

COMMODITY STORAGE REQUIREMENTS

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THIS 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 -1°C , is as follows.

Approximate Deterioration Rate of Fresh Produce	
Temperature, $^{\circ}\text{C}$	Deterioration Rate
20	8 to 10
10	4 to 5
5	3
3	2
0	1.25
-1	1

For example, fruit that remains marketable for 12 days when stored at -1°C may last only $12/3 = 4$ days when stored at 5°C . The best temperature to slow down deterioration is the lowest temperature that can safely be maintained without freezing the commodity, which is 0.5 to 1 K 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

ϕ = relative humidity, percent

For example, comparing the evaporative potential of air in storage rooms at 0°C and 10°C dry bulb, with 90% rh in each room, the vapor pressure deficit at 0°C is 60 Pa, while at 10°C it is 120 Pa. Thus, if all other factors are equal, commodities tend to lose water twice as fast at 10°C dry bulb as at 0°C at the same rh values. For equal water loss at the two temperatures, the rh has to be maintained at 95% at 10°C in comparison to 90% at 0°C . 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 water vapor in the air at 98 to

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., °C	Rel. Humidity, %	Highest Freezing Temp., °C	Ethylene Production Rate ^a	Ethylene Sensitivity ^b	Respiration Rate ^c	Approx. Postharvest Life	Observations and Beneficial CA ^d Conditions
Acerola (Barbados cherry)	<i>Malpighia glabra</i>	0	85 to 90	−1.4				6 to 8 weeks	
African horned melon (kiwano)	<i>Cucumis africanus</i>	13 to 15	90		Low	Moderate		6 months	
Amaranth (pigweed)	<i>Amaranthus</i> spp.	0 to 2	95 to 100		Very low	Moderate		10 to 14 days	
Anise (fennel)	<i>Foeniculum vulgare</i>	0 to 2	90 to 95	−1.1				2 to 3 weeks	
Apple									
Not chilling sensitive	<i>Malus pumila</i>	−1	90 to 95	−1.5	Very high	High	Low	3 to 6 months	2 to 3% O ₂ 1 to 2% CO ₂
Chilling sensitive	<i>Malus pumila</i> cv. Yellow Newton, Grimes golden, McIntosh	4	90 to 95	−1.5	Very high	High	Low	1 to 2 months	2 to 3% O ₂ 1 to 2% CO ₂
Apricot	<i>Prunus armeniaca</i>	−0.5 to 0	90 to 95	−1.1	Moderate	Moderate	Low	1 to 3 weeks	2 to 3% O ₂ 2 to 3% CO ₂
Artichokes									
Chinese	<i>Stachys affinis</i>	0	90 to 95		Very low	Very Low		1 to 2 weeks	
Globe	<i>Cynara scolymus</i>	0	95 to 100	−1.2	Very low	Low	High	2 to 3 weeks	2 to 3% O ₂ 3 to 5% CO ₂
Jerusalem	<i>Helianthus tuberosus</i>	−0.5 to 0	90 to 95	−2.5	Very low	Low	Low	4 months	
Arugula	<i>Eruca vesicaria</i> var. <i>sativa</i>	0	95 to 100		Very low	High	Moderate	7 to 10 days	
Asian pear (nashi)	<i>Pyrus serotina</i> <i>P. pyrifolia</i>	1	90 to 95	−1.6	High	High	Low	4 to 6 months	
Asparagus, green or white	<i>Asparagus officinalis</i>	2.5	95 to 100	−0.6	Very low	Moderate	Very high	2 to 3 weeks	5 to 12% CO ₂
Atemoya	<i>Annona squamosa</i> x <i>A. cherimola</i>	13	85 to 90		High	High		4 to 6 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Avocado									
Fuchs, Pollock	<i>Persea americana</i> cv. Fuchs, Pollock	13	85 to 90	−0.9	High	High	Moderate	2 weeks	
Fuerte, Hass	<i>Persea americana</i> cv. Fuerte, Hass	3 to 7	85 to 90	−1.6	High	High	Moderate	2 to 4 weeks	2 to 5% O ₂ 3 to 10% CO ₂
Lula, Booth	<i>Persea americana</i> cv. Lula, Booth	4	90 to 95	−0.9	High	High	Moderate	4 to 8 weeks	
Babaco (mountain papaya)	<i>Carica candamarcensis</i>	7	85 to 90					1 to 3 weeks	
Banana	<i>Musa paradisiaca</i> var. <i>sapientum</i>	13 to 15	90 to 95	−0.8	Moderate	High	Low	1 to 4 weeks	2 to 5% O ₂ 2 to 5% CO ₂
Barbados cherry	see Acerola								
Beans									
Fava (broad)	<i>Vicia faba</i>	0	90 to 95					1 to 2 weeks	
Lima	<i>Phaseolous lunatus</i>	5 to 6	95	−0.6	Low	Moderate	Moderate	5 to 7 days	
Long (yard-long)	<i>Vigna sesquipedalis</i>	4 to 7	90 to 95		Low	Moderate		7 to 10 days	
Snap (wax, green)	<i>Phaseolus vulgaris</i>	4 to 7	95	−0.7	Low	Moderate	Moderate	7 to 10 days	2 to 3% O ₂ 4 to 7% CO ₂
