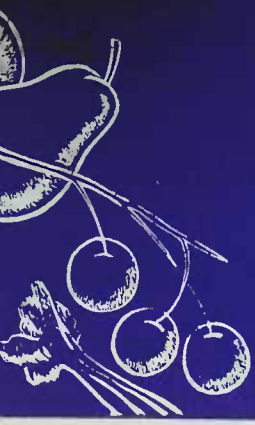

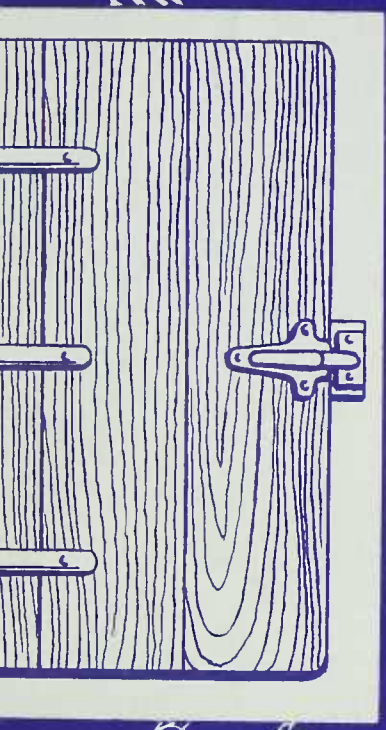

The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks

AGRICULTURE HAND BOOK No. 66

U. S. DEPARTMENT OF AGRICULTURE

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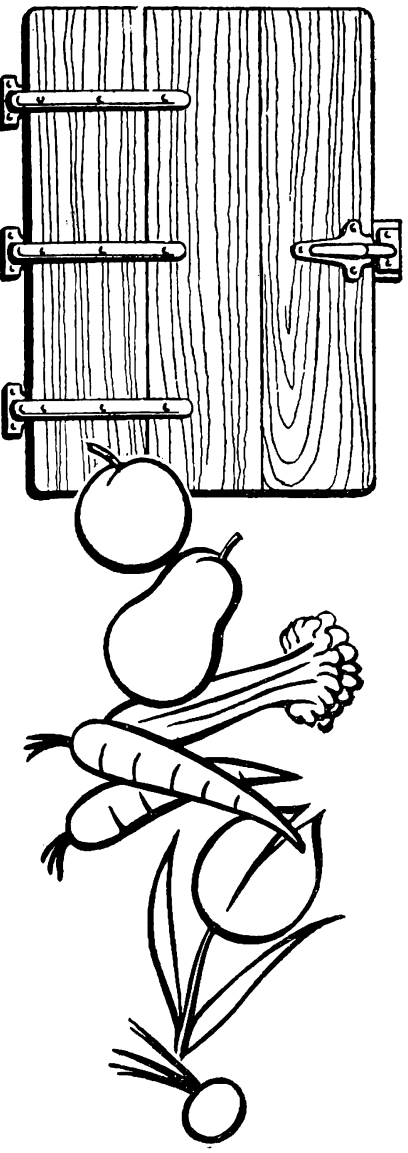

The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks

By R. C. WRIGHT, *senior physiologist*, DEAN H. ROSE, formerly *senior physiologist*, and T. M. WHITEMAN, *associate horticulturist*, *Biological Sciences Branch, Agricultural Marketing Service*

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Contents

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The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks[1]

By R. C. WRIGHT, *senior physiologist*, DEAN H. ROSE,[2] formerly *senior physiologist*, and T. M. WHITEMAN, *associate horticulturist, Biological Sciences Branch, Agricultural Marketing Service*

Introduction

The purpose of this handbook is to present a series of brief summaries of the essential average storage requirements of most of the important fresh fruits, vegetables, and cut flowers, and certain other horticultural crops that enter the market on a commercial scale. Many details are necessarily omitted, as the handbook is intended primarily for general practical reference. The conditions given should not be considered absolute or final, but rather as the safe limitations under which the various products can ordinarily be stored. Detailed information on the handling and storage of some of the commodities discussed is available elsewhere in the form of bulletins or textbooks; for many of them, only general information exists.

Fresh fruits, vegetables, cut flowers, and other similar commodities intended for storage should be as free as possible from skin breaks, bruises, and decay. They should be neither too immature nor overmature, because in either case their storage life may be impaired. The proper degree of maturity can usually be determined by consulting the various sections of this handbook or the publications listed in Literature Cited (p. 66); or it can be determined on the basis of previous experience. There is a seasonal variation, however, in the storage quality of certain products, particularly fruits; hence, care must be taken not to assume too much from 1 year's experience concerning the probable behavior of a given commodity grown the next year.

Decay and other deterioration in storage is too broad a subject to be discussed in detail in this publication; it is merely discussed generally in connection with various fruits and vegetables covered. For a discussion of the storage of the lesser known tropical fruits and vegetables not given herein, the reader is referred to Wardlaw's work (*183*).[3]

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[1] This handbook supersedes U. S. Department of Agriculture Circular 278, The Commercial Storage of Fruits, Vegetables, and Florists' Stocks.

[2] Retired.

[3] Italic numbers in parentheses refer to Literature Cited, p. 66.

Factors Involved in Cold Storage

Recommendations for the best conditions for the storage of fresh fruits, vegetables, and cut flowers are subject to change from time to time as more definite information is gained in the handling of these commodities. The conditions and requirements given are based on the best commercial practice at the present time and on scientific experimentation.

All temperature requirements are given in degrees Fahrenheit and represent the average air temperatures that should be maintained. The humidities are relative and are expressed in percentage of saturation; for example, when it is stated that a certain relative humidity should be 85 percent, this means that the air should be approximately 85 percent saturated with water vapor at the recommended temperature. Allowance has been made for the facts (1) that the temperature of fruits and vegetables in transit is usually higher than the recommended storage temperature; (2) that, except during winter weather, ripening or other changes are likely to go on more rapidly during a given transit period than during the same length of time in cold storage; and (3) that when the commodities arrive at destination, even if they had been in storage at shipping point, they are likely to be somewhat more mature than if they had remained in storage the whole time.

Temperature of Storage Rooms

If the best results are to be obtained in the cold storage of the products discussed herein, it is highly important that the temperature in storage rooms be held fairly constant. Variations of 2° or 3° F. above or below the desired temperature are too large in most cases. Variations can usually be prevented if the storage rooms are well insulated throughout and have adequate refrigeration, and if the spread between the temperature of the refrigerant and that of the room to be refrigerated is kept small. For example, in a room where 45° is the desired temperature, using ammonia evaporating at about 26° in the coils, fluctuations of ±1½° may occur in the air temperature in the room; whereas at 32°, with ammonia also at 26°, fluctuations in the room temperature are usually less than ±½°. However, the spread between the temperature of the refrigerant and that of the room is more important in maintaining humidity than in preventing fluctuations in the room temperature. This point is discussed in more detail on page 3. Storage rooms should be equipped either with reliable, accurate thermostats or with manual controls which are given frequent personal attention by someone charged with that duty. Even when reliable automatic controls are used, they should be checked periodically.

In commercial cold-storage rooms thermometers are usually placed at a height of about 5 feet for convenience in reading. It is important, however, to take temperatures frequently at the floor and the ceiling levels and at any other places where they might be expected to be undesirably high or low, including the insides of packages of the commodity. It would be shortsighted to rely on just one or two aisle temperatures. In providing recommended temperatures for given products, consideration should be given to differences between the temperatures of the air at the position of the thermometer and at

different places around and in the packages of the stored product, and also to differences between air and commodity temperatures. Often the packages are piled too closely together or distribution of refrigeration is inadequate to reach all parts of the piles of the stored commodity, and it is not unusual under such conditions to have commodities remain for several days or even weeks at temperatures several degrees higher than those indicated by the thermometer. This condition can be detected by opening the pile and taking commodity temperatures; and it can be corrected by wider spacing of packages and by the use of portable fans and baffles to direct the air currents to the centers of the piles. Rooms not equipped with some means of air circulation may need to be remodeled to provide more uniform temperatures and faster cooling of the commodities stored in them.

The importance of maintaining fairly constant temperatures in cold-storage rooms lies in the effect of such control, or the lack of it, on the keeping quality of stored commodities. Most varieties of apples keep best and longest if held constantly at 30° to 32° F.; the best temperature for Bartlett pears is between 29° and 31°. If the air temperature where either of these fruits is stored rises 2° or 3° above the upper limit mentioned, there is danger of increased decay and undue ripening, the danger being greater the longer the period during which the temperature is above 32°. For example, 3 or 4 days at 35° usually would have little or no effect, partly because of a slower rise in the temperature of the fruit than in that of the air; but 10 days at this temperature would probably shorten the life of the fruit by about a week and possibly result in more decay. On the other hand, if the temperature goes a degree or two below 29°, there is a chance that freezing will occur. Celery and cabbage allowed to remain too warm in storage may show yellowing and decay; potatoes are likely to begin to sprout if the temperature is too high and usually become undesirably sweet if it is too low. Other commodities undergo these or other kinds of deterioration if the temperature variations throughout long storage periods exceed the limits given for them in this handbook. In addition, there is always the possibility that fluctuations in temperature will cause condensation of moisture on stored products, which is undesirable because it favors the growth of mold and the development of decay.

Control of temperature is usually easier in large rooms than in small ones if both are filled to capacity. This is because of the "flywheel" effect produced by the larger mass of material, including both the commodity and the building material. Refrigeration is thus stored up, so to speak, and the temperature changes occur more slowly. For this reason small storage rooms usually require closer attention than large ones.

Humidity of Storage Rooms

The relative humidity of the air in storage rooms has a direct relation to the keeping quality of the products held in them. If it is too low, wilting is likely to occur in most fruits, vegetables, cut flowers, and similar products; if it is too high, it favors the development of decay, especially in rooms where there is considerable variation in temperature. The exact control of humidity is rather difficult, and in the past it was not often attempted in commercial storage warehouses.

