Tomatillo (husk tomato)	*Physalis ixocarpa*	45 to 55	85 to 90		Very low	Moderate	Low	3 weeks	
Tomato									
Mature, green	*Lycopersicon esculentum*	50 to 55	90 to 95	31.1	Very low	High	Low	2 to 5 weeks	3 to 5% O_2 2 to 3% CO_2
Firm, ripe	*Lycopersicon esculentum*	46 to 50	85 to 90	31.1	High	Low	Low	1 to 3 weeks	3 to 5% O_2 3 to 5% CO_2
Turnip root	*Brassica campetris* var. *Rapifera*	32	95	30.2	Very low	Low	Low	4 to 5 months	
Water chestnut	*Eleocharis dulcis*	32 to 36	85 to 90					2 to 4 months	
Watercress (garden cress)	*Lepidium sativum; Nasturtium officinales*	32	95 to 100	31.5	Very low	High	High	2 to 3 weeks	
Watermelon	*Citrullus vulgaris*	50 to 59	90	31.3	Very low	High	Low	2 to 3 weeks	No CA benefit
Yam	*Dioscorea* spp.	59	70 to 80	30.0	Very low	Low		2 to 7 months	
Yucca	see Cassava								

Note: Recommendations in this table are general guidelines. Recommended storage conditions and expected postharvest life for a specific produce item may be different from those listed here because of variations in growing conditions and postharvest care. Also, new cultivars (varieties) of a particular item may require different conditions and have a very different expected postharvest life from that listed in the table. Empty cells indicate that no data are available. For updates on guidelines, refer to the University of California Web site at http://postharvest.ucdavis.edu.

[a]Very low = <0.1 μL/(kg·h) at 68°F
Low = 0.1 to 1.0 μL/(kg·h)
Moderate = 1.0 to 10.0 μL/(kg·h)
High = 10 to 100 μL/(kg·h)
Very high = >100 μL/(kg·h)

[b]Detrimental effects include yellowing, softening, increased decay, abscission, and browning.

[c]At recommended storage temperature.
Low = <20 mg CO_2/(kg·h)
Moderate = <40 mg CO_2/(kg·h)
High = <60 mg CO_2/(kg·h)
Very high = >60 mg CO_2/(kg·h)

[d]CA = controlled atmosphere.

[e]For a more complete listing of grapes and pears, see International Institute of Refrigeration (IIR 2000).

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Table 2 Storage Requirements of Other Perishable Products

