

# COMMODITY STORAGE REQUIREMENTS

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**T**HIS chapter presents information on the 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 and handled and that have been properly 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 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 8. 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 8.

## 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 14 describes various cooling methods.

### Deterioration

The environment in which harvested produce is placed may greatly influence not only the respiration rate but 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 reduced as temperature is lowered. The specific relationships

between temperature and deterioration rate vary considerably among commodities and diseases. A generalization, assuming a deterioration rate of 1 for a fruit at 30°F, is as follows.

Temperature, °F	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 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 held at a temperature well above that usually recommended. The degree of susceptibility of an apple variety to chilling may vary with climatic and cultural factors. Products susceptible to chilling injury, its symptoms, and the lowest safe temperature are discussed in Chapters 8, 21, 22, and 23.

### 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
- $\phi$  = relative humidity, percent

For example, comparing the evaporative potential of air in storage rooms at 32°F and 50°F dry bulb, with 90% rh in each room, the vapor pressure deficit at 32°F is 0.018 in. Hg, while 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 dry bulb as at 32°F at the same rh values. 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 chemical materials to cause the water to be in equilibrium with

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



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

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

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



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

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Mamey sapote	<i>Calocarpum mammosum</i>	55 to 59	90 to 95		High	High		2 to 3 weeks	
Sapodilla (chicosapote)	<i>Achras sapota</i>	59 to 68	85 to 90		High	High		2 weeks	
White sapote	<i>Casimiroa edulis</i>	68	85 to 90	28.4				2 to 3 weeks	
Scorzonera	see Black salsify								
Shallot	<i>Allium cepa</i> var. <i>ascalonicum</i>	32 to 36	65 to 70	30.7	Low	Low			
Soursop	<i>Annona muricata</i>	55	85 to 90					1 to 2 weeks	
Spinach	<i>Spinacia oleracea</i>	32	95 to 100	31.5	Very low	High	Low	10 to 14 days	5 to 10% O <sub>2</sub> 5 to 10% CO <sub>2</sub>
Spondias (mombin, wi apple, jobo, hogplum)	<i>Spondias</i> spp.	55	85 to 90					1 to 2 weeks	
Sprouts from seeds		32	95 to 100					5 to 9 days	
Alfalfa sprouts	<i>Medicago sativa</i>	32	95 to 100					7 days	
Bean sprouts	<i>Phaseolus</i> sp.	32	95 to 100					7 to 9 days	
Radish sprouts	<i>Raphanus</i> sp.	32	95 to 100					5 to 7 days	
Squash									
Summer, soft rind (courgette)	<i>Cucurbita pepo</i>	45 to 50	95	31.1	Low	Moderate	Low	1 to 2 weeks	3 to 5% O <sub>2</sub> 5 to 10% CO <sub>2</sub>
Winter, hard rind (calabash)	<i>Cucurbitamoschata</i> ; <i>C. maxima</i>	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	<i>Ipomea batatas</i>	55 to 59	85 to 95	29.7	Very low	Low	Low	4 to 7 months	
Sweetsop (sugar apple, custard apple)	<i>Annona squamosa</i> ; <i>Annona</i> spp.	45	85 to 90		High	High		4 weeks	3 to 5% O <sub>2</sub> 5 to 10% CO <sub>2</sub>
Tamarillo (tree tomato)	<i>Cyphomandra betacea</i>	37 to 40	85 to 95		Low	Moderate		10 weeks	
Tamarind	<i>Tamarindus indica</i>	36 to 45	90 to 95	25.4	Very low	Very Low		3 to 4 weeks	
Taro (cocoyam, eddoe, dasheen)	<i>Colocasia esculenta</i>	45 to 50	85 to 90	30.4			Low	4 months	No CA benefit
Thyme	see Herbs								
Tomatillo (husk tomato)	<i>Physalis ixocarpa</i>	45 to 55	85 to 90		Very low	Moderate	Low	3 weeks	
Tomato									
Mature, green	<i>Lycopersicon esculentum</i>	50 to 55	90 to 95	31.1	Very low	High	Low	1 to 3 weeks	3 to 5% O <sub>2</sub> 2 to 3% CO <sub>2</sub>
Firm, ripe	<i>Lycopersicon esculentum</i>	46 to 50	85 to 90	31.1	High	Low	Low		3 to 5% O <sub>2</sub> 3 to 5% CO <sub>2</sub>
Turnip root	<i>Brassica campetris</i> var. <i>Rapifera</i>	32	95	30.2	Very low	Low	Low	4 to 5 months	
Water chestnut	<i>Eleocharis dulcis</i>	32 to 36	85 to 90					2 to 4 months	
Watercress (garden cress)	<i>Lepidium sativum</i> ; <i>Nasturtium officinales</i>	32	95 to 100	31.5	Very low	High	High	2 to 3 weeks	
Watermelon	<i>Citrullus vulgaris</i>	50 to 59	90	31.3	Very low	High	Low	2 to 3 weeks	No CA benefit
Yam	<i>Dioscorea</i> spp.	59	70 to 80	30.0	Very low	Low		2 to 7 months	
Yucca	see Cassava								

Note: The recommendations presented 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.