However, as new plants are designed and old ones remodeled, more accurate control is being developed. Of first importance in maintaining adequate relative humidity in the storage-room air, is the providing of sufficient coil area so that the spread between the temperature of the coil and the desired commodity temperature is as small as possible. Conversely, when a low relative humidity is desired, the coil area should be restricted and the temperature lowered so that the moisture in the air will be condensed. Valves can be installed to control the evaporating pressure of the refrigerant; these are essential to good temperature and humidity control. A quick, temporary method of lowering the humidity is to introduce heat into the room by a blower or strip heater; this added heat will necessitate more refrigeration that will condense more moisture from the air. To build up the humidity, various commercial devices are used in which water vapor is introduced in the form of steam or as an atomized water spray. A humidistat is useful in automatically regulating the relative humidity.

When warm products are placed in a cold room, the spread between commodity temperature and refrigeration temperature is wide at first. As the spread is reduced, the cooling proceeds more and more slowly. Eventually, if the temperature of the refrigerant is properly adjusted and there is adequate refrigerated surface, the desired temperature can be reached without subjecting the commodity to excessive desiccation.

For most fruits that are stored commercially, a relative humidity of 85 to 90 percent gives the best results. Exceptions are discussed at various places in this handbook. For leafy vegetables and root crops, the relative humidity should be about 90 to 95 percent; for other vegetables, except as noted, 85 to 90 percent. If it is necessary to increase the relative humidity in rooms used for common, or air-cooled, storage, this can be done by sprinkling the floor occasionally. Earth floors are more desirable in air-cooled storages than floors of concrete because they are more easily kept damp. *An increase in air circulation necessitates an increase in relative humidity if wilting of the stored commodity is to be avoided.* Allen and Pentzer (*6*) found that doubling the rate of air movement increased moisture loss by about one-third and was equivalent to about a 5-percent drop in relative humidity. The drying effect of increased rate of air movement is particularly marked if the humidity of the air is lower than the moisture content of the commodity.

(See also 7.)

Sanitation in Storage Rooms

Maintenance of sanitary conditions would not be a problem if constant "good housekeeping" were practiced. Storage rooms should at all times be kept free from decaying fruit or vegetable material. If the floor and walls become moldy, they should be scrubbed with a good cleaner—for instance, one containing either sodium hypochlorite or trisodium phosphate—then immediately rinsed; and the room should then be aired. Ozone introduced into the room atmosphere at the rate of 1 to 2 parts per million (p. p. m.) has been reported to be effective in controlling mold growth on packages and on walls and also as a deodorant.

(See *27*.)

Evolution of Heat by Commodity

In any consideration of the storage of fresh fruits and vegetables, cut flowers, and similar products, it should be remembered that these commodities are alive and that they therefore carry on within themselves many of the processes characteristic of all living things. The most important of these processes is respiration, by which the oxygen of the air is combined with the carbon of the plant tissues, occurring chiefly in sugars, to form various decomposition products and eventually carbon dioxide and water. During this process, energy is released in the form of heat, the amount of which varies with the commodity and increases as the temperature increases, up to about 100° F. This heat is always a part of the refrigeration load that must be considered in handling fruits, vegetables, and cut flowers in cold-storage rooms or refrigerator cars. The approximate rates of evolution of heat by various commodities at different storage temperatures are given in table 1.

Some products have much higher respiration rates than others at given temperatures. This means that they require considerably more refrigeration than the more slowly respiring products, to keep them at a specified temperature.

The storage life of apples (as represented by three varieties with short, medium, and long storage periods) varies inversely as the rate of evolution of heat. The same relation of storage life to heat evolution holds true for products like broccoli, lettuce, peas, spinach, and sweet corn which have a relatively high rate of evolution of heat; and for onions, potatoes and storage varieties of grapes which have a low evolution of heat. (See table 1.)

In determining the heat to be removed in cooling fruits and vegetables to cold-storage temperatures, the following factors should be considered: The specific heat of the product; the rate at which it produces heat by respiration; and its initial and final temperatures. If the product could be cooled to the storage temperature instantaneously, the heat to be removed would be the number of British thermal units (B. t. u.), obtained by multiplying the specific heat of the product by the difference between the initial and the final temperature, and this result by the weight. This is usually called the sensible heat. The cooling process, however, requires time, and during this interval additional heat is produced by the respiration of the stored fruit or vegetable.

When fruits and vegetables cool, the rate at which they produce heat decreases; therefore, in order to determine the total amount of heat produced, it is necessary to know the rate of heat production at different temperatures and the length of time the product is in each temperature range. For example, if the respiration rate (or rate of heat production) for a given commodity is twice as great at 70° F. as at 50°, the number of hours this commodity is at each of these temperatures must be known before the total heat produced can be calculated.

Table 2 shows the approximate amounts of sensible heat and of heat produced by respiration which must be removed from several kinds of fruit in cooling them from various temperatures to 35° F. These figures are based on experimental determinations of the rate of respiration at various temperatures; some of the data are from the tables given by Magness and his associates (*101*, *103*), and the remainder from data reported by Haller and coworkers (*62*). The figures for

TABLE 1.—*Approximate rates of evolution of heat by certain fresh fruits and vegetables when stored at the temperatures indicated*

Commodity	Temperature	Heat evolved per ton of fruits or vegetables per 24 hours [a]	Literature reference
	° *F.*	*B. t. u.*	
Apples:			
Yellow Transparent	32	1, 500	[b]
	40	2, 660	
	60	7, 880	
	70	12, 380	
Jonathan	32	700 to 800	*(103)*
	40	820 to 840	
	60	2, 610 to 3, 470	
Winesap	32	300 to 320	
	40	590 to 600	
	60	2, 270 to 2, 350	
Bananas:			
Green	54	3, 300	*(113)*
	68	8, 360	
Turning	68	9, 240	
Ripe	68	8, 360	
Beans, lima:			
Fordhook	32	2, 330	[c]
	40	4, 300	
	60	21, 990	
	70	29, 220	
Variety unknown	32	3, 160	[b]
	40	6, 100	
	60	27, 410	
	70	37, 120	
Beans, snap:			
Stringless flat-podded	32	5, 610	
	40	9, 160	
	60	32, 090	
	70	45, 370	
Black Valentine	32	5, 500	
	40	11, 390	
	60	44, 130	
	70	52, 950	
Stringless Green Pod	32	6, 160	[d]
	40	10, 600	
	60	40, 850	
	80	49, 590	
Beets, topped	32	2, 650	[b]
	40	4, 060	
	60	7, 240	
Broccoli (variety unknown)	32	7, 450	
	40	11, 000 to 17, 600	
	60	33, 800 to 50, 000	
	70	47, 340 to 100, 000	
Cabbage, Globe	32	1, 200	[c]
	40	1, 670	
	60	4, 080	
	70	6, 120	
Cantaloups, Turlock	32	1, 320	[d]
	40	1, 960	
	60	8, 500	
Carrots, topped	32	2, 130	
	40	3, 470	
	60	8, 080	
Celery, New York white	32	1, 620	[c]
	40	2, 420	
	60	8, 220	
	70	14, 150	

See footnotes at end of table, p. 9.

TABLE 1.—*Approximate rates of evolution of heat by certain fresh fruits and vegetables when stored at the temperatures indicated*—Continued

Commodity	Temperature	Heat evolved per ton of fruits or vegetables per 24 hours [a]	Literature reference
	° *F.*	*B. t. u.*	
Cherries:			
Sweet	31	1, 249	(*50*)
	36	1, 459	
	45	2, 811	
Sour	32	1, 320 to 1, 760	(*75*)
	60	11, 000 to 13, 200	
Corn, sweet (Golden Bantam cross; not husked)	32	6, 560	
	40	9, 390	
	60	38, 410	
	80	61, 950	
Cranberries:			
Early Black	32	600	([d])
	40	870	
	50	1, 800	
Howes	32	720	
	40	970	
	50	1, 650	
Cucumbers, Producer and Wanchula	32	1, 690	([c])
	40	2, 550	
	60	10, 460	
Grapefruit, Florida	32	370 to 950	(*62*)
	40	725 to 1, 300	
	50	1, 340 to 2, 130	
	60	2, 200 to 3, 980	
	70	2, 640 to 5, 720	
	90	5, 060 to 6, 840	
Grapes:			
Concord	32	602	(*93*)
	40	1, 170	
	60	3, 487	
	80	8, 481	
Cornichon and Flame Tokay	36	660 to 1, 100	([e])
	60	2, 200 to 2, 640	
	80	5, 500 to 6, 600	
Sultanina	32	430	
	43	1, 050	
	53	1, 690	
Emperor	32	350	
	43	850	
	53	1, 810	
Ohanez	32	300	
	43	740	
	53	1, 570	
Lemons, Eureka	32	480 to 900	(*66*)
	40	620 to 1, 890	
	50	1, 610 to 3, 670	
	60	2, 310 to 4, 950	
	70	4, 050 to 5, 570	
	80	4, 530 to 5, 490	
Lettuce	32	11, 320	([d])
	40	15, 990	
	60	45, 980	
Mushrooms, cultivated	32	6, 160	
	50	22, 000	
	70	58, 000	
Onions, dry, Yellow Globe	32	660 to 1, 100	
	50	1, 760 to 1, 980	
	70	3, 080 to 4, 180	

See footnotes at end of table, p. 9.

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TABLE 1.—*Approximate rates of evolution of heat by certain fresh fruits and vegetables when stored at the temperatures indicated*—Continued

Commodity	Temperature	Heat evolved per ton of fruits or vegetables per 24 hours [a]	Literature reference
	° *F.*	*B. t. u.*	
Oranges, Florida	32	420 to 1, 030	(62)
	40	1, 300 to 1, 560	
	50	2, 400 to 4, 820	
	60	3, 650 to 5, 170	
	90	5, 240 to 9, 420	
Peaches	32	850 to 1, 370	
	40	1, 440 to 2, 030	
	60	7, 260 to 9, 310	
	80	17, 930 to 22, 460	
Pears, Bartlett	32	660 to 880	(101)
	60	8, 800 to 13, 200	
Peas:			
Improved Pilot	32	8, 160	
	40	13, 220	
	60	39, 250	
	80	75, 500	
Laxtonian	32	8, 360	(d)
	40	16, 020	
	60	44, 510	
	80	82, 920	
Peppers, sweet	32	2, 720	
	40	4, 700	
	60	8, 470	
Potatoes, Irish Cobbler	32	440 to 880	
	40	1, 100 to 1, 760	
	70	2, 200 to 3, 520	
Raspberries	32	3, 850 to 5, 502	(65)
	36	4, 400 to 6, 600	
	40	6, 750 to 8, 470	
	60	18, 080 to 22, 250	
Spinach:			
Bloomsdale Savoy	32	4, 240	(f)
	40	7, 850	
	50	17, 940	
	60	38, 000	
Virginia Savoy	32	4, 860	
	40	11, 210	
	50	20, 640	
	60	36, 920	
Strawberries	32	2, 730 to 3, 800	(65)
	40	3, 610 to 6, 750	
	50	9, 480 to 13, 090	
	60	15, 640 to 20, 280	
	70	22, 510 to 30, 160	
	80	37, 220 to 46, 440	
Sweetpotatoes, Nancy Hall:			
Not cured	32	2, 440	(d)
	40	3, 350	
	60	6, 300	
Cured	32	1, 190	
	40	1, 710	
	60	4, 280	
Tomatoes:			
Mature-green	32	580	
	40	1, 070	
	60	6, 230	
Ripe	32	1, 020	
	40	1, 260	
	60	5, 640	

See footnotes at end of table, p. 9.