Product	Storage Temp., °F	Relative Humidity, %	Approximate Storage Life[a]
Fish			
Haddock, cod, perch	31 to 34	95 to 100	12 days
Hake, whiting	32 to 34	95 to 100	10 days
Halibut	31 to 34	95 to 100	18 days
Herring, kippered	32 to 36	80 to 90	10 days
smoked	32 to 36	80 to 90	10 days
Mackerel	32 to 34	95 to 100	6 to 8 days
Menhaden	34 to 41	95 to 100	4 to 5 days
Salmon	31 to 34	95 to 100	18 days
Tuna	32 to 36	95 to 100	14 days
Frozen fish	–20 to –4	90 to 95	6 to 12 months
Shellfish[a]			
Scallop meat	32 to 34	95 to 100	12 days
Shrimp	31 to 34	95 to 100	12 to 14 days
Lobster, American	41 to 50	In sea water	Indefinitely
Oysters, clams			
(meat and liquid)	32 to 36	100	5 to 8 days
in shell	41 to 50	95 to 100	5 days
Frozen shellfish	–30 to –4	90 to 95	3 to 8 months
Beef			
Beef, fresh, average	28 to 34	88 to 95	1 week
Beef carcass			
choice, 60% lean	32 to 39	85 to 90	1 to 3 weeks
prime, 54% lean	32 to 34	85	1 to 3 weeks
sirloin cut (choice)	32 to 34	85	1 to 3 weeks
round cut (choice)	32 to 34	85	1 to 3 weeks
dried, chipped	50 to 59	15	6 to 8 weeks
Liver	32	90	5 days
Veal, lean	28 to 34	85 to 95	3 weeks
Beef, frozen	–10 to 0	90 to 95	6 to 12 months
Pork			
Pork, fresh, average	32 to 34	85 to 90	3 to 7 days
carcass, 47% lean	32 to 34	85 to 90	3 to 5 days
bellies, 35% lean	32 to 34	85	3 to 5 days
fatback, 100% fat	32 to 34	85	3 to 7 days
shoulder, 67% lean	32 to 34	85	3 to 5 days
frozen	–10 to 0	90 to 95	4 to 8 months
Ham, 74% lean	32 to 34	80 to 85	3 to 5 days
light cure	37 to 41	80 to 85	1 to 2 weeks
country cure	50 to 59	65 to 70	3 to 5 months
frozen	–10 to 0	90 to 95	6 to 8 months
Bacon, medium fat class	37 to 41	80 to 85	2 to 3 weeks
cured, farm style	61 to 64	85	4 to 6 months
cured, packer style	34 to 39	85	2 to 6 weeks
frozen	–10 to 0	90 to 95	2 to 4 months
Sausage, links or bulk	32 to 34	85	1 to 7 days
country, smoked	32	85	1 to 3 weeks
Frankfurters, average	32	85	1 to 3 weeks
Polish style	32	85	1 to 3 weeks
Lamb			
Fresh, average	28 to 34	85 to 90	3 to 4 weeks
Choice, lean	32	85	5 to 12 days
Leg, choice, 83% lean	32	85	5 to 12 days
Frozen	–10 to 0	90 to 95	8 to 12 months
Poultry			
Poultry, fresh, average	28 to 32	95 to 100	1 to 3 weeks
Chicken, all classes	28 to 32	95 to 100	1 to 4 weeks
Turkey, all classes	28 to 32	95 to 100	1 to 4 weeks
breast roll	–4 to –1		6 to 12 months
frankfurters	0 to 15		6 to 16 months
Duck	28 to 32	95 to 100	1 to 4 weeks
Poultry, frozen	–10 to 0	90 to 95	12 months

Product	Storage Temp., °F	Relative Humidity, %	Approximate Storage Life[a]
Meat (Miscellaneous)			
Rabbits, fresh	32 to 34	90 to 95	1 to 5 days
Dairy Products			
Butter	32	75 to 85	2 to 4 weeks
Butter, frozen	–10	70 to 85	12 to 20 months
Cheese, cheddar			
long storage	32 to 34	65	12 months
short storage	40	65	6 months
processed	40	65	12 months
grated	40	65	12 months
Ice cream, 10% fat	–20 to –15	90 to 95	3 to 23 months
premium	–30 to –40	90 to 95	3 to 23 months
Milk			
fluid, pasteurized	39 to 43		7 days
grade A (3.7% fat)	32 to 34		2 to 4 months
raw	32 to 39		2 days
dried, whole	70	Low	6 to 9 months
nonfat	45 to 70	Low	16 months
evaporated	40		24 months
evaporated, unsweetened	70		12 months
condensed, sweetened	40		15 months
Whey, dried	70	Low	12 months
Eggs			
Shell	29 to 32[b]	80 to 90	5 to 6 months
farm cooler	50 to 55	70 to 75	2 to 3 weeks
Frozen			
Whole	0		1 year plus
yolk	0		1 year plus
white	0		1 year plus
whole egg solids	35 to 40	Low	6 to 12 months
Yolk solids	35 to 40	Low	6 to 12 months
Flake albumen solids	Room	Low	1 year plus
Dry spray albumen solids	Room	Low	1 year plus
Candy			
Milk chocolate	0 to 34	40	6 to 12 months
Peanut brittle	0 to 34	40	1.5 to 6 months
Fudge	0 to 34	65	5 to 12 months
Marshmallows	0 to 34	65	3 to 9 months
Miscellaneous			
Alfalfa meal	0	70 to 75	1 year plus
Beer, keg	35 to 40		3 to 8 weeks
bottles and cans	35 to 40	65 or below	3 to 6 months
Bread	0		3 to 13 weeks
Canned goods	32 to 60	70 or lower	1 year
Cocoa	32 to 40	50 to 70	1 year plus
Coffee, green	35 to 37	80 to 85	2 to 4 months
Fur and fabrics	34 to 40	45 to 55	Several years
Honey	50		1 year plus
Hops	28 to 32	50 to 60	Several months
Lard (without	45	90 to 95	4 to 8 months
antioxidant)	0	90 to 95	12 to 14 months
Nuts	32 to 50	65 to 75	8 to 12 months
Oil, vegetable, salad	70		1 year plus
Oleomargarine	35	60 to 70	1 year plus
Orange juice	30 to 35		3 to 6 weeks
Popcorn, unpopped	32 to 40	85	4 to 6 weeks
Yeast, baker's compressed	31 to 32		
Tobacco, hogshead	50 to 65	50 to 65	1 year
bales	35 to 40	70 to 85	1 to 2 years
cigarettes	35 to 46	50 to 55	6 months
cigars	35 to 50	60 to 65	2 months