<sup>a</sup>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)

<sup>b</sup>Detrimental effects include yellowing, softening, increased decay, abscission, and browning.

<sup>c</sup>At recommended storage temperature.

Low = <20 mg CO<sub>2</sub>/(kg·h)

Moderate = <40 mg CO<sub>2</sub>/(kg·h)

High = <60 mg CO<sub>2</sub>/(kg·h)

Very high = >60 mg CO<sub>2</sub>/(kg·h)

<sup>d</sup>CA = controlled atmosphere.

<sup>e</sup>For a more complete listing of grapes and pears, see *Recommendations for Chilled Storage of Perishable Foods*, International Institute of Refrigeration, 1979.

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Table 2 Storage Requirements of Other Perishable Products

Product	Storage Temp., °F	Relative Humidity, %	Approximate Storage Life <sup>a</sup>	Product	Storage Temp., °F	Relative Humidity, %	Approximate Storage Life <sup>a</sup>
<b>Fish</b>				<b>Meat (Miscellaneous)</b>			
Haddock, Cod, Perch	31 to 34	95 to 100	12 days	Rabbits, fresh	32 to 34	90 to 95	1 to 5 days
Hake, Whiting	32 to 34	95 to 100	10 days	<b>Dairy Products</b>			
Halibut	31 to 34	95 to 100	18 days	Butter	32	75 to 85	2 to 4 weeks
Herring, Kippered	32 to 36	80 to 90	10 days	Butter, frozen	-10	70 to 85	12 to 20 months
Herring, Smoked	32 to 36	80 to 90	10 days	Cheese, Cheddar			
Mackerel	32 to 34	95 to 100	6 to 8 days	long storage	32 to 34	65	12 months
Menhaden	34 to 41	95 to 100	4 to 5 days	short storage	40	65	6 months
Salmon	31 to 34	95 to 100	18 days	processed	40	65	12 months
Tuna	32 to 36	95 to 100	14 days	grated	40	65	12 months
Frozen fish	-20 to -4	90 to 95	6 to 12 months	Ice cream, 10% fat premium	-20 to -15	90 to 95	3 to 23 months
<b>Shellfish<sup>a</sup></b>					-30 to -40	90 to 95	3 to 23 months
Scallop meat	32 to 34	95 to 100	12 days	<b>Milk</b>			
Shrimp	31 to 34	95 to 100	12 to 14 days	Fluid, pasteurized	39 to 43		7 days
Lobster American	41 to 50	In sea water	Indefinitely	Grade A (3.7% fat)	32 to 34		2 to 4 months
Oysters, Clams (meat and liquid)	32 to 36	100	5 to 8 days	Raw	32 to 39		2 days
Oyster in shell	41 to 50	95 to 100	5 days	Dried, whole	70	Low	6 to 9 months
Frozen shellfish	-30 to -4	90 to 95	3 to 8 months	Dried, nonfat	45 to 70	Low	16 months
<b>Beef</b>				Evaporated	40		24 months
Beef, fresh, average	28 to 34	88 to 95	1 week	Evaporated, unsweetened	70		12 months
Beef carcass				Condensed, sweetened	40		15 months
Choice, 60% lean	32 to 39	85 to 90	1 to 3 weeks	Whey, dried	70	Low	12 months
Prime, 54% lean	32 to 34	85	1 to 3 weeks	<b>Eggs</b>			
Sirloin cut (choice)	32 to 34	85	1 to 3 weeks	Shell	29 to 32 <sup>b</sup>	80 to 90	5 to 6 months
Round cut (choice)	32 to 34	85	1 to 3 weeks	Shell, farm cooler	50 to 55	70 to 75	2 to 3 weeks
Dried, chipped	50 to 59	15	6 to 8 weeks	Frozen,			
Liver	32	90	5 days	Whole	0		1 year plus
Veal, lean	28 to 34	85 to 95	3 weeks	Yolk	0		1 year plus
Beef, frozen	-10 to 0	90 to 95	6 to 12 months	White	0		1 year plus
<b>Pork</b>				Whole egg solids	35 to 40	Low	6 to 12 months
Pork, fresh, average	32 to 34	85 to 90	3 to 7 days	Yolk solids	35 to 40	Low	6 to 12 months
Pork, Carcass, 47% lean	32 to 34	85 to 90	3 to 5 days	Flake albumen solids	Room	Low	1 year plus
Pork, Bellies, 35% lean	32 to 34	85	3 to 5 days	Dry spray albumen solids	Room	Low	1 year plus
Pork, Fatback, 100% fat	32 to 34	85	3 to 7 days	<b>Candy</b>			
Pork, Shoulder, 67% lean	32 to 34	85	3 to 5 days	Milk chocolate	0 to 34	40	6 to 12 months
Pork, Frozen	-10 to 0	90 to 95	4 to 8 months	Peanut brittle	0 to 34	40	1.5 to 6 months
Ham, 74% lean	32 to 34	80 to 85	3 to 5 days	Fudge	0 to 34	65	5 to 12 months
Ham, Light cure	37 to 41	80 to 85	1 to 2 weeks	Marshmallows	0 to 34	65	3 to 9 months
Ham, Country cure	50 to 59	65 to 70	3 to 5 months	<b>Miscellaneous</b>			