TABLE 1.—*Approximate rates of evolution of heat by certain fresh fruits and vegetables when stored at the temperatures indicated*—Continued

Commodity	Temperature	Heat evolved per ton of fruits or vegetables per 24 hours [a]	Literature reference
	° *F.*	*B. t. u.*	
Turnips, topped	32	1, 940	[d]
	40	2, 150	
	60	5, 280	

[a] The figures in this column were obtained (1) by assuming that the heat liberated by respiration is produced by the respiration of a hexose sugar, and (2) by multiplying the milligrams of carbon dioxide produced per hour by each kilogram of respiring material by the factor 220.

[b] Unpublished report by T. M. Whiteman.

[c] Unpublished report by Morris Lieberman.

[d] Unpublished report on the respiration of vegetables by R. C. Wright and T. M. Whiteman.

[e] Unpublished report by W. T. Pentzer.

[f] Unpublished report by D. H. Rose and M. H. Haller.

Bartlett pears are based on the maximum values given by Magness and Ballard (*101*). The figures given in this table have been obtained by assuming that the heat of respiration is produced by oxidation of a hexose sugar to carbon dioxide and water, and they can be calculated from the rate of production of carbon dioxide, which has been determined experimentally. Very few calorimetric measurements of heat production by fruits and vegetables have been made; this assumption, therefore, seems to be the best available basis for calculating heat production at any given temperature. Investigations (*55*) indicate that calculations made on this assumption give values that are within 10 percent of those obtained calorimetrically.

The assumption has also been made, although it is believed to be only approximately correct for fruits and vegetables, that the rate of temperature drop during cooling is proportional to the difference between room temperature and fruit temperature. With this assumption as a basis, the temperature and thus the rate of respiration at any time during the cooling period, as well as the total heat produced during the whole cooling period, have been calculated.[4]

As a result of these calculations, it has been found that the heat produced by the respiration of fruit while it cools is directly proportional to the length of the cooling period. The figures for cooling periods of 3, 4, 5, 6, and 8 days are therefore set at 0.3, 0.4, 0.5, 0.6, and 0.8 (to the nearest thousand) of the figure for 10 days. The specific heat has been calculated by the formula $S=0.008a+0.20$, in which S signifies the specific heat of a substance containing a percent of water; 0.20 is the value that has been assumed to represent the specific heat of the solid constituents of the substance in question (*151*).

The values given in table 2 are only approximate. However, in view of the results of the investigations mentioned on page 5, it is believed

[4] The writers wish to acknowledge the valuable assistance given by W. V. Hukill, Agricultural Engineering Research Branch, Agricultural Research Service, in making the calculations and in preparing this statement on the production of heat by fruits and vegetables.

TABLE 2.—*Approximate amounts of heat of respiration and sensible heat to be removed from certain fruits in cooling them from 60°, 70°, or 80° to 35° F. in a room at 32°, when the cooling takes place in 3, 4, 5, 6, 8, or 10 days*

Kind of fruit	Initial temperature	Heat of respiration per ton of fruit during—						Sensible heat per ton [1]
		3 days	4 days	5 days	6 days	8 days	10 days	
	°F.	*B.t.u.*	*B.t.u.*	*B.t.u.*	*B.t.u.*	*B.t.u.*	*B.t.u.*	*B.t.u.*
Apples:	80	8,000	11,000	14,000	16,000	22,000	27,000	80,000
Winesap	70	7,000	9,000	12,000	14,000	19,000	23,000	62,000
	60	6,000	8,000	10,000	12,000	16,000	20,000	44,000
	80	12,000	16,000	20,000	24,000	32,000	40,000	80,000
Grimes Golden	70	10,000	13,000	17,000	20,000	26,000	33,000	62,000
	60	8,000	11,000	13,000	16,000	21,000	27,000	44,000
Peaches:	80	13,000	18,000	22,000	26,000	35,000	44,000	80,000
Elberta	70	10,000	13,000	17,000	20,000	26,000	33,000	62,000
	60	7,000	10,000	12,000	14,000	19,000	24,000	44,000
	80	16,000	22,000	27,000	32,000	43,000	54,000	80,000
Carman	70	13,000	17,000	21,000	25,000	34,000	42,000	62,000
	60	10,000	13,000	16,000	19,000	25,000	32,000	44,000
Pears:	70	16,000	22,000	27,000	33,000	44,000	54,000	61,000
Bartlett	60	13,000	17,000	22,000	26,000	35,000	43,000	43,000
Strawberries:	80	30,000	39,000	49,000	59,000	79,000	99,000	83,000
Chesapeake	70	24,000	32,000	40,000	49,000	65,000	81,000	64,000
	60	19,000	26,000	32,000	39,000	51,000	64,000	46,000
	80	38,000	51,000	64,000	77,000	102,000	128,000	83,000
Howard 17	70	31,000	42,000	52,000	63,000	84,000	104,000	64,000
	60	25,000	34,000	42,000	51,000	68,000	84,000	46,000
Oranges:	80	9,000	12,000	15,000	18,000	24,000	30,000	81,000
Florida seedling [2]	70	8,000	10,000	13,000	15,000	20,000	26,000	63,000
	60	6,000	9,000	11,000	13,000	17,000	22,000	45,000

[1] For any one kind of fruit at a given temperature, these figures are assumed to be the same for all cooling periods included in the table.

[2] The rate of respiration is practically the same for both Florida seedling oranges and California navel oranges.

that the two assumptions that have been made lead to fairly accurate results. The figures are presented to help cold-storage-plant operators estimate the refrigeration required for cooling the specified fruits under the various conditions given. As an example of how the figures can be used, the following calculation may be of interest: A ton of Bartlett pears cooling from 70° to 35° F. in 10 days in a 32° room is shown to be capable of producing about 54,000 B. t. u. Its sensible heat at 70° (35° above its final temperature) is 61,000 B. t. u. The sum of the two is 115,000 B. t. u. If this is multiplied by the capacity of the room in tons of fruit, say 600 (the capacity of some of the commercial cold-storage rooms in the United States) and divided by 288,000 (the number of British thermal units in a ton of refrigeration), the quotient 239 is obtained; this is approximately the number of tons of refrigeration required to cool 600 tons of Bartlett pears to 35° in 10 days under the conditions specified. The corresponding figure for Winesap apples is 177, and that for Grimes Golden apples, 200.

Cold Injury and Freezing Injury

Certain fruits and vegetables are susceptible to cold injury by temperatures that are not low enough to cause them to freeze. A list of commodities subject to such injury, together with their critical temperatures and symptoms of injury, is given in table 3.

Experimental observations and experience of commercial operators have shown a wide variation among commodities in their susceptibility to freezing injury. Some may be frozen and thawed a number of times without permanent injury, whereas others are permanently injured by even slight freezing. The freezing point of the commodity is no indication of the damage to be expected by freezing or chilling. For example, tomatoes and parsnips both have a freezing point of 30° F., but parsnips can be frozen and thawed several times without apparent injury, whereas tomatoes are ruined after one freezing. Again, mature-green tomatoes will be injured so that they will not ripen properly if held at 32° to 40° for longer than 3 to 5 days, whereas parsnips may be held at 30° for many weeks without deterioration provided they are not permitted to dry out.

The following tabulation gives the relative susceptibility of a number of commodities to actual freezing injury and shows their approximate freezing points. The commodities are arranged somewhat arbitrarily into three groups: (1) Most susceptible; (2) moderately susceptible; and (3) least susceptible. The first group comprises those that are likely to be injured by 1 light freezing; the second group, those that will recover from 1 or 2 light freezings; and those in the third group can be lightly frozen several times without serious damage. Commodities must be handled with special care while frozen because then they are much more susceptible to bruising.

Commodity and group:	*Approximate freezing point*[1] °F.
Most susceptible:	
Asparagus	30
Avocados	27
Bananas	30
Beans, snap	30
Berries	30
Cucumbers	31
Eggplant	30
Lemons	28
Limes	29
Peppers, sweet	30
Potatoes, white	29
Squash, summer	29
Sweetpotatoes	29
Tomatoes	30
Moderately susceptible:	
Apples	28
Broccoli, sprouting	29
Cabbage, new	31
Celery	30
Cranberries	27
Grapefruit	28
Grapes:	
American	28
Vinifera	25
Moderately susceptible—Continued	
Lettuce	31
Onions	30
Oranges	28
Parsley	(2)
Peaches	29
Pears	28
Peas	30
Plums	28
Squash, winter	29
Least susceptible:	
Beets	27
Brussels sprouts	(2)
Cabbage, old and Savoy	31
Carrots	30
Cauliflower	30
Kale	30
Parsnips	30
Rutabagas	30
Salsify	29
Spinach	30
Turnips	31

[1] Most of these temperatures are the approximate average freezing points; individual specimens may freeze at slightly higher or slightly lower temperatures.

[2] Freezing point not known.

For a further discussion of low-temperature responses, see Miller (*107*) and Wright (*205*).