Note: The text in this chapter or the appropriate commodity chapter gives additional information on many of the commodities listed. For a complete listing of frozen food practical storage life, see IIR (1986).

[a]Storage life is not based on maintaining nutritional value.
[b]Eggs with weak albumen freeze just below 30°F.

Other important factors in desiccation include product size, surface-to-volume ratio, the kind of protective surface on the product, and air movement. Of these, the storage operator can control only the last, and this control is greatly influenced by the container, kind of pack, and stacking arrangement (i.e., the ability of the air to move past individual fruits and vegetables).

As a rule, shrivelling does not become a serious market problem until fruits lose about 5% of their weight, but any loss reduces the salable amount. Moisture losses of 3 to 6% are enough to cause a marked loss of quality for many kinds of produce. A few kinds may lose 10% moisture and still be marketable, although some trimming may be necessary, as for stored cabbage.

The vapor pressure deficit cannot be kept at a zero level, but it should be maintained as low as possible. A maximum of about 0.018 in. Hg, which corresponds to 90% rh at 32°F, is recommended. Some compromise is possible for short storage periods. In many instances, the refrigerated storage operator may find it desirable to add moisture, or, in special cases, the owner of the produce may find it desirable to use moisture barriers such as film liners.

REFRIGERATED STORAGE PLANT OPERATION

Checking Temperatures and Humidity

To maintain top product quality, temperature in the cold storage room must be accurately maintained. Variations of 2 to 3°F in the product temperature above or below the desired temperature are too large in most cases. Storage rooms should be equipped either with accurate thermostats or with manual controls that receive frequent attention.

In refrigerated storage rooms, thermometers are usually placed at a height of about 5 ft for convenient reading. Temperatures should be monitored where they might be undesirably high or low; one or two aisle temperatures is not enough. A record of both product and air temperatures is necessary to determine performance of the storage plant. A thermometer or recording device of good quality that is periodically calibrated is essential.

Temperature in less accessible storage locations, such as the middle of stacks, can be obtained conveniently with distant-reading equipment such as thermocouples or electrical-resistance thermometers.