Winged	<i>Psophocarpus tetragonolobus</i>	10	90					4 weeks	
Beet									
Bunched	<i>Beta vulgaris</i>	0	98 to 100	−0.4	Very low	Low	Low	10 to 14 days	
Topped	<i>Beta vulgaris</i>	0	98 to 100	−0.9	Very low	Low	Low	4 months	
Berries									
Blackberry	<i>Rubus</i> spp.	−0.5 to 0	90 to 95	−0.8	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., °C	Rel. Humidity, %	Highest Freezing Temp., °C	Ethylene Production Rate ^a	Ethylene Sensitivity ^b	Respiration Rate ^c	Approx. Postharvest Life	Observations and Beneficial CA ^d Conditions
Blueberry	<i>Vaccinium corymbosum</i>	-0.5 to 0	90 to 95	-1.3	Low	Low	Low	10 to 18 days	2 to 5% O ₂ 12 to 20% CO ₂
Cranberry	<i>Vaccinium macrocarpon</i>	2 to 5	90 to 95	-0.9	Low	Low	Low	8 to 16 weeks	1 to 2% O ₂ 0 to 5% CO ₂
Dewberry	<i>Rubus</i> spp.	-0.5 to 0	90 to 95	-1.3	Low	Low		2 to 3 days	
Elderberry	<i>Rubus</i> spp.	-0.5 to 0	90 to 95	-0.9	Low	Low		5 to 14 days	
Loganberry	<i>Rubus</i> spp.	-0.5 to 0	90 to 95	-1.3	Low	Low		2 to 3 days	
Raspberry	<i>Rubus idaeus</i>	-0.5 to 0	90 to 95	-0.9	Low	Low	Moderate	3 to 6 days	5 to 10% O ₂ 15 to 20% CO ₂
Strawberry	<i>Fragaria</i> spp.	0	90 to 95	-0.8	Low	Low	Low	7 to 10 days	5 to 10% O ₂ 15 to 20% CO ₂
Bittermelon (bitter melon)	<i>Momordica</i>	10 to 12	85 to 90		Low	Moderate	Moderate	2 to 3 weeks	2 to 3% O ₂ 5% CO ₂
Black salsify (scorzonera)	<i>Scorzonera hispanica</i>	0 to 1	95 to 98		Very low	Low		6 months	
Bok choy	<i>Brassica chinensis</i>	0	95 to 100		Very low	High		3 weeks	
Breadfruit	<i>Artocarpus altilis</i>	13 to 15	85 to 90					2 to 6 weeks	
Broccoli	<i>Brassica oleracea</i> var. <i>Italica</i>	0	95 to 100	-0.6	Very low	High	Moderate	10 to 14 days	1 to 2% O ₂ 5 to 10% CO ₂
Brussels sprouts	<i>Brassica oleracea</i> var. <i>Gemmifera</i>	0	95 to 100	-0.8	Very low	High	Moderate	3 to 5 weeks	1 to 2% O ₂ 5 to 7% CO ₂
Cabbage									
Chinese (Napa)	<i>Brassica campestris</i> var. <i>Pekinensis</i>	0	95 to 100	-0.9	Very low	High	Low	2 to 3 months	1 to 2% O ₂ 0 to 6% CO ₂
Common, early crop	<i>Brassica oleracea</i> var. <i>Capitata</i>	0	98 to 100	-0.9	Very low	High	Low	3 to 6 weeks	
Common, late crop	<i>Brassica oleracea</i> var. <i>Capitata</i>	0	95 to 100	-0.9	Very low	High	Low	5 to 6 months	3 to 5% O ₂ 3 to 7% CO ₂
Cactus leaves (nopalitos)	<i>Opuntia</i> spp.	5 to 10	90 to 95		Very low	Moderate		2 to 3 weeks	
Cactus fruit (prickly pear fruit)	<i>Opuntia</i> spp.	5	85 to 90	-1.8	Very low	Moderate		3 weeks	
Caimito	see Sapotes								
Calamondin	see Citrus								
Canistel	see Sapotes								
Carambola (starfruit)	<i>Averrhoa carambola</i>	9 to 10	85 to 90	-1.2			Low	3 to 4 weeks	
Carrot									
Topped	<i>Daucus carota</i>	0	98 to 100	-1.4	Very low	High	Low	6 to 8 months	No CA benefit
Bunched, immature	<i>Daucus carota</i>	0	98 to 100	-1.4	Very low	High	Moderate	10 to 14 days	Ethylene causes bitterness
Cashew, apple	<i>Anacardium occidentale</i>	0 to 2	85 to 90					5 weeks	
Cassava (yuca, manioc)	<i>Manihot esculenta</i>	0 to 5	85 to 90		Very low	Low	Low	1 to 2 months	No CA benefit
Cauliflower	<i>Brassica oleracea</i> var. <i>Botrytis</i>	0	95 to 98	-0.8	Very low	High	Moderate	3 to 4 weeks	2 to 5% O ₂ 2 to 5% CO ₂
Celeriac	<i>Apium graveolens</i> var. <i>Rapaceum</i>	0	98 to 100	-0.9	Very low	Low	Low	6 to 8 months	2 to 4% O ₂ 2 to 3% CO ₂
Celery	<i>Apium graveolens</i> var. <i>Dulce</i>	0	98 to 100	-0.5	Very low	Moderate	Low	1 to 2 months	1 to 4% O ₂ 3 to 5% CO ₂
Chard	<i>Beta vulgaris</i> var. <i>Cida</i>	0	95 to 100		Very low	High		10 to 14 days	
Chayote	<i>Sechium edule</i>	7	85 to 90				Low	4 to 6 weeks	
Cherimoya (custard apple)	<i>Annona cherimola</i>	13	90 to 95	-2.2	High	High	Very high	2 to 4 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Cherries									
Sour	<i>Prunus cerasus</i>	0	90 to 95	-1.7			Low	3 to 7 days	3 to 10% O ₂ 10 to 12% CO ₂
Sweet	<i>Prunus avium</i>	-1 to 0	90 to 95	-2.1			Low	2 to 3 weeks	10 to 20% O ₂ 20 to 25% CO ₂
Chicory	see Endive								