TABLE 3.—*Commodities susceptible to cold injury when stored at only moderately low temperatures*

Commodity	Approximate lowest safe temperature	Character of injury when stored between 32° F. and safe temperature
	° *F.*	
Apples—certain varieties	34 to 36	Internal browning, soggy breakdown.
Avocados	45	Internal browning.
Bananas, green or ripe	56	Dull color when ripened.
Beans (snap)	45 to 50	Pitting increasing on removal, russeting on removal.
Cranberries	34	Low-temperature breakdown.
Cucumbers	45	Pitting, water-soaked spots, decay.
Eggplants	45	Pitting or bronzing, increasing on removal.
Grapefruit	45	Scald, pitting, watery breakdown, internal browning.
Lemons	55 to 58	Internal discoloration, pitting.
Limes	45	Pitting.
Mangoes	50	Internal discoloration.
Melons:		
Cantaloups	(1)	Pitting, surface decay.
Honey Dew	40 to 50	Do.
Casaba	40 to 50	Do.
Crenshaw and Persian	40 to 50	Do.
Watermelons	36	Pitting, objectionable flavor.
Okra	40	Discoloration, water-soaked areas, pitting, decay.
Olives, fresh	45	Internal browning.
Oranges, California	35 to 37	Rind disorders.
Papayas	45	Breakdown.
Peppers, sweet	45	Pitting, discoloration near calyx.
Pineapples	(2)	Dull green when ripened.
Potatoes, Chippewa and Sebago	40	Mahogany browning.
Squash, winter	50 to 55	Decay.
Sweetpotatoes	55	Decay, pitting, internal discoloration.
Tomatoes:		
Ripe	50	Breakdown.
Mature-green	55	Poor color when ripe; tendency to decay rapidly.

[1] See Cantaloups, p. 41, and table 6, p. 31.
[2] See Pineapples, p. 28, and table 6, p. 30.

Ammonia Injury

Damage from escaping ammonia sometimes occurs to products in storage where direct-expansion refrigeration systems are used. Slight injury may be indicated by brown to greenish-black discoloration of the outer tissues of fruits and vegetables; this injury is usually rated as blemishes. Severe injury may be marked by discoloration and softening of the deeper tissues, which render the products unmarketable.

It was demonstrated that an ammonia concentration of 0.8 percent caused injury to apples, pears, bananas, peaches, and onions within an hour (*130*, *131*), and that concentrations that were barely detectable by odor caused darkening of the skins of pecan nuts (*137*). It has recently been reported that sulfur dioxide serves as a satisfactory neutralizing agent for light ammonia damage to commodities that are tolerant to sulfur dioxide, such as grapes, almonds, and filberts. In this test 1 percent sulfur dioxide was used for grapes and 5 percent for the nuts (*34*). This treatment is unsatisfactory for pecans because the discoloration can only be removed temporarily, and it reappears when the sulfur dioxide is removed.

Waxing

The application of waxing preparations to certain perishable products has been practiced commercially for several years. It probably started with the waxing of citrus fruits and was followed by the waxing of rutabagas. Wax is used commercially on some other products, such as cucumbers, tomatoes, cantaloups, potatoes, and sweetpotatoes. (See Sweetpotatoes, p 47.) The materials used are either paraffin or a vegetable wax and paraffin formulation. Citrus fruits, cucumbers, parsnips, and rutabagas are definitely benefited by waxing, because shrinkage due to water loss is restricted. With most other products, improved appearance seems to be the only advantage. (See *24*, *127*, *141*, *177*, *204*.)

Effect of Cold Storage on Subsequent Behavior of Fruits and Vegetables

There is a belief that cold storage predisposes fruits and vegetables to rapid deterioration after removal, but there is no evidence to support this viewpoint except in instances of overrefrigeration of those products that are sensitive to cold. (See tabulation, p. 11.) At unrefrigerated temperatures the commodity usually ages quickly and spoilage soon takes place. At refrigerated temperatures these processes are retarded, and the net result is longer life. As some of the potential life is used up in storage, it is not reasonable to expect the commodity to keep so long after removal as freshly harvested produce; but if the correct temperature and humidity are employed and suitable storage periods are not exceeded, there will be sufficient time for the commodity to pass through the normal marketing channel after removal. Extremely perishable fruits and vegetables have a short storage life and must be used soon after they are taken from storage.

Sweating

When fruits or vegetables are removed from a low temperature to a higher one, there is frequently a condensation of moisture from the air on the cool surface of the commodity. This is known as sweating; and the higher the relative humidity of the outside air, the more marked it becomes. It should be prevented whenever possible in the case of onions and the more tender fruits, because it favors the development of decay. This does not mean that when any of these products sweat after removal from an iced refrigerator car or a refrigerated room they are sure to decay; it does mean that they are more likely to

decay than if they were dry after being unloaded and remained dry until consumed. In this connection, dryness means merely the absence of liquid water on the surface.

Sweating can be prevented to some extent by allowing the fruits or vegetables to warm up gradually. Usually, if the commodity temperature is raised to only 50° or 55° F., little or no condensation occurs. Under commercial conditions, however, such precautions are rarely practical. Ordinarily, the best procedure in very damp weather is to handle the product carefully and get it into consumption without undue delay.

Choice of Storage Conditions

Unless otherwise noted the storage conditions recommended herein are the optimum for newly harvested products. Under certain circumstances it may be necessary to choose conditions that are not optimum because desired conditions are not available. The storage temperatures given in this handbook are usually as low as is safe or practical, and if an alternate temperature must be chosen, it should in most instances be higher than that recommended. When a higher temperature is chosen, it should be recognized that the storage life will be proportionately shortened, and frequent inspections should be made to determine the condition of the product. At times it may be necessary to store different products together; experience has shown that this is safe except with some products where there is a cross-transfer of odors. Combinations that should be avoided in storage rooms are apples with celery, cabbage, potatoes, or onions; celery with onions; and citrus fruit with any of the strongly scented vegetables. Odors from apples and citrus fruits are readily absorbed by dairy products. As a rule, when apples and potatoes are stored together at about 40° F. or higher, the apples acquire an unpleasant earthy taste and odor. If these are held together at 32°, little or no odor transfer is noticeable, but this temperature is undesirable for potatoes (see Potatoes, p. 44). Additional undesirable combinations are mentioned in connection with the various commodities discussed later in this handbook.

Fresh Fruits

By R. C. Wright and Dean H. Rose

The recommended temperature, relative humidity, approximate length of storage period, and average freezing point where applicable, for the commercial storage of fresh, dried, and frozen fruits, and nuts are given in table 6 (see pp. 30–31). Detailed descriptions of these requirements are given in the text.

Apples

(Temperature, see text; relative humidity, 85 to 90 percent)

There is a wide variation in the storage quality of different varieties of apples. Table 4 shows the comparative storage life and susceptibility to specific storage disorders of most of the important commercial varieties. Storage quality within a variety differs greatly, depending on such factors as the locality where grown, seasonal climatic conditions in the locality, cultural and spraying practices of the grower, maturity when picked, care in handling, length of time

between picking and storage, and storage practices. As an example of how varieties vary when grown in different localities, McIntosh apples grown in the Middle Atlantic States mature as early fall apples and are suitable for only 2 to 3 weeks of storage; when grown in New England, they mature late and are suitable for storage as long as 4 to 5 months. In the same locality storage disorders vary with growing conditions during different seasons. The amount of storage scald varies from year to year. Severe scald has been associated with ample soil moisture during the growing season (*60*). When picked in an early stage of maturity, apples are more subject to scald, whereas those picked late are more likely to develop breakdown in storage (*64*, *103*). The use of a preharvest spray of growth-regulating materials to control dropping has made it possible to delay harvest until later than formerly, when the tendency was to harvest early to avoid dropping. If, however, the delay in harvest afforded by this spray extends beyond optimum maturity, the storage quality of the fruit may be adversely affected.

TABLE 4.—*Normal and maximum storage period for apples of certain important varieties and their susceptibility to storage disorders*

Variety	Storage period		Tendency to storage scald	Other disorders likely to occur in storage
	Normal	Maximum		
	Months	*Months*		
Gravenstein	0 to 1	3	Slight	Bitter pit, Jonathan spot.
Wealthy	0 to 1	3	do	Soft scald, Jonathan spot.
Grimes Golden	2 to 3	4	Severe	Soggy breakdown, bitter pit, shriveling.
Jonathan	2 to 3	4	Slight	Jonathan spot, water core, soft scald, internal breakdown.
McIntosh	2 to 4	4 to 5	do	Brown core, soft scald.
Cortland	3 to 4	5	Medium	Breakdown.
Rhode Island Greening.	3 to 4	6	Severe	Bitter pit, internal breakdown.
Golden Delicious	3 to 4	6	Very slight	Shriveling, soggy breakdown.
Delicious	3 to 4	6	Slight to medium.	Bitter pit, water core, internal breakdown.
Stayman Winesap	4 to 5	5 to 6	Severe	Internal breakdown, water core.
York Imperial	4 to 5	5 to 6	do	Bitter pit.
Arkansas, Black Twig	4 to 5	6	do	Bitter pit, water core.
Northern Spy	4 to 5	6	Slight	Bitter pit.
Baldwin	4 to 5	6 to 7	Medium to severe.	Do.
Rome Beauty	4 to 5	6 to 7	do	Bitter pit, brown core, soft scald, internal breakdown, Jonathan spot.
Ben Davis	4 to 5	8	Medium	
Yellow Newtown	5 to 6	8	Slight	Bitter pit, internal browning (in California).
Winesap	5 to 7	8	Medium	Water core, shriveling.

Water core develops in fruit of some varieties, especially when harvested late. This is reported to be caused by abnormally high growing temperatures (*41*). The disorder usually decreases as the storage period lengthens, and if not severe it may entirely disappear from firm-textured varieties, such as Winesap and Yellow Newtown. Water core in soft-textured varieties, such as Jonathan, Delicious, Stayman Winesap, and Rome Beauty, frequently develops into breakdown; and if this condition is found, the fruit should be marketed early.

To insure good keeping quality, apples must not only be sound and at the proper stage of maturity but they must be carefully handled in all operations, including picking, grading, and packing. It is essential that apples be cooled as quickly as possible after harvest. If the apples are picked during hot weather, it may be advantageous to allow the crates to remain stacked in the orchard in the shade and store them the next morning while they are cool. If adequate refrigeration and air circulation are not provided, apples take several weeks to cool and their storage life is shortened (*42*, *48*, *152*). Storage practices can, to a considerable extent, be coordinated with the harvesting, handling, and marketing. Apples that for any reason are likely to have a poor storage-life expectancy should be segregated and marketed early (*79*).