Storage instructions or recommendations usually specify a relative humidity within 3 to 5% of the desired levels. An ordinary sling psychrometer at temperatures of 32°F or lower cannot be read that closely. An error of 0.5°F in reading either the wet- or the dry-bulb thermometer will cause an error of 5% rh. Carefully calibrated thermometers graduated to 0.1°F with a range of 25 to 40°F are best adapted for this purpose in fruit storage. A convenient device for measuring humidity consists of a pair of these thermometers, mounted in a short length of metal casing attached to a spring or motor-operated fan that draws air past the thermometers at a speed of 3 ft/s or faster. Thermometers should be placed so that they will not be heated by the fan motor, and they should be read quickly to prevent warming (these are often referred to as aspirated psychrometers). The advantage of this instrument over the sling psychrometer is that it can be left in the room long enough to get a true wet-bulb reading. This may require 15 min or more if ice is formed on the wet bulb. Under these conditions, a thin coating of ice is preferable to a thick one in getting accurate readings. Hair hygrometers are satisfactory if not subjected to sudden large changes in humidity and temperature and if checked regularly with a psychrometer. There are now a number of electronic relative humidity probes based on capacitance and resistance of water-absorbing membranes; they can be accurate to within 3% for a wide range of temperatures and relative humidity if they are regularly calibrated. Many are sensitive to condensation, so this should be avoided (e.g., taking a probe from a cold area into the ambient air).

Perhaps a more accurate method of determining relative humidity is to electrically record the dew-point temperature of the air and to use a resistance thermometer of suitable sensitivity to record the ambient or dry-bulb temperature. From these temperature records, relative humidity can be calculated.

Air Circulation

Air must be circulated to keep refrigerated storage rooms at a uniform temperature throughout. Commodity temperatures in a storage room may vary because air temperature rises as air passes through the room and absorbs heat from the commodity; also, heat leakage may vary in different parts of the storage. In a duct system, air near the return ducts is warmer than the air near delivery ducts. In many storages, refrigeration units are installed over the center aisle. Air circulates from the center of rooms outward to the walls, down through the rows of produce, and back up through the center of the room.

Rapid air circulation is needed most during removal of field heat. Sometimes this is best done in separate cooling rooms that have more refrigerating and air-moving capacity than regular refrigerated storage rooms (see Chapter 15). After field heat is removed, a high air velocity is usually undesirable. Air movement is needed only to remove respiratory heat, if any, and heat entering the room through exterior surfaces and doorways. Excessive air movement can increase moisture loss from a product, with a resulting loss of both weight and quality. However, some air, circulated by fans or blowers, must be uniformly distributed through all parts of the room. Also, if air circulation or refrigeration is turned off, some precaution is needed to ensure that the stored product does not become too warm, particularly for respiring products.

The type of container and the manner of stacking are important factors that influence cooling performance. An elaborate system for air distribution is useless if poor stacking prevents airflow. If spacing is irregular, wider spaces will get a greater volume of air than narrower ones. If some spaces are partially blocked, dead air zones will occur, with resultant higher temperatures.

Sanitation and Air Purification

The refrigerated storage and product containers must be clean. Fruits and vegetables coming into the storage are generally contaminated with mold spores, which can enter through punctures or breaks in the skin of the product. Contaminated commodities can foster rapid development of the spores, which are carried by air currents throughout the storage. Removing decaying raw material from storage and sanitizing the product container reduces the problem. If mold contamination is excessive, the storage develops a musty or moldy odor that is quickly picked up by the fruits and vegetables, a fault of many apple varieties and other products held for several months in refrigerated storage. This problem can best be controlled by means of special cleaners, sanitizers, and deodorizers (see Chapters 10, 22, 23, and 24 for details on product diseases).

During several months of storage, even at 31°F, molds may grow on the surface of packages and on the walls and ceilings of rooms under high relative humidity. These surface molds generally will not rot fruits and vegetables. However, because surface molds are unsightly, storage warehouses should have a thorough cleaning at least once a year. Good air circulation alone is of considerable value in minimizing growth of surface molds. If floors and walls become moldy, they can be scrubbed with a cleaner containing sodium hypochlorite or trisodium phosphate, then rinsed and aired. Field boxes and equipment can be cleaned with 0.25% calcium hypochlorite solutions or by exposing to steam for 2 min.