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Chiles	see Peppers								
Chinese broccoli (gailan)	<i>Brassica alboglabra</i>	0	95 to 100		Very low	High		10 to 14 days	
Chives	<i>Allium schoenoprasum</i>	0	95 to 100		Very low	High		2 to 3 weeks	
Cilantro (Chinese parsley)	<i>Coriandrum sativum</i>	0 to 2	95 to 100		Very low	High	High	2 weeks	
Citrus									
Calamondin orange	<i>Citrus reticulata</i> x. <i>Fortunella</i> spp.	9 to 10	90	−2.0			Low	2 weeks	
Grapefruit									
CA, AZ, dry areas	<i>Citrus paradisi</i>	14 to 15	85 to 90	−1.1	Very low	Moderate	Low	6 to 8 weeks	3 to 10% O ₂ 5 to 10% CO ₂
FL, humid areas	<i>Citrus paradisi</i>	10 to 15	85 to 90	−1.1	Very low	Moderate	Low	6 to 8 weeks	3 to 10% O ₂ 5 to 10% CO ₂
Kumquat	<i>Fortunella japonica</i>	4	90 to 95				Low	2 to 4 weeks	
Lemon	<i>Citrus limon</i>	10 to 13	85 to 90	−1.4			Low	1 to 6 months	5 to 10% O ₂ 0 to 10% CO ₂ Store at 0 to 4°C for < 1 mo.
Lime (Mexican, Tahitian or Persian)	<i>Citrus aurantifolia</i> ; <i>C. latifolia</i>	9 to 10	85 to 90	−1.6			Low	6 to 8 weeks	5 to 10% O ₂ 0 to 10% CO ₂
Orange									
CA, AZ, dry areas	<i>Citrus sinensis</i>	3 to 9	85 to 90	−0.8	Very low	Moderate	Low	3 to 8 weeks	5 to 10% O ₂ 0 to 5% CO ₂
FL, humid areas	<i>Citrus sinensis</i>	0 to 2	85 to 90	−0.8	Very low	Moderate	Low	8 to 12 weeks	5 to 10% O ₂ 0 to 5% CO ₂
Blood orange	<i>Citrus sinensis</i>	4 to 7	90 to 95	−0.8			Low	3 to 8 weeks	5 to 10% O ₂ 0 to 5% CO ₂
Seville (sour)	<i>Citrus aurantium</i>	10	85 to 90	−0.8	Low		Low	12 weeks	
Pummelo	<i>Citrus grandis</i>	7 to 9	85 to 90	−1.6			Low	12 weeks	
Tangelo (minneola)	<i>Citrus reticulata</i> x <i>paradisi</i>	7 to 10	85 to 95	−0.9			Low		
Tangerine (mandarin)	<i>Citrus reticulata</i>	4 to 7	90 to 95	−1.1	Very low	Moderate	Low	2 to 4 weeks	
Coconut	<i>Cocos nucifera</i>	0 to 2	89 to 85	−0.9				1 to 2 months	
Collards and kale	<i>Brassica oleracea</i> var. <i>Acephala</i>	0	95 to 100	−0.5	Very low	High	High	10 to 14 days	
Corn, sweet and baby	<i>Zea mays</i>	0	95 to 98	−0.6	Very low	Low	High	5 to 8 days	2 to 4% O ₂ 5 to 10% CO ₂
Cucumber	<i>Cucumis sativus</i>	10 to 12	85 to 90	−0.5	Low	High	Low	10 to 14 days	3 to 5% O ₂ 0 to 5% CO ₂
Cucumber, pickling	<i>Cucumis sativus</i>	4	95 to 100		Low	High		7 days	3 to 5% O ₂ 3 to 5% CO ₂
Currants	<i>Ribes sativum</i> ; <i>R. nigrum</i> ; <i>R. rubrum</i>	−0.5 to 0	90 to 95	−1.0	Low	Low		1 to 4 weeks	
Custard apple	see Cherimoya								
Daikon (Oriental radish)	<i>Raphanus sativus</i>	0 to 1	95 to 100		Very low	Low		4 months	
Dasheen	see Taro								
Date	<i>Phoenix dactylifera</i>	−18 to 0	75	−15.7	Very low	Low	Low	6 to 12 months	
Dill	see Herbs								
Durian	<i>Durio zibethinus</i>	4 to 6	85 to 90					6 to 8 weeks	3 to 5% O ₂ 5 to 15% CO ₂
Eggplant	<i>Solanum melongena</i>	10 to 12	90 to 95	−0.8	Low	Moderate	Low	1 to 2 weeks	3 to 5% O ₂ 0% CO ₂
Endive (escaraole)	<i>Cichorium endivia</i>	0	95 to 100	−0.1	Very low	Moderate	High	2 to 4 weeks	

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Common Name (Other Common Name)	Scientific Name	Storage Temp., °C	Rel. Humidity, %	Highest Freezing Temp., °C	Ethylene Production Rate ^a	Ethylene Sensitivity ^b	Respiration Rate ^c	Approx. Postharvest Life	Observations and Beneficial CA ^d Conditions
Belgian endive (Witloof chicory)	<i>Cichorium intybus</i>	2 to 3	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)	<i>Feijoa sellowiana</i>	5 to 10	90		Moderate	Low		2 to 3 weeks	
Fennel	see Anise								
Fig, fresh	<i>Ficus carica</i>	-0.5 to 0	85 to 90	-2.4	Moderate	Low	Low	7 to 10 days	5 to 10% O ₂ 15 to 20% CO ₂
Garlic	<i>Allium sativum</i>	0	65 to 70	-0.8	Very low	Low	Low	6 to 7 months	0.5% O ₂ 5 to 10% CO ₂
Ginger	<i>Zingiber officinale</i>	13	65		Very low	Low		6 months	No CA benefit
Gooseberry	<i>Ribes grossularia</i>	-0.5 to 0	90 to 95	-1.1	Low	Low	Low	3 to 4 weeks	
Granadilla	see Passionfruit								
Grape ^e									
Table grape	<i>Vitis vinifera</i>	-0.5 to 0	90 to 95	-2.7	Very low	Low	Low	2 to 8 weeks	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	<i>Vitis labrusca</i>	-1 to -0.5	90 to 95	-1.4	Very low	Low	Low	1 to 6 months	
Grapefruit	see Citrus						Low		
Guava	<i>Psidium guajava</i>	5 to 10	90		Low	Moderate	Moderate	2 to 3 weeks	
Herbs, fresh culinary									5 to 10% O ₂ 5 to 10% CO ₂
Basil	<i>Ocimum basilicum</i>	10	90		Very low	High		7 days	
Chives	<i>Allium schoenorassum</i>	0	95 to 100	-0.9	Low	Moderate			
Dill	<i>Anethum graveolens</i>	0	95 to 100	-0.7	Very low	High		1 to 2 weeks	
Epazote	<i>Chenopodium ambrosioides</i>	0 to 5	90 to 95		Very low	Moderate		1 to 2 weeks	
Mint	<i>Mentha</i> spp.	0	95 to 100		Very low	High		2 to 3 weeks	
Oregano	<i>Origanum vulgare</i>	0 to 5	90 to 95		Very low	Moderate		1 to 2 weeks	
Parsley	<i>Petroselinum crispum</i>	0	95 to 100	-1.1	Very low	High	Very high	1 to 2 months	
Perilla (shiso)	<i>Perilla frutescens</i>	10	95		Very low	Moderate		7 days	
Sage	<i>Salvia officinalis</i>	0	90 to 95					2 to 3 weeks	
Thyme	<i>Thymus vulgaris</i>	0	90 to 95					2 to 3 weeks	
Horseradish	<i>Amoracia rusticana</i>	-1 to 0	98 to 100	-1.8	Very low	Low		10 to 12 months	
Husk tomato	see Tomatillo								
Jaboticaba	<i>Myrciaria cauliflora</i> = <i>Eugenia cauliflora</i>	13 to 15	90 to 95					2 to 3 days	
Jackfruit	<i>Artocarpus heterophyllus</i>	13	85 to 90		Moderate	Moderate		2 to 6 weeks	
Jerusalem artichoke	see Artichoke								
Jicama (yambean)	<i>Pachyrrhizus erosus</i>	13 to 18	85 to 90		Very low	Low	Low	1 to 2 months	
Jujube (Chinese date)	<i>Ziziphus jujuba</i>	2.5 to 10	85 to 90	-1.6	Low	Moderate		1 month	
Kaki	see Persimmon								
Kale	see Collards and kale								
Kiwano	see African horned melon								
Kiwifruit (Chinese gooseberry)	<i>Actinidia chinensis</i>	0	90 to 95	-0.9	Low	High	Low	3 to 5 months	1 to 2% O ₂ 3 to 5% CO ₂
Kohlrabi	<i>Brassica oleracea</i> var. <i>Gongylodes</i>	0	98 to 100	-1.0	Very low	Low	Low	2 to 3 months	
Lo Bok	see Daikon								
Langsat (lanzone)	<i>Aglaia</i> sp.; <i>Lansium</i> sp.	11 to 14	85 to 90					2 weeks	