Apples that have become frozen before removal from the orchard should be allowed to thaw before being handled, as bruising and freezing injury may be increased by handling the fruit while frozen. Moderate freezing does not affect the keeping quality, but if freezing is severe the storage life may be shortened. If apples are stored in field crates, to be packed later when labor becomes more available, packing and wrapping in oiled paper should not be delayed too long or the benefit of oiled paper for control of scald will be lost.

Scald is probably the most serious disorder of apples in storage. Packing in shredded, oiled paper (one-half pound per bushel) or using oiled wraps are the most dependable means of reducing damage from this disorder. Even these treatments do not give complete control for susceptible varieties, especially when the apples are picked early or during seasons that favor susceptibility. Scald is frequently not visible in storage but develops rapidly when the fruit is removed. To determine whether apples are nearing the end of their storage life, it is advisable to remove a sample to outside room temperature and watch for the development of scald, particularly with susceptible varieties (table 4).

The various diseases that develop in apples during storage are described and discussed in Miscellaneous Publication 168 (*143*). (See also *17*, *42*, *53*, *58*, *126*.)

In most varieties of apples the longest storage life is obtained by maintaining a temperature of 30° to 32° F. and a relative humidity of 85 to 90 percent. However, unless the temperature can be uniformly and accurately controlled, a temperature as low as 30° should not be attempted since this is relatively close to the freezing point of apples (28.4°) and accidental freezing might occur. Somewhat higher temperatures are recommended for certain varieties because of their susceptibility to storage disorders induced by temperatures as low as 30° to 32°. Yellow Newtown apples, grown in Pajaro Valley of California, and McIntosh and Rhode Island Greening apples, grown in New York and New England, are best stored at 36° to 38° to prevent the development of internal browning. Grimes Golden apples are gener-

ally stored at 30° to 32°, but when they are grown in some areas they should be stored at 34° to 36° to avoid soggy breakdown. Jonathan and Delicious apples are sometimes subject to soft scald at the lower temperature range. This can be controlled in Jonathans by storage at 34° to 36°, but at this range Jonathan spot and breakdown are encouraged.

Tests on Delicious apples in the Northwest have shown that storage for 8 weeks at 34° previous to lowering the temperature to 30° was effective in controlling soft scald in susceptible stock (*54*, *178*). The storage temperature for these special varieties will have to be determined by experience with similar fruit. Soggy breakdown and soft scald are more likely to occur when storage has been delayed; and when these injuries occur, the higher storage temperature and early disposal of the fruit are advisable. (See *5*, *17*, *20*, *42*, *63*, *68*, *78*, *103*, *123*, *124*, *125*, *126*, *136*, *153*, *157*.)

Apples in storage should be inspected frequently so that they may be removed and sold while still in good condition and with sufficient shelf life to permit usual marketing. Ripening and deterioration will be greatly accelerated by the higher temperatures met with after removal from storage. Investigations have shown that ripening at 40° F. is about twice as fast as at 32°; at 50°, about twice as fast as at 40°; and at 70°, about twice as fast as at 50°. (See *42*, *58*, *63*, *78*, *79*, *126*, *136*, *153*, *157*, *158*.)

With certain varieties of apples, principally the McIntosh in New York and New England and the Yellow Newtown in California, for which it is desirable to use a higher storage temperature (36° to 38° F.) to prevent the low-temperature disorders discussed, the faster ripening at the higher temperatures can usually be prevented by a controlled atmosphere. This means an atmosphere adjusted to contain about 10 percent carbon dioxide and 5 percent oxygen instead of the normal amounts (0.2 to 0.3 percent carbon dioxide and 21.0 percent oxygen). This practice has proved successful in special instances but is subject to certain objections, including the great expense of rendering a storage airtight and the difficulty of maintaining the proper concentrations in the atmosphere. Such a storage must be kept closed during the storage period, and it cannot be entered frequently as is customary in this country. (See *23*, *27*, *43*, *83*, *122*, *123*, *155*, *159*.)

Another modification of the storage atmosphere is that in which the room air is circulated through activated coconut-shell carbon to remove volatile emanations from the fruit. This has been adopted by some commercial storages. Investigations in New York have indicated a reduction in scald and retardation in ripening by this air-purification treatment. Studies elsewhere, however, have failed to show this effect consistently, probably because of differences in the methods of approach or the use of fruits at different stages of maturity. (See *23*, *39*, *53*, *153*, *156*.)

Ozone introduced in the storage-room atmosphere at the rate of 1 to 2 p. p. m. has proved effective as a deodorizing agent and in controlling the growth of molds on packages and on walls, but it has not controlled decay and scald. Concentrations as high as 3.25 p. p. m. increased decay and impaired flavor. (See *146*, *154*.)

Early, or summer-maturing, apples in the East are seldom stored except temporarily, as most of them are perishable and go directly to

the fresh-fruit market. On the west coast, however, the Gravenstein apple, which matures in July, can be stored as long as 3 months to prolong its season for the fresh-fruit market and for processing. (See table 4.) (See *8*.)

Apricots

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

Apricots are seldom stored in commercial quantities, although they keep well for 1 to 2 weeks at 31° to 32° F. Fruit picked when firm enough to ship or store has about the same maturity as that commonly used for canning and lacks the character and full flavor of the ripened fruit.

Avocados

(Temperature, see text; relative humidity, 85 to 90 percent)

The best general storage temperature for most varieties of avocados is close to 45° F., although some of the West Indian varieties are best held at 55°. Most varieties can be held in storage for about 4 weeks. Slow ripening occurs at 55°.

When held below 45° F., avocados tend to become discolored internally and fail to soften when removed from storage. At the higher temperature (55°) anthracnose, a fungus disease of avocados, will probably be an important factor in the storage of this fruit. At the lower temperature (45°) decay is not likely to be troublesome even during long storage.

(See *97*, *114*, *182*, *184*, *202*.)

Bananas

(Temperature: Ripening, 62° to 70° F.; holding ripe fruit, 56° to 60°. Relative humidity: Green fruit, 90 to 95 percent; ripe fruit, somewhat reduced but not below about 85 percent)

The banana is one of the fruits that must be shipped to market green, because in this condition it can be handled for a longer time without becoming overripe and without serious injury from bruising during the marketing process. Furthermore, bananas of the Gros Michel variety, which make up the great bulk of bananas shipped into this country, if allowed to ripen on the plant, become mealy, lack flavor, and are subject to splitting, with subsequent decay.

The bunches of green bananas as they are received from the tropics are usually hung closely together in special rooms, where they start to ripen, at 68° to 70° F. for 24 hours, with a relative humidity of 90 to 95 percent. Steam or water mist may be introduced during the first 3 or 4 hours. Each day thereafter the temperature is reduced about 2° until 60° is reached. The relative humidity is reduced gradually, but it should not go below 85 percent. It takes about 7 days to ripen most bananas as they arrive at the market. Prolonged exposure to high temperatures causes poor color and weak necks, and hastens decay.

The lowest temperature at which green bananas can safely be held to delay ripening is about 56° F.; below this they become chilled and injury to the peel results. Both green and ripe bananas are susceptible to chilling caused by low but not freezing temperatures. Ripe fruit is slightly more susceptible to chilling injury than green fruit. Fruit

chilled in the green stage does not develop a bright-yellow color on ripening, but instead, a smoky, dull color. Fruit chilled after ripening develops a dull-brown color when later exposed to higher temperatures and is very susceptible to handling marks; the slightest bruising causes discoloration.

The best holding temperature for ripe bananas is generally considered to be 60° F. or slightly lower. At this temperature, they retain their good appearance and flavor and remain edible for a week or 10 days, although ordinarily they do not keep firm enough for shipment for more than half that time. Ripe bananas are extremely perishable, and ripening should be timed so that they need not be held more than a few days after they are ready for the market.

(See *47*, *187*.)

Blackberries

Short storage only. See Raspberries.

Cherries

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

The approximate limit for the successful commercial cold storage of fresh sweet cherries at shipping point is probably about 10 days to 2 weeks. It is doubtful whether fresh cherries from California and the Pacific Northwest can be held satisfactorily in cold storage for more than about a week after arrival at eastern markets. This would mean about 16 days from harvest. If held longer than the period indicated, they begin to lose flavor and the bright, attractive appearance characteristic of the fresh fruit. The stems may also dry out noticeably, especially if the relative humidity is low. Color changes and decay can be retarded by the use of carbon dioxide gas in transit (*52*). In fact, the treatment has proved so beneficial in this respect that it is now being used commercially for shipments of cherries from the West and Northwest to eastern markets.

Sweating is particularly troublesome on cherries because of the dull appearance it produces on fruit displayed for sale soon after removal from iced cars. If cherries are held too long after removal from storage, especially if they are wet from sweating, brown rot and gray, blue, or green mold rots may develop.

Sour cherries are generally unsuitable for storage, except for a few days at 32° F. to extend the processing period.

For a further discussion of storage diseases of cherries, see Miscellaneous Publication 228 (*142*).

Coconuts

(Temperature, 32° to 35° F.; relative humidity, 80 to 85 percent)

Coconuts are best stored at 32° to 35° F. and can be held satisfactorily within that range for 1 to 2 months.

Cranberries

(Temperature, 36° to 40° F.; relative humidity, 85 to 90 percent)

A large part of the cranberry crop is held at the bog every year until wanted for Thanksgiving and the Christmas holidays. When so held it is usually kept either in common (air-cooled) storage or in arti-

ficially refrigerated warehouses. The storage period is usually not longer than about 3 months, and for this length of time the range from 36° to 40° F. has been found to be the most desirable.

Keeping quality is determined to some extent by maturity and variety. However, storage life may vary from year to year in fruit from the same bogs.

Poorly colored fruit may be held at 45° to 50° F. for a few weeks, to permit more rapid coloring than would occur at lower temperatures. Storage for more than about 4 months, in the range from 36° to 40°, is not satisfactory because of the common occurrence of end rot, a fungus disease that can develop at low temperatures (*208*). Shrinkage of the berries as a result of water loss is also a limiting factor.

Cranberries for long-time storage are best held "in the chaff" in the picking crates as they come from the field. Thus handled, they keep better than if sorted and cleaned previous to storage.