Ham, Frozen	-10 to 0	90 to 95	6 to 8 months	Alfalfa meal	0	70 to 75	1 year plus
Bacon, Medium fat class	37 to 41	80 to 85	2 to 3 weeks	Beer, keg	35 to 40		3 to 8 weeks
Bacon, Cured, farm style	61 to 64	85	4 to 6 months	Beer, bottles and cans	35 to 40	65 or below	3 to 6 months
Bacon, Cured, packer style	34 to 39	85	2 to 6 weeks	Bread	0		3 to 13 weeks
Bacon, Frozen	-10 to 0	90 to 95	2 to 4 months	Canned goods	32 to 60	70 or lower	1 year
Sausage, Links or bulk	32 to 34	85	1 to 7 days	Cocoa	32 to 40	50 to 70	1 year plus
Sausage, Country, smoked	32	85	1 to 3 weeks	Coffee, green	35 to 37	80 to 85	2 to 4 months
Frankfurters, average	32	85	1 to 3 weeks	Fur and fabrics	34 to 40	45 to 55	Several years
Polish style	32	85	1 to 3 weeks	Honey	50		1 year plus
<b>Meat (Lamb)</b>				Hops	28 to 32	50 to 60	Several months
Fresh, average	28 to 34	85 to 90	3 to 4 weeks	Lard (without antioxidant)	45	90 to 95	4 to 8 months
Choice, lean	32	85	5 to 12 days	Maple syrup	0	90 to 95	12 to 14 months
Leg, choice, 83% lean	32	85	5 to 12 days	Nuts	32 to 50	65 to 75	8 to 12 months
Frozen	-10 to 0	90 to 95	8 to 12 months	Oil, vegetable, salad	70		1 year plus
<b>Poultry</b>				Oleomargarine	35	60 to 70	1 year plus
Poultry, fresh, average	28 to 32	95 to 100	1 to 3 weeks	Orange juice	30 to 35		3 to 6 weeks
Chicken, all classes	28 to 32	95 to 100	1 to 4 weeks	Popcorn, unpopped	32 to 40	85	4 to 6 weeks
Turkey, all classes	28 to 32	95 to 100	1 to 4 weeks	Yeast, baker's compressed	31 to 32		
Turkey breast roll	-4 to -1		6 to 12 months	Tobacco, Hogshead	50 to 65	50 to 65	1 year
Turkey frankfurters	0 to 15		6 to 16 months	Bales	35 to 40	70 to 85	1 to 2 years
Duck	28 to 32	95 to 100	1 to 4 weeks	Cigarettes	35 to 46	50 to 55	6 months
Poultry, frozen	-10 to 0	90 to 95	12 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 *Recommendations for the Processing and Handling of Frozen Foods*, 3rd ed., International Institute of Refrigeration, 1986.

<sup>a</sup>Storage life is not based on maintaining nutritional value.

<sup>b</sup>Eggs with weak albumen freeze just below 30°F.

water vapor in the air at 98 to 99% rh instead of 100% rh. Lowering the vapor pressure deficit by lowering the air temperature is an excellent means of reducing water loss during storage.

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 convenience in 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 thermometer 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°F 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. The thermometers should be placed so that they will not be heated by the fan motor, and they should be read quickly to prevent warming. 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 minutes 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.

Perhaps a more accurate method of determining the 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, the relative humidity can be calculated.

### Air Circulation

Air must be circulated to keep refrigerated storage rooms at an even temperature throughout. Commodity temperatures in a storage room may vary because the air temperature rises as the 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, the air near the return ducts will be warmer than the air near delivery ducts. In many storages, refrigeration units are installed over the center aisle. Air circulates from the center of the 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 14](#)). After field heat is removed, a high air velocity is usually undesirable. Air movement is needed only to remove respiratory heat 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 the air circulation or refrigeration is turned off, some precaution is needed to ensure that the stored product does not become too warm.