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Common Name (Other Common Name)	Scientific Name	Storage Temp., °C	Rel. Humidity, %	Highest Freezing Temp., °C	Ethylene Production Rate ^a	Ethylene Sensitivity ^b	Respiration Rate ^c	Approx. Postharvest Life	Observations and Beneficial CA ^d Conditions
Leafy greens									
Cool-season	various	0	95 to 100	−0.6	Very low	High		10 to 14 days	
Warm-season	various	7 to 10	95 to 100	−0.6	Very low	High		5 to 7 days	
Leek	<i>Allium porrum</i>	0	95 to 100	−0.7	Very low	Moderate	Moderate	2 months	1 to 2% O ₂ 2 to 5% CO ₂
Lemon	see Citrus								
Lettuce	<i>Lactuca sativa</i>	0	98 to 100	−0.2	Very low	High	Low	2 to 3 weeks	2 to 5% O ₂ 0% CO ₂
Lime	see Citrus								
Longan	<i>Dimocarpus longan</i> = <i>Euphoria longan</i>	1 to 2	90 to 95	−2.4				3 to 5 weeks	
Loquat	<i>Eriobotrya japonica</i>	0	90	−1.9				3 weeks	
Luffa (Chinese okra)	<i>Luffa</i> spp.	10 to 12	90 to 95		Low	Moderate		1 to 2 weeks	
Lychee (litchi)	<i>Litchi chinensis</i>	1 to 2	90 to 95		Moderate	Moderate	Low	3 to 5 weeks	3 to 5% O ₂ 3 to 5% CO ₂
Malanga (tania, new cocoyam)	<i>Xanthosoma sagittifolium</i>	7	70 to 80		Very low	Low		3 months	
Mamey	see Sapotes								
Mandarin	see Citrus								
Mango	<i>Mangifera indica</i>	13	85 to 90	−1.4	Moderate	Moderate	Moderate	2 to 3 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Mangosteen	<i>Garcinia mangostana</i>	13	85 to 90		Moderate	High		2 to 4 weeks	
Melons									
Cantaloupes and other netted melons	<i>Cucurbita melo</i> var. <i>reticulatus</i>	2 to 5	95	−1.2	High	Moderate	Low	2 to 3 weeks	3 to 5% O ₂ 10 to 15% CO ₂
Casaba	<i>Cucurbita melo</i>	7 to 10	85 to 90	−1.0	Low	Low		3 to 4 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Crenshaw	<i>Cucurbita melo</i>	7 to 10	85 to 90	−1.1	Moderate	High		2 to 3 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Honeydew, orange-flesh	<i>Cucurbita melo</i>	5 to 10	85 to 90	−1.1	Moderate	High	Low	3 to 4 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Persian	<i>Cucurbita melo</i>	7 to 10	85 to 90	−0.8	Moderate	High		2 to 3 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Mint	see Herbs								
Mombin	see Spondias								
Mushrooms	<i>Agaricus</i> , other genera	0	90	−0.9	Very low	Moderate	High	7 to 14 days	3 to 21% O ₂ 15 to 15% CO ₂
Mustard greens	<i>Brassica juncea</i>	0	90 to 95		Very low	High		7 to 14 days	
Nashi	see Asian pear								
Nectarine	<i>Prunus persica</i>	−0.5 to 0	90 to 95	−0.9	Moderate	Moderate	Low	2 to 4 weeks	1 to 2% O ₂ 3 to 5% CO ₂ Internal breakdown at 3 to 10°C
Okra	<i>Abelmoschus esculentus</i>	7 to 10	90 to 95	−1.8	Low	Moderate	High	7 to 10 days	Air 4 to 10% CO ₂
Olives, fresh	<i>Olea europea</i>	5 to 10	85 to 90	−1.4	Low	Moderate	Low	4 to 6 weeks	2 to 3% O ₂ 0 to 1% CO ₂
Onion									
Mature bulbs, dry	<i>Allium cepa</i>	0	65 to 70	−0.8	Very low	Low	Low	1 to 8 months	1 to 3% O ₂ 5 to 10% CO ₂
Green	<i>Allium cepa</i>	0	95 to 100	−0.9	Low	High	Moderate	3 weeks	2 to 4% O ₂ 10 to 20% CO ₂
Orange	see Citrus								
Papaya	<i>Carica papaya</i>	7 to 13	85 to 90	−0.9			Low	1 to 3 weeks	2 to 5% O ₂ 5 to 8% CO ₂
Parsley	see Herbs								