Cleaned and sorted cranberries can safely be stored at the market in crates or in prepackaged ventilated consumer units for a short period of 2 to 3 weeks at 32° F., but fruit held for a longer time at that temperature is likely to develop "low-temperature breakdown." Berries in this condition are rubbery when pressed between the fingers; the flesh is permeated with red pigment from the skin, and some of the natural luster disappears. Such berries closely resemble those that have been frozen. Fruit held at 36° to 40° is less likely to discolor and become rubbery but is more likely to decay than if held at 32°.

(See *10*, *45*, *138*.)

Dates

(Temperature, see text; relative humidity, see text)

Dates readily absorb moisture and odors from the air. The rate of absorption is much less at temperatures below 32° F. than at those above 32°. Deterioration caused by humidity above 75 percent is slow at storage temperatures below 28°. The dates of commerce are of three grades with respect to storage life—dried, cured, and noncured. The cured and noncured grades are perishable. A temperature as low as 0° has no deleterious effect upon dates but is actually beneficial to them. If the moisture content is kept at about 23 percent, dates can be kept for several months, but if they gain in moisture they will become perishable and if they lose moisture they become too dry for consumer acceptance.

Dates are of two different types, and fruits of each type can be either dry, cured, or noncured. The cane-sugar type is usually firm, light-colored, and comparatively dry, whereas the invert-sugar type is usually softer, darker colored, and inclined to be slightly sticky or sirupy.

Deglet Noor, the most important variety grown in this country, is of the hard cane-sugar type. Dates of this variety, cured grade, keep well until March at 28° to 32° F. and for a year at 24° to 26° or lower, whereas the noncured grade requires 18° or lower for storage until March and 0° to 10° for a year. In Deglet Noor dates that have become overripe or have been held under unfavorable storage conditions the cane sugar is inverted and the dates become soft, sirupy, and darker in color. Such dates are commonly graded as "dark soft." If they can be dried down somewhat, they can be stored at 28° to 32° until Christmas without becoming objectionably dark and sirupy,

although a temperature of 0° to 10° will be needed if they are to be stored until March. (See *11, 76, 144, 145.*)

Halawy, Khadrawy, Zahidi, and Saidy dates are all of the invert-sugar type, and the cured grades can be kept until Christmas at 28° to 32° F. without forming sugar spots but require a temperature of 18° or lower if stored until March. Noncured grades of these varieties require 0° to 10° for even short storage. After Christmas it is well to shift all dates of the invert-sugar type remaining in storage to "freezers" at 0° to 10°. (See *2, 11*).

Dewberries

Short storage only. See Raspberries.

Figs, Fresh

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

Fresh figs in storage require a temperature of 31° to 32° F. and a relative humidity of 85 to 90 percent, but even under these conditions they cannot be expected to keep satisfactorily for more than about 10 days. Alternaria spotting that may start while figs are on the tree and continue to develop in storage, especially at near 50°, greatly detracts from the appearance of the fruit.

Grapefruit

(Temperature, see text; relative humidity, 85 to 90 percent)

Storage rooms for grapefruit should have a relative humidity of 85 to 90 percent. Lower humidities favor the development of pitting where cells have been damaged by chilling injury, and higher humidities may increase decay.

For short-time storage, grapefruit can be held satisfactorily at a temperature of 32° F. For longer periods, the temperature to be used will depend on the character of the fruit and the troubles most likely to be encountered, especially stem-end rot.

In sections where stem-end rot caused by *Phomopsis*, which readily develops at temperatures of 50° to 55° F., is prevalent, a storage temperature of about 32° is needed; and about a month is as long as this fruit can be stored. Where stem-end rot caused by *Diplodia*—which grows slowly at 50° to 55°—is prevalent, the limiting factors are likely to be storage pitting, scald, and watery breakdown, which develop most seriously at temperatures of 40° or lower. For this fruit, a temperature of 45° to 55° is more satisfactory; and the more rapid development of undesirable high color and the increase in blue mold and green mold rots at the higher temperatures have not been found so objectionable on such fruit as the pitting that results from storage at lower temperatures.

Sound fruit that is not overmature or likely to suffer from stem-end rot can usually be held for 4 to 6 weeks without serious spoilage at 45° to 50° F., and this storage period can sometimes be doubled with satisfactory results. However, storage for as long as 10 to 12 weeks should be attempted with great caution because of the loss of quality or flavor and rapid breakdown after removal from storage (*81*). Fruit of low acidity (0.5 percent citric acid) is not considered to be of good storage quality, and probably for this reason midseason fruit

generally keeps better than late-picked fruit. Weak or overmature fruit requires close watching from the time it is removed from the tree, regardless of storage conditions.

The percentage of stem-end rot in Florida and Texas grapefruit will be greatly reduced if the fruit is properly treated with borax, sodium metaborate, or Dowicide A-hexamine; pulled from the tree instead of being clipped (*199*); and precooled before being shipped. The disbuttoning that may occur during handling and packing is also effective in reducing loss from stem-end rot. As compared with stem-end rot, blue mold and green mold rots are relatively less important on Florida grapefruit in storage. Stem-end rot is not known to occur on California and Arizona grapefruit.

The use of diphenyl-treated box liners has proved advantageous in controlling decay found at the market.

For a description of diseases of grapefruit, see (*139*). For a digest of literature on grapefruit storage, see Bibliographical Bulletin 13 (*141*).

(See also *18*, *46*, *66*, *160*, *161*, *198*, *199*, *200*.)

Grapes

Vinifera

(Temperature, 30° to 31° F.; relative humidity, 85 to 90 percent)

Large quantities of the European, or vinifera, grapes, grown principally in California, are stored every year. The most important of the varieties stored are Emperor and Ohanez (Almeria). Olivette de Vendemain, Malaga, Sultanina (Thompson Seedless), Cornichon, and Alphonse Lavallee (Ribier) are also stored occasionally. Largely because of their high sugar content, all these grapes have freezing points that are lower than the freezing points of any other important fresh fruit. Although for most varieties there is no danger of freezing injury at temperatures as low as 28° F. (*21*), they are usually held at temperatures of 30° to 31°.

Grapes should be well matured when harvested, since they do not ripen after harvest as do apples. Picking should not be delayed after full maturity has been reached. Rapid cooling is essential. Grapes are sometimes precooled before being stored, but most of the volume goes directly into storage, where adequate refrigeration and air movement are essential. Air volumes of 4,000 to 6,000 cubic feet per minute (c. f. m.) per carload are recommended for the first 24 to 36 hours for rapid cooling, after which the volume is reduced to prevent wilting; but some air movement is needed to insure a uniform temperature. Air velocities of 100 to 150 c. f. m. in the aisles are not uncommon; and under these conditions, a relative humidity of about 90 percent is desirable. If the room does not have forced-air circulation, humidities of 85 to 88 percent may suffice.

Most California grapes are stored in display-type, lidded lugs. The older sawdust pack in chests or lugs is still used to a limited extent. Only good, sound fruit should be selected for storage. Heavy rains prior to harvest favor infection by decay organisms; therefore the best storage quality is obtained in seasons with dry weather before and during harvest. Fruit injured in harvesting and handling should be removed during packing. Varieties differ in keeping quality. The best storage varieties, when properly handled, can be held 3 to 6 months

in storage at 30° to 31° F. Emperor, Ohanez, and Alphonse Lavallee (Ribier) belong to this group.

Treating grapes with sulfur dioxide has helped to reduce spoilage in storage. The common practice is to fumigate with concentrations of about 1 percent of sulfur dioxide before storage and to refumigate with about 0.2 percent of the gas at intervals of 1 week to 10 days. Under these conditions fruit has been held fully as long in the display-type lugs as in the more expensive sawdust packs. When fruit packed in display lugs cannot be refumigated in storage, 5 grams of sodium bisulfite is often added to the pads before packing, and this is followed by the usual prestorage fumigation. Mixing 5 grams of sodium bisulfite (per lug, chest, or keg) with the sawdust used in packing grapes has also been effective in checking decay. When grapes are shipped with the intention of storing them, they should be fumigated before shipment, since during picking and packing the grapes may be sufficiently injured to allow the entrance of mold that will cause decay unless it is killed by fumigation. In plants used exclusively for grape storage, the fumigating gas is often introduced into the air system, thus insuring even distribution.

(See *7*, *21*, *115*, *117*.)

American

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

The eastern, or American, varieties of grapes, the most important of which is Concord, are not adapted to long storage; they hold up well under storage conditions for only 3 or 4 weeks at the most, depending on the variety. After that, they begin to deteriorate in flavor, and considerable decay may develop if the temperature is not kept close to 32° F. Catawba grapes keep better than most other eastern varieties and, if in good condition when stored, can be held for 3 to 8 weeks even in common storage in the districts where this variety is grown on a commercial scale. Eastern grapes are not fumigated with sulfur dioxide because of their susceptibility to injury.

Too low humidity is undesirable for grapes, since it causes shriveling, especially of the stems. Stock intended for storage should be handled carefully to prevent cracking of the berries or loosening at the cap stem, because such injuries allow juice to exude and thus furnish conditions favorable to incipient decay.

Muscadine grapes are shipped only short distances if at all and are not known to be held in cold storage anywhere in commercial quantities.

(See *6*, *93*.)

Lemons

(Temperature: 55° to 58° F. during storage at point of origin; 50° to 55° on arrival at market. Relative humidity, 85 to 90 percent)

Lemons are picked during any month of the year, but the bulk are picked during the winter months when consumption is relatively light. Fortunately, fruits picked during this time have the capacity to endure storage and are even improved by it, so that they are better able to withstand shipping and marketing operations. Most lemons when harvested are not ready for immediate consumption but need conditioning to develop color, juice content, and flavor. This is customarily done in air-conditioned, refrigerated warehouses maintained at 55°

to 58° F. with a relative humidity of 85 to 90 percent. Under these conditions lemons should keep 1 to 4 months. Experience has shown that at temperatures much below 58°, pitting, staining of the membranes separating the segments, and red blotch develop. Temperatures higher than this favor the growth of decay organisms and otherwise shorten the storage life. Lemons that are of proper size and dark-green color when picked have the longest storage life. Tree-ripened fruit does not keep well in storage. Lemons from different production areas have different keeping qualities (*100*).

On arrival at distant markets the fruit is less capable of withstanding decay organisms such as blue mold, green mold, and alternaria rots; and tests (*73*) show that there is risk of considerable spoilage if lemons are stored for more than a few weeks. Only lemons of strong storage potential should be held at terminal storages for more than a few days. Strong stock may be held at any convenient temperature from 32° to 55° F. for less than 4 weeks, but for longer periods a temperature of 50° to 55° should be used. Frequent inspections should be made during storage to determine the condition of the fruit. The lemons should be removed in time to allow 1 to 2 weeks at 70° for marketing and consumer holding until used.