All inspected plants and warehouses operate under regulations with sanitation requirements clearly set forth in inspection service orders. Plants should be constructed to prevent the entrance of insects and rodents. This involves ratproof building construction and adequate screening. For doors frequently opened, special measures must be taken to prevent the entrance of insects.

The frequency of cleanup and the detergents and sanitizing agents used should be specified by the quality control leader. A representative from quality control should inspect all areas after cleanup and determine whether a suitable job has been done. Waste and miscellaneous trash accumulation areas must receive special attention around warehouses, because they become breeding places for rodents and insects. In any food warehouse, the successful quality control and sanitation program depends on the cooperation and vigilance of management.

Air may be purified in storage rooms where odors or volatiles may contribute to off-flavors and hasten deterioration. Air may be cleaned with trays or canisters containing 6 to 14 mesh activated carbon. Pinewood volatiles are removed by activated carbon air-purifying units. Some produce volatiles are also removed, but ethylene, a ripening gas, is not removed by activated carbon alone.

Air washing with water to remove volatiles does not retard fruit ripening, but it may increase the relative humidity and thus help maintain good fruit appearance by reducing weight loss.

Removal of Produce from Storage

When produce is removed from storage, undue warming and condensation of moisture, which promote decay and deterioration, must be prevented. Because many storages are built on railroad sidings, canvas tunnels should be installed between the car and the storage through which the produce will be conveyed to minimize warming and condensation of moisture.

When produce is removed from storage for distribution to wholesale and retail markets, the storage operator can do little to prevent undesirable condensation. Warming the packages until they are above the dew point of the air would prevent it, but this takes time and space and is seldom practical. Deterioration in flavor and condition proceeds rapidly after long storage periods. Therefore, the produce should be moved to consumers as rapidly as possible.

STORAGE OF FROZEN FOODS

Frozen foods deteriorate during the period between production and consumption. The extent of deterioration depends mainly on storage temperature and time, although other factors, such as protection provided by the package, are important. Bacteria in frozen foods may be killed during freezing and frozen storage, but all the bacteria present are never completely destroyed. When defrosting, frozen foods are still subject to bacterial decomposition.

OTHER PRODUCTS

Beer

Because beer in bottles or cans is either pasteurized or filtered to destroy or remove the living yeast cells, it does not require as low a storage temperature as keg beer. Bottled beer may be stored at an ordinary room temperature of 70 to 75°F, but for convenience, it is often stored with keg beer at a lower temperature of 35 to 40°F. The bottled product should be protected from strong light, especially direct sunlight. Storage life varies from 3 to 6 months, depending largely on the method of processing and packaging. Keg beer, stored at 35 to 40°F, usually has a storage life of 3 to 6 weeks.

Canned Foods

Canned foods that are heat-processed in hermetically sealed containers do not benefit from refrigerated storage if they are to be stored for no longer than 2 or 3 months at temperatures that rarely exceed 75°F. However, seasonal commodities produced to provide an inventory for an entire year or longer do benefit from reduced-temperature/humidity storage, which delays the onset of considerable color, texture, and flavor changes, loss of nutrients, and container corrosion. Notable examples are canned asparagus, cherries, and catsup. Reduced temperature and humidity storage for canned goods is essential in environments where ambient temperatures and humidities regularly exceed 90°F and 70% rh.

Dried Foods

Dried foods and feeds, particularly those expected to supply a high level of protein, such as dehydrated milk or alfalfa meal, should be protected against high temperature and humidity. Good packaging, such as canning in vacuum, can maintain dried food nutritive value and quality for a year or longer if ambient temperatures do not exceed 90°F regularly. When stored in bulk or in bags that are not good water vapor barriers, storage at 40% rh and 70°F should be limited to less than one year, and at 90°F to less than 6 months. At 60% rh and 70°F, storage should be limited to 6 months, and at 90°F to not more than 3 to 4 months. The only process by which dried foods can maintain quality and nutritive values for a year and longer at elevated temperatures is by packaging in zero oxygen. Similar or better results can be obtained with 0°F storage regardless of adequacy of the package or relative humidity.