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

Common Name (Other Common Name)	Scientific Name	Storage Temp., °C	Rel. Humidity, %	Highest Freezing Temp., °C	Ethylene Production Rate ^a	Ethylene Sensitivity ^b	Respiration Rate ^c	Approx. Postharvest Life	Observations and Beneficial CA ^d Conditions
Parsnips	<i>Pastinaca sativa</i>	0	95 to 100	−0.9	Very low	High	Low	4 to 6 months	Ethylene causes bitterness
Passionfruit	<i>Passiflora</i> spp.	10	85 to 90		Very high	Moderate	Very high	3 to 4 weeks	
Peach	<i>Prunus persica</i>	−0.5 to 0	90 to 95	−0.9	High	Moderate	Low	2 to 4 weeks	1 to 2% O ₂ 3 to 5% CO ₂ Internal breakdown at 3 to 10°C
Pear, American ^e	<i>Pyrus communis</i>	−1.5 to −0.5	90 to 95	−1.7	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)	<i>Pisum sativum</i>	0 to 1	90 to 98	−0.6	Very low	Moderate	Very high	1 to 2 weeks	2 to 3% O ₂ 2 to 3% CO ₂
Southern peas (cowpeas)	<i>Vigna sinensis</i> = <i>V. unguiculata</i>	4 to 5	95					6 to 8 days	
Pepino (melon pear)	<i>Solanum muricatum</i>	5 to 10	95		Low	Moderate		4 weeks	
Peppers									
Bell pepper or paprika	<i>Capsicum annuum</i>	7 to 10	95 to 98	−0.7	Low	Low	Low	2 to 3 weeks	2 to 5% O ₂ 2 to 5% CO ₂
Hot peppers (chiles)	<i>Capsicum annuum</i> and <i>C. frutescens</i>	5 to 10	85 to 95	−0.7	Low	Moderate		2 to 3 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Persimmon (kaki)	<i>Dispyros kaki</i>								3 to 5% O ₂ 5 to 8% CO ₂
Fuyu	<i>Dispyros kaki</i> var. <i>Fuyu</i>	0	90 to 95	−2.2	Low	High	Low	1 to 3 months	
Hachiya	<i>Dispyros kaki</i> var. <i>Hachiya</i>	0	90 to 95	−2.2	Low	High	Low	2 to 3 months	
Pineapple	<i>Ananas comosus</i>	7 to 13	85 to 90	−1.1	Low	Low	Low	2 to 4 weeks	2 to 5% O ₂ 5 to 10% CO ₂
Plantain	<i>Musa paradisiaca</i> var. <i>paradisiaca</i>	13 to 15	90 to 95	−0.8	Low	High		1 to 5 weeks	
Plums and prunes	<i>Prunus domestica</i>	−0.5 to 0	90 to 95	−0.8	Moderate	Moderate	Low	2 to 5 weeks	1 to 2% O ₂ 0 to 5% CO ₂
Pomegranate	<i>Punica granatum</i>	5	90 to 95	−3.0			Low	2 to 3 months	3 to 5% O ₂ 5 to 10% CO ₂
Potato									
Early crop	<i>Solanum tuberosum</i>	10 to 15	90 to 95	−0.8	Very low	Moderate	Low	10 to 14 days	No CA benefit
Late crop	<i>Solanum tuberosum</i>	4 to 12	95 to 98	−0.8	Very low	Moderate	Low	5 to 10 months	No CA benefit
Pumpkin	<i>Cucurbita maxima</i>	12 to 15	50 to 70	−0.8	Very low	Moderate	Low	2 to 3 months	
Quince	<i>Cydonia oblonga</i>	−0.5 to 0	90	−2.0	Low	High		2 to 3 months	
Raddichio	<i>Cichorium intybus</i>	0 to 1	95 to 100					3 to 4 weeks	
Radish	<i>Raphanus sativus</i>	0	95 to 100	−0.7	Very low	Low	Low	1 to 2 months	1 to 2% O ₂ 2 to 3% CO ₂
Rambutan	<i>Nephelium lappaceum</i>	12	90 to 95		High	High		1 to 3 weeks	3 to 5% O ₂ 7 to 12% CO ₂
Rhubarb	<i>Rheum rhaponticum</i>	0	95 to 100	−0.9	Very low	Low	Low	2 to 4 weeks	
Rutabaga	<i>Brassica napus</i> var. <i>Napobrassica</i>	0	98 to 100	−1.1	Very low	Low	Low	4 to 6 months	
Sage	see Herbs								
Salsify (vegetable oyster)	<i>Trapopogon porrifolius</i>	0	95 to 98	−1.1	Very low	Low	Low	2 to 4 months	
Sapotes									
Black sapote	<i>Diospyros ebenaster</i>	13 to 15	85 to 90	−2.3				2 to 3 weeks	
Caimito (star apple)	<i>Chrysophyllum cainito</i>	3	90	−1.2				3 weeks	
Canistel (eggfruit)	<i>Pouteria campechiana</i>	13 to 15	85 to 90	−1.8				3 weeks	