It is of the utmost importance that lemons be handled carefully during picking and packing in order to avoid clipper cuts, scratches, and bruises and consequent damage later by green mold rot and blue mold rot. The fungus that causes the blue mold rot is able to penetrate the uninjured skin of lemons but it is likely to cause more loss if the skin of the fruit is broken. It can also spread from one fruit to another in the package and for this reason is frequently referred to as "blue contact rot." Air conditioning as now used in some of the lemon storage houses in California furnishes a means of preventing condensation of moisture on fruit and so decreases the amount of decay.

Lemons and other citrus fruits should not be stored in the same rooms with dairy products because of the readiness with which the latter absorb odors. (See also p. 14.)

(See *73*.)

Limes

(Temperature, 48° to 50° F.; relative humidity, 85 to 90 percent)

Preliminary investigations with Tahiti (Persian) limes indicate that fruit from a well-kept grove may be stored satisfactorily at a temperature of 48° to 50° F. for 6 to 8 weeks, provided the relative humidity is kept above 85 percent or the fruits are wrapped so as to prevent moisture loss. Prevention of desiccation is very important. For best quality, the Tahiti lime should be picked while still green but after the fruit has become "full" and smooth, having lost the "dimpled" appearance around the blossom end.

Key (Mexican, or Dominican) limes can be stored satisfactorily at the temperatures recommended for Tahiti limes. The preferred color for this variety on the markets of the United States is yellow.

Temperatures above those recommended permit the development of stem-end rot, which is often a serious factor in the marketing of limes from Florida and the West Indies. Limes are subject to pitting at temperatures below 45° F. This condition develops soon after removal from storage. Under aggravated conditions the pits may coalesce, forming brown blemishes of various sizes.

Logan Blackberries

Short storage only. See Raspberries.

Mangoes

(Temperature, 50° F.; relative humidity, 85 to 90 percent)

Mangoes should keep 2 to 3 weeks at 50° F. and at 85 to 90 percent relative humidity.

Nectarines

See Peaches and Nectarines.

Olives, Fresh

(Temperature, 45° to 50° F.; relative humidity, 85 to 90 percent)

The best storage temperature for fresh olives (*118*) lies between 45° and 50° F., and the safe storage period is 4 to 6 weeks. At lower temperatures the flesh of green fresh olives becomes brown, beginning around the seed and at the stem end. Ripe fresh olives develop more browning than green ones, showing severe discoloration even at 50° if stored for more than about a month. Browning in its early stages can be detected only by cutting the fruit.

Oranges

(Temperature: Florida, 30° to 32° F.; California, 35° to 37°. Relative humidity, 85 to 90 percent)

Most of the commercial varieties of oranges go directly to the fresh-fruit market during the winter and spring months. The Valencia, which is a late variety in both Florida and California, is harvested over a relatively long season. Part of it goes to the fresh-fruit market, but part is stored to extend its marketing season far into the summer.

The successful storage of oranges demands that the fruit be harvested at the peak of maturity and carefully handled during all operations; and also that, when transported over long distances to terminal storage, it be precooled and refrigerated in transit. On arrival, prompt refrigeration at the recommended temperature is important.

The orange does not improve in quality in storage. It is subject to several kinds of decay and other disorders that may develop in storage. The most common decay in Florida oranges is stem-end rot, whereas California fruit is particularly subject to blue mold and green mold rots (*139*). Decay is being reduced by the use of a wash containing Dowicide A-hexamine (*100*). Stem-end rot is being controlled to some extent by the use of diphenyl-impregnated liners.

Recent tests with Florida Valencia oranges (*70*) have shown that they can be stored successfully with a minimum of stem-end rot for 8 to 12 weeks at a temperature of 30° to 32° F., with a relative humidity of 85 to 90 percent. California oranges, being somewhat more subject to rind disorders than Florida oranges at low temperatures, are best stored at a range of 35° to 37°. At this range, navel oranges should keep 5 to 8 weeks and Valencias 6 to 8 weeks. At this temperature range, however, blue mold and green mold rots and rind pitting may occur after 8 weeks. (See *69*.)

Oranges should not be stored with eggs or butter, or in places where it is possible for the orange odor to penetrate into egg- or butter-storage rooms. (See also p. 14.) It is desirable that oranges in storage be examined often to prevent loss from the development of pitting or decay. After such examinations, a decision as to how long the fruit can safely be left in storage should take account of the fact that if pitting and decay are found they will increase rapidly after the fruit is removed to higher temperatures.

(See *19, 100, 160, 161, 198, 200.*)

Papayas

(Temperature, 45° F.; relative humidity, 85 to 90 percent)

Papayas should be picked when mature-green and then brought to a firm-ripe condition at about 80° F. before storage or shipping. Stored in a firm-ripe condition at 45°, they should keep satisfactorily for 7 to 21 days with minimum spoilage. They should be kept under refrigeration until they reach the consumer. Anthracnose is the principal decay. Ethylene-dibromide treatment during ripening is reported to control this disease (*150*).

(See also *183.*)

Peaches and Nectarines

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

Peaches are not adapted to cold storage. However, if they are sound and well-matured but not overripe, they can be held at 31° to 32° F. for 2 to 4 weeks, depending on the variety, with little or no bad effect on the flavor, texture, or appearance of the fruit. Storage for longer periods is usually harmful to all of these characters. Peaches lose their flavor and natural bright color, become dry and mealy, or wet and mushy, and show marked browning of the flesh, especially around the stone. The loss in flavor is more rapid at 36° and 40° than at 32°, and breakdown develops sooner at 36° and 40° than at either lower or higher temperatures. Such varieties as Tuskena (Tuscan) can ordinarily be held in storage for 8 weeks; Salwey, 4 weeks; Elberta and J. H. Hale, 3 to 4 weeks. Belle and Hiley are less desirable as storage varieties and cannot be expected to hold up well, even under optimum conditions, for more than 2 or 3 weeks. Many clingstone varieties are stored for 3 weeks to a month or more before canning.

(See *3, 59, 61.*)

Nectarines have the same storage requirements as peaches.

Pears

(Temperature 30° to 31° F.; relative humidity, 90 to 95 percent)

The most desirable temperature for the storage of pears is 30° to 31° F., sometimes 29° (*78, 119*), with a relative humidity of 90 to 95 percent. Such humidities are maintained in connection with air velocities of 100 to 200 feet per minute. In general, pears undergo the same postharvest changes as apples, but these changes, particularly in the Bartlett variety, are more rapid than in apples; therefore, speed in handling and quick cooling are even more essential. For the best results, extra refrigeration capacity with an air temperature as low as 25° may be required for the initial cooling. Obviously, close atten-

tion to fruit and air temperatures must be given to prevent freezing. Pears lose moisture more rapidly than apples, and it is advisable to hold the humidity to a minimum of 90 percent.

There are noticeable differences in the keeping qualities of pears from different production areas. Those from relatively cool areas generally have a shorter life. Pears to be stored after shipment should be precooled. If picked when too immature, pears are subject to wilting and scald; core breakdown is commonly found in pears picked too late in the harvest period.

The best ripening temperature for all pears after storage is about 65° F. (*203*). At 75° to 80°, they usually fail to soften. The skin of pears is sensitive to the fumes from chlorine solutions or sulfur dioxide used in plant sanitation. Thorough ventilation after using these materials will prevent fruit damage.

For a description of storage diseases, see Miscellaneous Publication 168 (*143*).

Bartlett Pears

Bartlett pears for storage should not be removed from the tree until the ground color begins to lighten and the lenticels have corked over. When this variety begins to show yellow in storage, it is a sign that it has been stored too long and will fail to ripen or soften on removal. The fruit should be removed while still light green. The maximum storage period for canning and local fresh markets is about 90 days, and at terminal markets, 45 to 60 days. As with apples, preharvest sprays are being used to control early dropping, and if picking is delayed beyond optimum maturity, storage breakdown may occur.

(See *4*, *7*, *78*, *101*, *102*.)

Fall and Winter Pears

The length of time for which it is safe to store fall and winter pears depends on the variety and when the fruit is picked, and also on whether it is shipped before or after storage (table 5). In using the table, it should be remembered that wide differences in keeping quality are often found in pears from various producing sections of the country. If Bosc, Flemish Beauty, and Comice pears are held in cold storage beyond their season, they do not ripen satisfactorily or they may not ripen at all (*51*).

The commonest and most serious decays of fall and winter pears in storage are gray mold rot, caused by the fungus *Botrytis*, and blue mold rot, caused by the fungus *Penicillium*. Gray mold rot is able to spread from decaying to sound, healthy fruit and for that reason is frequently called "nest rot." Losses from this rot can be reduced by the use of paper wrappers impregnated with copper (*28*). In the Pacific Northwest, blue mold rot, in the form known as pinhole rot, is sometimes more important on pears, particularly Winter Nelis, than gray mold rot. Losses from blue mold can be greatly reduced by careful picking and handling, prompt storage at 29° to 31° F. after harvest, and the use of paper wrappers to prevent direct contact between diseased and sound fruit.

Some control of decay has been obtained by treating the fruit with a 0.4- to 0.6-percent solution of sodium chloro-2-phenylphenate (*84*). Anjou pears are subject to a scald similar to apple scald that can be

TABLE 5.—*Length of time at 30° to 31° F. for safe storage of certain varieties of fall and winter pears at shipping point and after shipment to market (119)*

Storage treatment and variety	Length of storage period	End of storage period
Stored immediately after harvest:	*Months*	
Hardy	2 to 3	September to November.
Comice	2 to 3	November to December.
Bosc	3 to 3½	Do.
Kieffer	2 to 3	September to November.
Anjou	5 to 6	March.
Winter Nelis	6 to 7	March to May.
Easter Beurré	5 to 7	Do.
Stored after 12-day transit period (precooled):		
Anjou	4 to 5	March.
Hardy	2 to 3	September to November.
Comice	2 to 3	November to December.
Bosc	2 to 3	Do.
Winter Nelis	6 to 7	March to May.

controlled by oiled-paper wraps; however, oiled wraps are not effective against scald on other varieties of pears (*71*).