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, the 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 the 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. Commodities so contaminated can foster a rapid development of the spores, which are carried by air currents throughout the storage. Removing decaying raw material from the storage and sanitizing the product container will reduce 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 9, 21, 22, and 23](#) 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 conditions. 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 operations 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 or not 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 coconut shell 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. Air washing may increase the relative humidity and thus aid in maintaining 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 most 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 storage 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. The storage life will vary from 3 to 6 months, depending largely on the method of processing and packaging. Keg beer, usually stored at 35 to 40°F, 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 and 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, the storage life 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, the storage life 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. The 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.

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 vitality 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. Food should not be stored with fur garments. 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 will maintain original quality for several years and retard or prevent fermentation. The range between 50 and 65°F should be avoided, as it promotes granulation; this 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, since 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 reliquified 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.

**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 <sup>a</sup>	1
10 to 15	4	—	1
15 to 19	—	—	1
20 to 25	21	67	4
25 to 30	21	125 <sup>b</sup>	7
30 to 35	—	283 <sup>c</sup>	—

Table adapted from USDA *Publication AMS-57* (1955).

<sup>a</sup>50 to 95% of larvae may be killed in 2 days.

<sup>b</sup>A few larvae survived this period.

<sup>c</sup>Larvae survived this period.

Finely granulated honey (honey spread, Dyce process honey, and honey cream) must not be stored above about 75°F. Higher temperatures will, in time, cause partial liquefaction and destroy the texture. Any subsequent regranulation by lower temperatures will produce 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, the 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 redispense 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 the 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, while 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
<i>Cut Flowers</i>					
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	
<i>Greens</i>					
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
<i>Bulbs</i>					
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
<i>Nursery Stock</i>					
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* No. 66.

\*For details for various trees, shrubs, and perennials, see Storage of Nursery Stock (AAN 1960).

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.

## REFERENCES

- Hardenburg, R.E., A.E. Watada, and C.Y. Wang. 1986. The commercial storage of fruits, vegetables, and florist and nursery stocks. *USDA Handbook No. 66*. USDA, Washington, D.C.
- Thompson, J.F., P. Brecht, R.T. Hirsch, and A.A. Kader. 2000. Marine container transport of chilled perishable produce. *Publication 21595*. University of California, Division of Agriculture and Natural Resources.
- USDA. 1955. Protecting stored furs from insects. *USDA Publication AMS-57*.

## BIBLIOGRAPHY

- Hunt Ashby, B. 1987. Protecting perishable foods during transport by truck. *USDA Handbook No. 669*. USDA, Washington, D.C.
- IIR. 1993. *Cold Stores Guide*. International Institute of Refrigeration, Paris.
- IIR. 1990. Principles of refrigerated preservation of perishable foodstuffs. Manual of refrigerated storage in the warmer developing countries. International Institute of Refrigeration, Paris.
- IIR. 1986. General principles for the freezing, storage and thawing of foodstuffs. Recommendations for the processing and handling of frozen foods. International Institute of Refrigeration, Paris.
- ISO. 1974. Avocados—Guide for storage and transport. International Organization for Standardization, Geneva.
- Kader, A.A. 1986. Biochemical basis for effect of controlled and modified atmospheres on fruits and vegetables. *Food Technology*.
- Scott, V.N. 1989. Interaction of factors to control microbial spoilage of refrigerated foods. *Journal of Food Protection*.
- Schlimme, D.V., M.A. Smith, and L.M. Ali. 1991. Influence of freezing rate, storage temperature, and storage duration on the quality of cooked turkey breast roll. *ASHRAE Transactions* 97(1).
- Schlimme, D.V., M.A. Smith, and L.M. Ali. 1991. Influence of freezing rate, storage temperature, and storage duration on the quality of turkey frankfurters. *ASHRAE Transactions* 97(1).
- Tressler, D.K. and C.F. Evers. 1957. *The freezing preservation of foods*, 3rd ed. AVI Publishing Co., Inc., Westport, CT.
- Ulrich, R. 1979. Fruits and vegetables. Recommendations for chilled storage of perishable produce. International Institute of Refrigeration, Paris.
- Valenzuela Segura, G., D.D. Delgado, and D.R. Ramirez. 1972. Handling, storage and transport systems for exported refrigerated perishable foods. *Revista del Instituto de Investigaciones Tecnológicas*, Bogota, Columbia.
- Webb, B.H., A.H. Johnson, and J.A. Alford. 1973. *Fundamentals of dairy chemistry*. AVI Publishing Co., Inc., Westport, CT.