Furs and Fabrics

Refrigerated storage effectively protects furs, floor coverings, garments, and other materials containing wool against insect damage. Commonly used refrigerated storage temperatures do not kill the insects, but inactivate them, preventing insect damage while the susceptible items are in storage (Table 3). However, if insects are present, the article is susceptible to damage as soon as it is removed from refrigerated storage.

Articles should be free of any possible infestation before placement in refrigerated storage. Those items that can be cleaned should be so treated. Others can be either fumigated or mothproofed. Food should not be stored with fur garments.

Furs and garments should be stored at 34 to 40°F. A temperature of 40°F is most widely used commercially. The low temperature not only inactivates fabric insects but also preserves the integrity and luster of furs and the tensile strength of fabrics.

Continuous storage below 34 to 40°F is a wasteful expense as far as protection from insect damage is concerned. Some storage firms maintain constant temperatures in their fur vaults between 14 and 32°F and claim excellent results. However, no research indicates that temperatures in this range are required for storing dressed furs or fabrics. Cured raw furs (but not processed) should be stored at –10 to 10°F with 45 to 60% rh and will keep up to 2 years.

Honey

Both extracted (liquid) and comb honey can be held satisfactorily in common dry storage for about a year. The slow darkening and flavor deterioration at ordinary room temperatures becomes objectionable after this time. Although cold storage is not necessary, temperatures below 50°F maintain original quality for several years and retard or prevent fermentation. The range between 50 and 65°F

Table 3 Temperature and Time Requirements for Killing Moths in Stored Clothing

Storage Temperature, °F	All Eggs Dead After, Days	All Larvae Dead After, Days	All Adults Dead After, Days
–0.4 to 5	1	2	1
5 to 10	2	21[a]	1
10 to 15	4	—	1
15 to 19	—	—	1
20 to 25	21	67	4
25 to 30	21	125[b]	7
30 to 35	—	283[c]	—

Table adapted from USDA *Publication* AMS-57 (1955).
[a]50 to 95% of larvae may be killed in 2 days.
[b]A few larvae survived this period.
[c]Larvae survived this period.

should be avoided, because it promotes granulation, which increases the probability of fermentation of raw (unheated) honey.

As storage temperature increases in the 80 to 100°F range, deterioration is accelerated; temperatures constantly above 85°F are unsuitable, and above 90°F, quite damaging.

Honey for export is best kept in cold storage, because the half-life for honey diastase at 77°F is about 17 months.

Raw honey of greater than 20% moisture is always in danger of fermentation; the likelihood is much less at or below 18.6% moisture. Below 17% moisture, raw honey will not ordinarily ferment. Granulation increases the possibility of fermentation of raw honey by increasing the moisture content of the liquid portion. Properly pasteurized honey will not ferment at any moisture content. Granulated honey can be reliquefied by warming to 120 to 140°F.

Comb honey should not be stored above 60% rh to avoid moisture absorption through the wax, which leads to fermentation.

Finely granulated honey (honey spread, Dyce process honey, and honey cream) must not be stored above about 75°F. Higher temperatures eventually cause partial liquefaction and destroy the texture. Any subsequent regranulation by lower temperatures produces an undesirable coarse texture. For holding more than 4 months, cold storage is required.

Maple Syrup

Maple syrup keeps indefinitely at room temperatures without darkening or losing flavor, if packed hot (at or within a few degrees of its boiling point) and in clean containers, which are promptly closed airtight and laid on their sides or inverted to self-sterilize the closure, and then cooled. Refrigerated storage is not necessary. However, once opened, syrup in a bottle, can, or drum may become contaminated by organisms in the air. Mold or yeast spores, which may be present in improperly pasteurized syrup, though unable to germinate in full-density syrup, may grow in the thin syrup on the surface caused by condensed water. Small packages not completely sterile, containing spores, can be kept free of vegetative growth by periodically inverting the containers to redisperse any thin syrup on the surface caused by condensed water. Maple syrup should never be packaged at temperatures below 180°F. After pasteurizing, cool the syrup as quickly as possible to prevent stack burn, which darkens the syrup and causes a lowering of its grade.