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

Common Name (Other Common Name)	Scientific Name	Storage Temp., °C	Rel. Humidity, %	Highest Freezing Temp., °C	Ethylene Production Rate ^a	Ethylene Sensitivity ^b	Respiration Rate ^c	Approx. Postharvest Life	Observations and Beneficial CA ^d Conditions
Mamey sapote	<i>Calocarpum mammosum</i>	13 to 15	90 to 95		High	High		2 to 3 weeks	
Sapodilla (chicosapote)	<i>Achras sapota</i>	15 to 20	85 to 90		High	High		2 weeks	
White sapote	<i>Casimiroa edulis</i>	20	85 to 90	-2.0				2 to 3 weeks	
Scorzonera	see Black salsify								
Shallot	<i>Allium cepa</i> var. <i>ascalonicum</i>	0 to 2.5	65 to 70	-0.7	Low	Low			
Soursop	<i>Annona muricata</i>	13	85 to 90					1 to 2 weeks	
Spinach	<i>Spinacia oleracea</i>	0	95 to 100	-0.3	Very low	High	Low	10 to 14 days	5 to 10% O ₂ 5 to 10% CO ₂
Spondias (mombin, wi apple, jobo, hogplum)	<i>Spondias</i> spp.	13	85 to 90					1 to 2 weeks	
Sprouts from seeds		0	95 to 100					5 to 9 days	
Alfalfa sprouts	<i>Medicago sativa</i>	0	95 to 100					7 days	
Bean sprouts	<i>Phaseolus</i> sp.	0	95 to 100					7 to 9 days	
Radish sprouts	<i>Raphanus</i> sp.	0	95 to 100					5 to 7 days	
Squash									
Summer, soft rind (courgette)	<i>Cucurbita pepo</i>	7 to 10	95	-0.5	Low	Moderate	Low	1 to 2 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Winter, hard rind (calabash)	<i>Cucurbita moschata</i> ; <i>C. maxima</i>	12 to 15	50 to 70	-0.8	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>	13 to 15	85 to 95	-1.3	Very low	Low	Low	4 to 7 months	
Sweetsop (sugar apple, custard apple)	<i>Annona squamosa</i> ; <i>Annona</i> spp.	7	85 to 90		High	High		4 weeks	3 to 5% O ₂ 5 to 10% CO ₂
Tamarillo (tree tomato)	<i>Cyphomandra betacea</i>	3 to 4	85 to 95		Low	Moderate		10 weeks	
Tamarind	<i>Tamarindus indica</i>	2 to 7	90 to 95	-3.7	Very low	Very Low		3 to 4 weeks	
Taro (cocoyam, eddoe, dasheen)	<i>Colocasia esculenta</i>	7 to 10	85 to 90	-0.9			Low	4 months	No CA benefit
Thyme	see Herbs								
Tomatillo (husk tomato)	<i>Physalis ixocarpa</i>	7 to 13	85 to 90		Very low	Moderate	Low	3 weeks	
Tomato									
Mature, green	<i>Lycopersicon esculentum</i>	10 to 13	90 to 95	-0.5	Very low	High	Low	1 to 3 weeks	3 to 5% O ₂ 2 to 3% CO ₂
Firm, ripe	<i>Lycopersicon esculentum</i>	8 to 10	85 to 90	-0.5	High	Low	Low		3 to 5% O ₂ 3 to 5% CO ₂
Turnip root	<i>Brassica campetris</i> var. <i>Rapifera</i>	0	95	-1.0	Very low	Low	Low	4 to 5 months	
Water chestnut	<i>Eleocharis dulcis</i>	1 to 2	85 to 90					2 to 4 months	
Watercress (garden cress)	<i>Lepidium sativum</i> ; <i>Nasturtium officinales</i>	0	95 to 100	-0.3	Very low	High	High	2 to 3 weeks	
Watermelon	<i>Citrullus vulgaris</i>	10 to 15	90	-0.4	Very low	High	Low	2 to 3 weeks	No CA benefit
Yam	<i>Dioscorea</i> spp.	15	70 to 80	-1.1	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.

^aVery low = <0.1 µL/(kg·h) at 20°C

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)

^bDetrimental effects include yellowing, softening, increased decay, abscission, and browning.

^cAt recommended storage temperature.

Low = <20 mg CO₂/(kg·h)

Moderate = <40 mg CO₂/(kg·h)

High = <60 mg CO₂/(kg·h)

Very high = >60 mg CO₂/(kg·h)

^dCA = controlled atmosphere.