Nursery Stock and Cut Flowers

Low temperature (31 to 33°F) and dry packaging prevent, or at least greatly retard, flower disintegration and extend storage life. The temperature and storage life given in Table 4 for cut flowers allow for a reasonable shelf life after removal from storage; however, the storage period may be extended beyond that listed. These conditions, though not widely used commercially, are recommended. Proper dry packing requires a moisture/vaporproof container in which flowers can be sealed. No free water is added because the package prevents almost all water loss.

Flowers held in water should not be crowded in the containers and should be arranged on shelves or racks to allow good air circulation. Forced air circulation should be provided, but flowers must be kept out of a direct draft. Use clean water and clean containers.

Many kinds of nursery stock can also be stored at temperatures of 31 to 35°F. Open packages and harden flowers before marketing if the blooms have been stored for long periods. Flowers conditioned at about 50°F following storage regain full turgidity most rapidly. Cut or crush stem ends and then place in water or a food solution at 80 to 100°F for 6 to 8 h.

Many kinds of cut flowers and greens are injured if stored in the same room with certain fruits, principally apples and pears, which give off gases (such as ethylene) during ripening. These gases cause premature aging of blooms and may defoliate greens. Greens should not be stored in the same room with cut flowers because the greens, acting in the same way as fruit, can hasten bloom deterioration.

Table 4 Storage Conditions for Cut Flowers and Nursery Stock

Commodity	Storage Temp., °F	Relative Humidity, %	Approx. Storage Life	Method of Holding	Highest Freezing Point, °F
Cut Flowers					
Calla Lily	40	90 to 95	1 week	Dry pack	
Camellia	45	90 to 95	3 to 6 days	Dry pack	30.6
Carnation	31 to 32	90 to 95	3 to 4 weeks	Dry pack	30.8
Chrysanthemum	31 to 32	90 to 95	3 to 4 weeks	Dry pack	30.5
Daffodil (Narcissus)	32 to 33	90 to 95	1 to 3 weeks	Dry pack	31.8
Dahlia	40	90 to 95	3 to 5 days	Dry pack	
Gardenia	32 to 34	90 to 95	2 weeks	Dry pack	31.0
Gladiolus	36 to 42	90 to 95	1 week	Dry pack	31.4
Iris, tight buds	31 to 32	90 to 95	2 weeks	Dry pack	30.6
Lily, Easter	32 to 35	90 to 95	2 to 3 weeks	Dry pack	31.1
Lily-of-the-valley	31 to 32	90 to 95	2 to 3 weeks	Dry pack	
Orchid	45 to 55	90 to 95	2 weeks	Water	31.4
Peony, tight buds	32 to 35	90 to 95	4 to 6 weeks	Dry pack	30.1
Rose, tight buds	32	90 to 95	2 weeks	Dry pack	31.2
Snapdragon	40 to 42	90 to 95	1 to 2 weeks	Dry pack	30.4
Sweet Peas	31 to 32	90 to 95	2 weeks	Dry pack	30.4
Tulips	31 to 32	90 to 95	2 to 3 weeks	Dry pack	
Greens					
Asparagus (plumosus)	35 to 40	90 to 95	2 to 3 weeks	Polylined cases	26.0
Fern, dagger and wood	30 to 32	90 to 95	2 to 3 months	Dry pack	28.9
Fern, leatherleaf	34 to 40	90 to 95	1 to 2 months	Dry pack	
Holly	32	90 to 95	4 to 5 weeks	Dry pack	27.0
Huckleberry	32	90 to 95	1 to 4 weeks	Dry pack	26.7
Laurel	32	90 to 95	2 to 4 weeks	Dry pack	27.6
Magnolia	35 to 40	90 to 95	2 to 4 weeks	Dry pack	27.0
Rhododendron	32	90 to 95	2 to 4 weeks	Dry pack	27.6
Salal	32	90 to 95	2 to 3 weeks	Dry pack	26.8
Bulbs					
Amaryllis	38 to 45	70 to 75	5 months	Dry	30.8
Caladium	70	70 to 75	2 to 4 months		29.7
Crocus	48 to 63		2 to 3 months		29.7
Dahlia	40 to 48	70 to 75	5 months	Dry	28.7
Gladiolus	45 to 50	70 to 75	5 to 8 months	Dry	28.2
Hyacinth	63 to 68		2 to 5 months		29.3
Iris, Dutch, Spanish	68 to 77	70 to 75	4 months	Dry	29.3
Gloriosa	50 to 63	70 to 75	3 to 4 months	Polyliner	
Candidum	31 to 33	70 to 75	1 to 6 months	Polyliner and peat	
Croft	31 to 33	70 to 75	1 to 6 months	Polyliner and peat	
Longiflorum	31 to 33	70 to 75	1 to 10 months	Polyliner and peat	28.9
Speciosum	31 to 33	70 to 75	1 to 6 months	Polyliner and peat	
Peony	33 to 35	70 to 75	5 months	Dry	
Tuberose	40 to 45	70 to 75	4 to 12 months	Dry	
Tulip	63	70 to 75	2 to 6 months	Dry	27.6
Nursery Stock					
Trees and shrubs	32 to 36	95	4 to 5 months	*	
Rose bushes	31 to 36	85 to 95	4 to 5 months	Bare rooted w/polyliner	
Strawberry plants	30 to 32	80 to 85	8 to 10 months	Bare rooted w/polyliner	29.9
Rooted cuttings	31 to 36	85 to 95		Polywrap	
Herbaceous perennials	27 to 28	80 to 85	4 to 8 months	*	
	31 to 35	80 to 85	3 to 7 months		
Christmas trees	22 to 32	80 to 85	6 to 7 weeks		

Data from USDA *Agricultural Handbook* 66.

*For details for various trees, shrubs, and perennials, see ANSI/ANLA *Standard* Z60.1.

Greens, bulbs, and certain nursery stock are usually packaged or crated when stored. Some bulbs and nursery stock are packed in damp moss or similar material, and low temperatures are required to keep them dormant. Polyethylene wraps or box liners are very effective for maintaining quality of strawberry plants, bare-root rose bushes, and certain cuttings and other nursery stock in storage. Strawberry plants can be stored up to 10 months in polyethylene-lined crates at 30 to 32°F.

Popcorn

Store popcorn at 32 to 40°F and about 85% rh. This relative humidity yields the optimum popping condition and the desired moisture content of about 13.5%.

Vegetable Seeds

Seeds generally benefit from low temperatures and low-humidity storage. High temperatures and high humidity favor loss of viability. Most vegetable seeds undergo no significant decrease in germination during one season when stored at 50°F and 50% rh. Full viability is retained far longer than one year as temperature and humidity are reduced. A temperature of 20°F and 15 to 25% rh are considered ideal but rarely necessary unless seed viability must be maintained for many years. Aster, pepper, tomato, and lettuce seeds stored under these conditions had equal or better viability after 13 years than did the fresh seed.

Low moisture content of the seed is important for germination. Hemp seed containing 9.5% moisture was mostly dead after 12 years storage at 50°F, but lost only 12% viability when moisture content was 5.7%. If stored at about 0°F, moisture percentage should not exceed 10% for many species. Seed with higher moisture content, when stored at 0°F, eventually equilibrates at a lower moisture level but may initially suffer frost damage. At higher temperatures, if it is impossible to keep humidity low enough, seeds must be stored in moistureproof containers.

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