^eFor 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., °C	Relative Humidity, %	Approximate Storage Life ^a	Product	Storage Temp., °C	Relative Humidity, %	Approximate Storage Life ^a
Fish				Meat (Miscellaneous)			
Haddock, Cod, Perch	−0.5 to 1	95 to 100	12 days	Rabbits, fresh	0 to 1	90 to 95	1 to 5 days
Hake, Whiting	0 to 1	95 to 100	10 days	Dairy Products			
Halibut	−0.5 to 1	95 to 100	18 days	Butter	0	75 to 85	2 to 4 weeks
Herring, Kippered	0 to 2	80 to 90	10 days	Butter, frozen	−23	70 to 85	12 to 20 months
Herring, Smoked	0 to 2	80 to 90	10 days	Cheese, Cheddar			
Mackerel	0 to 1	95 to 100	6 to 8 days	long storage	0 to 1	65	12 months
Menhaden	1 to 5	95 to 100	4 to 5 days	short storage	4	65	6 months
Salmon	−0.5 to 1	95 to 100	18 days	processed	4	65	12 months
Tuna	0 to 2	95 to 100	14 days	grated	4	65	12 months
Frozen fish	−30 to −20	90 to 95	6 to 12 months	Ice cream, 10% fat	−30 to −25	90 to 95	3 to 23 months
Shellfish^a				premium	−35 to −40	90 to 95	3 to 23 months
Scallop meat	0 to 1	95 to 100	12 days	Milk			
Shrimp	−0.5 to 1	95 to 100	12 to 14 days	Fluid, pasteurized	4 to 6		7 days
Lobster American		In sea water	Indefinitely	Grade A (3.7% fat)	0 to 1		2 to 4 months
Oysters, Clams	5 to 10			Raw	0 to 4		2 days
(meat and liquid)		100	5 to 8 days	Dried, whole	21	Low	6 to 9 months
Oyster in shell	0 to 2	95 to 100	5 days	Dried, nonfat	7 to 21	Low	16 months
Frozen shellfish	5 to 10	90 to 95	3 to 8 months	Evaporated	4		24 months
Beef				Evaporated, unsweetened	21		12 months
Beef, fresh, average	−2 to 1	88 to 95	1 week	Condensed, sweetened	4		15 months
Beef carcass				Whey, dried	21	Low	12 months
Choice, 60% lean	0 to 4	85 to 90	1 to 3 weeks	Eggs			
Prime, 54% lean	0 to 1	85	1 to 3 weeks	Shell	−1.5 to 0 ^b	80 to 90	5 to 6 months
Sirloin cut (choice)	0 to 1	85	1 to 3 weeks	Shell, farm cooler	10 to 13	70 to 75	2 to 3 weeks
Round cut (choice)	0 to 1	85	1 to 3 weeks	Frozen,			
Dried, chipped	10 to 15	15	6 to 8 weeks	Whole	−20		1 year plus
Liver	0	90	5 days	Yolk	−20		1 year plus
Veal, lean	−2 to 1	85 to 95	3 weeks	White	−20		1 year plus
Beef, frozen	−20	90 to 95	6 to 12 months	Whole egg solids	1.5 to 4	Low	6 to 12 months
Pork				Yolk solids	1.5 to 4	Low	6 to 12 months
Pork, fresh, average	0 to 1	85 to 90	3 to 7 days	Flake albumen solids	Room	Low	1 year plus
Pork, Carcass, 47% lean	0 to 1	85 to 90	3 to 5 days	Dry spray albumen solids	Room	Low	1 year plus
Pork, Bellies, 35% lean	0 to 1	85	3 to 5 days	Candy			
Pork, Fatback, 100% fat	0 to 1	85	3 to 7 days	Milk chocolate	−20 to 1	40	6 to 12 months
Pork, Shoulder, 67% lean	0 to 1	85	3 to 5 days	Peanut brittle	−20 to 1	40	1.5 to 6 months
Pork, Frozen	−20	90 to 95	4 to 8 months	Fudge	−20 to 1	65	5 to 12 months
Ham, 74% lean	0 to 1	80 to 85	3 to 5 days	Marshmallows	−20 to 1	65	3 to 9 months
Ham, Light cure	3 to 5	80 to 85	1 to 2 weeks	Miscellaneous			
Ham, Country cure	10 to 15	65 to 70	3 to 5 months	Alfalfa meal	−20	70 to 75	1 year plus
Ham, Frozen	−20	90 to 95	6 to 8 months	Beer, keg	1.5 to 4		3 to 8 weeks
Bacon, Medium fat class	3 to 5	80 to 85	2 to 3 weeks	Beer, bottles and cans	1.5 to 4	65 or below	3 to 6 months
Bacon, Cured, farm style	16 to 18	85	4 to 6 months	Bread	−20		3 to 13 weeks
Bacon, Cured, packer style	1 to 4	85	2 to 6 weeks	Canned goods	0 to 15	70 or lower	1 year
Bacon, Frozen	−20	90 to 95	2 to 4 months	Cocoa	0 to 4	50 to 70	1 year plus
Sausage, Links or bulk	0 to 1	85	1 to 7 days	Coffee, green	1.5 to 3	80 to 85	2 to 4 months
Sausage, Country, smoked	0	85	1 to 3 weeks	Fur and fabrics	1 to 4	45 to 55	Several years
Frankfurters, average	0	85	1 to 3 weeks	Honey	10		1 year plus
Polish style	0	85	1 to 3 weeks	Hops	−2 to 0	50 to 60	Several months
Meat (Lamb)				Lard (without antioxidant)	7	90 to 95	4 to 8 months
Fresh, average	−2 to 1	85 to 90	3 to 4 weeks	Maple syrup	0	90 to 95	12 to 14 months
Choice, lean	0	85	5 to 12 days	Nuts	0 to 10	65 to 75	8 to 12 months
Leg, choice, 83% lean	0	85	5 to 12 days	Oil, vegetable, salad	21		1 year plus
Frozen	−20	90 to 95	8 to 12 months	Oleomargarine	1.5	60 to 70	1 year plus
Poultry				Orange juice	−1 to 1.5		3 to 6 weeks
Poultry, fresh, average	−2 to 0	95 to 100	1 to 3 weeks	Popcorn, unpopped	0 to 4	85	4 to 6 weeks
Chicken, all classes	−2 to 0	95 to 100	1 to 4 weeks	Yeast, baker's compressed	−0.5 to 0		
Turkey, all classes	−2 to 0	95 to 100	1 to 4 weeks	Tobacco, Hogshead	10 to 18	50 to 65	1 year
Turkey breast roll	−4 to −1		6 to 12 months	Bales	2 to 4	70 to 85	1 to 2 years
Turkey frankfurters	−20 to −10		6 to 16 months	Cigarettes	2 to 8	50 to 55	6 months
Duck	−2 to 0	95 to 100	1 to 4 weeks	Cigars	2 to 10	60 to 65	2 months
Poultry, frozen	−20	90 to 95	12 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.

^aStorage life is not based on maintaining nutritional value.

^bEggs with weak albumen freeze just below −1°C.

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 mass, 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 60 Pa, which corresponds to 90% rh at 0°C, 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 1 to 1.5 K 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 1.5 m 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 0°C or lower cannot be read that closely. An error of 0.3 K in reading either the wet- or the dry-bulb thermometer will cause an error of 5% rh. Carefully calibrated thermometers graduated to 0.05 K with a range of -5°C to +5°C 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 0.9 m/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 mass 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 -0.5°C, 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 (2 to 4 mm spacing of 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 mass 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 21 to 24°C, but for convenience, it is often stored with keg beer at a lower temperature of 2 to 4°C. 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 2 to 4°C, 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 24°C. 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 30°C 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 30°C regularly. When stored in bulk or in bags that are not good water vapor barriers, the storage life at 40% rh and 21°C should be limited to less than one year, and at 30°C to less than 6 months. At 60% rh and 21°C, the storage life should be limited to 6 months, and at 30°C 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 -20°C 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 1 to 4°C. A temperature of 4°C 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 1 to 4°C 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 -10 and 0°C 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 -23 to -12°C 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 10°C will maintain original quality for several years and retard or prevent fermentation. The range between 10 and 18°C should be avoided, as it promotes granulation; this increases the probability of fermentation of raw (unheated) honey. As storage temperature increases in the 27 to 38°C range, deterioration is accelerated; temperatures constantly above 30°C are unsuitable and above 32°C, quite damaging.

Honey for export is best kept in cold storage, since the half-life for honey diastase at 25°C 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 50 to 60°C.

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, °C	All Eggs Dead After, Days	All Larvae Dead After, Days	All Adults Dead After, Days
-18 to -15	1	2	1
-15 to -12	2	21 ^a	1
-12 to -9	4	—	1
-9 to -7	—	—	1
-7 to -4	21	67	4
-4 to -1	21	125 ^b	7
-1 to +2	—	283 ^c	—

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

^a50 to 95% of larvae may be killed in 2 days.

^bA few larvae survived this period.

^cLarvae survived this period.

Finely granulated honey (honey spread, Dyce process honey, and honey cream) must not be stored above about 25°C. 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 82°C. 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 (0°C±0.5°C) 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 -0.5 to 2°C. Open packages and harden flowers before marketing if the blooms have been stored for long periods. Flowers conditioned at about 10°C following storage regain full turgidity most rapidly. Cut or crush stem ends and then place in water or a food solution at 27 to 38°C 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

Table 4 Storage Conditions for Cut Flowers and Nursery Stock

Commodity	Storage Temp., °C	Relative Humidity, %	Approx. Storage Life	Method of Holding	Highest Freezing Point, °C
<i>Cut Flowers</i>					
Calla Lily	4.4	90 to 95	1 week	Dry pack	
Camellia	7	90 to 95	3 to 6 days	Dry pack	-0.8
Carnation	-0.6 to 0	90 to 95	3 to 4 weeks	Dry pack	-0.7
Chrysanthemum	-0.6 to 0	90 to 95	3 to 4 weeks	Dry pack	-0.8
Daffodil	0 to 0.6	90 to 95	1 to 3 weeks	Dry pack	-0.1
(Narcissus)					
Dahlia	4.4	90 to 95	3 to 5 days	Dry pack	
Gardenia	0 to 1	90 to 95	2 weeks	Dry pack	-0.6
Gladiolus	2 to 5.5	90 to 95	1 week	Dry pack	-0.3
Iris, tight buds	-0.6 to 0	90 to 95	2 weeks	Dry pack	-0.8
Lily, Easter	0 to 1.7	90 to 95	2 to 3 weeks	Dry pack	-0.5
Lily-of-the-valley	-0.6 to 0	90 to 95	2 to 3 weeks	Dry pack	
Orchid	7 to 13	90 to 95	2 weeks	Water	-0.3
Peony, tight buds	0 to 1.7	90 to 95	4 to 6 weeks	Dry pack	-1.1
Rose, tight buds	0	90 to 95	2 weeks	Dry pack	-0.4
Snapdragon	4.4 to 5.5	90 to 95	1 to 2 weeks	Dry pack	-0.9
Sweet Peas	-0.6 to 0	90 to 95	2 weeks	Dry pack	-0.9
Tulips	-0.6 to 0	90 to 95	2 to 3 weeks	Dry pack	
<i>Greens</i>					
Asparagus (plumosus)	1.7 to 4	90 to 95	2 to 3 weeks	Polylined cases	-3.3
Fern, dagger and wood	-1 to 0	90 to 95	2 to 3 months	Dry pack	-1.7
Fern, leatherleaf	1 to 4	90 to 95	1 to 2 months	Dry pack	
Holly	0	90 to 95	4 to 5 weeks	Dry pack	-2.8
Huckleberry	0	90 to 95	1 to 4 weeks	Dry pack	-2.9
Laurel	0	90 to 95	2 to 4 weeks	Dry pack	-2.4
Magnolia	1.7 to 4.4	90 to 95	2 to 4 weeks	Dry pack	-2.8
Rhododendron	0	90 to 95	2 to 4 weeks	Dry pack	-2.4
Salal	0	90 to 95	2 to 3 weeks	Dry pack	-2.9
<i>Bulbs</i>					
Amaryllis	3 to 7	70 to 75	5 months	Dry	-0.7
Caladium	21	70 to 75	2 to 4 months		-1.3
Crocus	9 to 17		2 to 3 months		-1.3
Dahlia	4 to 9	70 to 75	5 months	Dry	-1.8
Gladiolus	7 to 10	70 to 75	5 to 8 months	Dry	-2.1
Hyacinth	17 to 20		2 to 5 months		-1.5
Iris, Dutch, Spanish	20 to 25	70 to 75	4 months	Dry	-1.5
Gloriosa	10 to 17	70 to 75	3 to 4 months	Polyliner	
Candidum	-0.6 to 0.6	70 to 75	1 to 6 months	Polyliner and peat	
Croft	-0.6 to 0.6	70 to 75	1 to 6 months	Polyliner and peat	
Longiflorum	-0.6 to 0.6	70 to 75	1 to 10 months	Polyliner and peat	-1.7
Speciosum	-0.6 to 0.6	70 to 75	1 to 6 months	Polyliner and peat	
Peony	0.6 to 1.7	70 to 75	5 months	Dry	
Tuberose	4.4 to 7	70 to 75	4 to 12 months	Dry	
Tulip	17	70 to 75	2 to 6 months	Dry	-2.4
<i>Nursery Stock</i>					
Trees and shrubs	0 to 2	95	4 to 5 months	*	
Rose bushes	-0.5 to 2	85 to 95	4 to 5 months	Bare rooted w/ polyliner	
Strawberry plants	-1 to 0	80 to 85	8 to 10 months	Bare rooted w/ polyliner	-1.2
Rooted cuttings	-0.5 to 2	85 to 95		Polywrap	
Herbaceous perennials	-2.8 to -2.2	80 to 85	4 to 8 months	*	
	-0.6 to 1.7	80 to 85	3 to 7 months		
Christmas trees	-5.5 to 0	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 -1 to 0°C .

Popcorn

Store popcorn at 0 to 4°C 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 10°C and 50% rh. Full viability is retained far longer than one year as temperature and humidity are reduced. A temperature of -7°C 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 10°C , but lost only 12% viability when moisture content was 5.7%. If stored at about -20°C , moisture percentage should not exceed 10% for many species. Seed with higher moisture content, when stored at -20°C , 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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