Kieffer pears, if they are sound, firm, and still green when stored and are held under the conditions recommended for other fall and winter pears, can be expected to keep satisfactorily for 2 or 3 months. If intended for storage, they and other varieties should be handled with extreme care during the picking and packing process, because even slightly bruised or rubbed places are very likely to turn black and seriously damage the sales value of the fruit. Investigations (*31*) by the United States Department of Agriculture have shown that, as for other varieties, a ripening temperature of 60° to 65° F. is essential for the attainment of maximum quality in Kieffer pears for either dessert or canning.

Persimmons, Japanese

(Temperature, 30° F.; relative humidity, 85 to 90 percent)

Persimmons can be kept for about 2 months at 30° F. and a relative humidity of 85 to 90 percent.

Pineapples

(Temperature: Mature-green, 50° to 60° F.; ripe, 40° to 45°. Relative humidity, 85 to 90 percent)

Pineapples are not adapted to long storage. Fully ripe fruits can be held satisfactorily at 40° to 45° F. for 2 to 4 weeks. Mature-green fruits should not be held at temperatures below 50°, and even at this temperature some of them will retain part of the green color in the skin and will fail to develop good flavor in the flesh after removal to room temperature. The maximum storage period for such fruit at 50° is 3 to 4 weeks. When held at 60°, mature-green fruit ripens slowly,

but after 2 or 3 weeks losses from decay, chiefly black rot, may be expected. The relative humidity for pineapples in storage should range from about 85 to 90 percent.

(See *183, 186, 197.*)

Plums, Including Prunes

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

Plums and prunes (fresh) are not stored extensively and are not adapted to long cold storage. The storage period, at 31° to 32° F., ranges from 3 to 4 weeks, depending on the variety. After that time the soft-fleshed varieties are likely to become too soft for commercial handling and may suffer somewhat from breakdown, darkening of the flesh, and loss of flavor. Kelsey and Wickson varieties are subject to breakdown which is usually more severe at 40° than at 31° to 32° (*116*).

One of the most important commercial shipping and storage varieties is the Italian Prune. At a temperature of 32° F., 2 weeks is about the maximum cold-storage period for this fruit if a shipping period is necessary before it goes on the market. After arrival at market, prunes shipped immediately after harvest can ordinarily be held in cold storage for about 3 weeks. If held longer there is danger that shriveling, mealiness, and internal browning, as well as abnormal flavor, will develop. Too much confidence should not be placed in the appearance and condition of the fruit while it is in storage, as more deterioration—decay, shriveling, and internal browning—may take place in 3 days after removal from storage than during the whole storage period. Fresh prunes shipped out of storage at shipping point cannot safely be stored again after arrival at eastern markets. Storage disorders can be largely prevented by partly ripening the fruit prior to storage or by holding it at 40° to 45°, since immediate storage at the low temperature seems to favor breakdown.

(See *3, 49, 142, 179.*)

Pomegranates

(Temperature, 34° to 35° F.; relative humidity, 85 to 90 percent)

Pomegranates should keep 2 to 4 months at 34° to 35° F. and at a relative humidity of 85 to 90 percent.

Quinces

(Temperature, 31° to 32° F.; relative humidty, 85 to 90 percent)

The behavior of quinces in storage is about the same as that of early varieties of apples such as Jonathan and Grimes Golden.

Raspberries

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

Fresh raspberries, blackberries, Logan blackberries, and dewberries are not adapted to storage and are usually not stored commercially. For short periods, 5 to 7 days, most of them can be kept in fair condition by storage at 31° to 32° F. in a relative humidity of about 85 to 90 percent. Young and Boysen dewberries cannot be stored satisfactorily for more than 2 to 4 days.

Strawberries

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

Fresh strawberries are not stored commercially except for very short periods; 10 days is probably the maximum. Even for so short a time as this, the temperature must be kept below 40° F. to prevent loss from decay caused by certain low-temperature fungi such as gray mold and *Phytophthora*, the fungus that causes leather rot; 31° to 32° is recommended. After about 10 days, sometimes sooner, the fruit loses its fresh, bright color, shrivels more or less, and deteriorates in flavor (*201*).

Tangerines

(Temperature, 31° to 38° F.; relative humidity, 90 to 95 percent)

Tangerines are not adapted to long storage. They cannot be expected to keep in good condition for much over 4 weeks and are subject to excessive loss in weight, loss in flavor, and decay.

TABLE 6.—*Recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of fresh, dried, and frozen fruits; nuts; fresh, dried, and frozen vegetables; vegetable seeds; and the average freezing points of these commodities*

Commodity	Temperature	Relative humidity	Approximate length of storage period	Average freezing point [1]
Fresh fruits:	° *F.*	*Percent*		° *F.*
Apples	(2)	85 to 90	(3)	28.4
Apricots	31 to 32	85 to 90	1 to 2 weeks	28.1
Avocados	(2)	85 to 90	(2)	27.2
Bananas	(2)	(2)	(2)	(4)
Blackberries	31 to 32	85 to 90	5 to 7 days [2]	28.9
Cherries	31 to 32	85 to 90	10 to 14 days	(5)
Coconuts	32 to 35	80 to 85	1 to 2 months	25.5
Cranberries	36 to 40	85 to 90	1 to 3 months	27.2
Dates	(2)	(2)	(2)	−4.1
Dewberries	31 to 32	85 to 90	5 to 7 days [2]	
Figs, fresh	31 to 32	85 to 90	10 days	27.1
Grapefruit	(2)	85 to 90	(2)	28.4
Grapes:				
Vinifera	30 to 31	85 to 90	3 to 6 months	24.9
American	31 to 32	85 to 90	3 to 4 weeks [2]	27.5
Lemons	(2)	85 to 90	1 to 4 months	28.1
Limes	48 to 50	85 to 90	6 to 8 weeks	29.3
Logan blackberries	31 to 32	85 to 90	5 to 7 days [2]	29.5
Mangoes	50	85 to 90	15 to 20 days	29.8
Olives, fresh	45 to 50	85 to 90	4 to 6 weeks	28.5
Oranges	(2)	85 to 90	(2)	(6)
Papayas, firm-ripe	45	85 to 90	7 to 21 days	30.1
Peaches and nectarines	31 to 32	85 to 90	2 to 4 weeks	29.4
Pears:				
Bartlett	30 to 31	90 to 95	(2)	28.5
Fall and winter varieties.	30 to 31	90 to 95	(2)	(7)
Persimmons, Japanese	30	85 to 90	2 months	28.3
Pineapples:				
Mature-green	50 to 60	85 to 90	2 to 3 weeks	29.1
Ripe	40 to 45	85 to 90	2 to 4 weeks	29.9

See footnotes at end of table, p. 32.

TABLE 6.—*Recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of fresh, dried, and frozen fruits; nuts; fresh, dried, and frozen vegetables; vegetable seeds; and the average freezing points of these commodities*—Continued

Commodity	Temperature	Relative humidity	Approximate length of storage period	Average freezing point [1]
Fresh fruits—Continued	°F.	*Percent*		°F.
Plums, including prunes	31 to 32	85 to 90	3 to 4 weeks [2]	28.0
Pomegranates	34 to 35	85 to 90	2 to 4 months	
Quinces	31 to 32	85 to 90	2 to 3 months	28.1
Raspberries	31 to 32	85 to 90	5 to 7 days [2]	29.9
Strawberries	31 to 32	85 to 90	7 to 10 days [2]	29.9
Tangerines	31 to 38	90 to 95	2 to 4 weeks	28
Dried fruits	[2]	[2]	[2]	
Frozen fruits	[2]	[2]	[2]	
Nuts	[2]	65 to 75	8 to 12 months	[3]
Fresh vegetables:				
Artichokes:				
Globe	32	90 to 95	30 days	29.1
Jerusalem	31 to 32	90 to 95	2 to 5 months	27.5
Asparagus	32	85 to 90	3 to 4 weeks	29.8
Beans:				
Green, or snap	45 to 50	85 to 90	8 to 10 days	29.7
Lima:				
Shelled	32	85 to 90	15 days	30.1
	40	85 to 90	4 days	
Unshelled	32	85 to 90	14 to 20 days	
	40	85 to 90	10 to 14 days	
Beets:				
Topped	32	90 to 95	1 to 3 months	26.9
Bunched	32	90 to 95	10 to 14 days	
Broccoli (Italian, or sprouting).	32	90 to 95	7 to 10 days	29.2
Brussels sprouts	32	90 to 95	3 to 4 weeks	
Cabbage:				
Early	32	90 to 95	3 to 6 weeks	31.2
Late	32	90 to 95	3 to 4 months	
Carrots:				
Topped	32	90 to 95	4 to 5 months	29.6
Bunched	32	90 to 95	10 to 14 days	
Cauliflower	32	85 to 90	2 to 3 weeks	30.1
Celeriac	32	90 to 95	3 to 4 months	
Celery	31 to 32	90 to 95	2 to 4 months	29.7
Corn, sweet	31 to 32	85 to 90	[2]	28.9
Cucumbers	45 to 50	85 to 95	2 to 3 weeks	30.5
Eggplants	45 to 50	85 to 90	10 days	30.4
Endive, or escarole	32	90 to 95	2 to 3 weeks	30.9
Garlic, dry	32	70 to 75	6 to 8 months	25.4
Horseradish	30 to 32	90 to 95	10 to 12 months	26.4
Kohlrabi	32	90 to 95	2 to 4 weeks	30.0
Leeks, green	32	90 to 95	1 to 3 months	29.2
Lettuce	32	90 to 95	2 to 3 weeks	31.2
Melons:				
Watermelons	36 to 40	85 to 90	do	[9] 29.2 [10] 28.8
Cantaloups (muskmelons):				
Full-slip	40 to 45	85 to 90	4 to 8 days	[9] 29.0 [10] 28.4
Half-slip	45 to 50	85 to 90	1 to 2 weeks	

See footnotes at end of table, p. 32.

TABLE 6.—*Recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of fresh, dried, and frozen fruits; nuts; fresh, dried, and frozen vegetables; vegetable seeds; and the average freezing points of these commodities*—Continued

Commodity	Temperature	Relative humidity	Approximate length of storage period	Average freezing point [1]
Fresh vegetables—Con.				
Melons—Continued	°F.	*Percent*		°F.
Honey Dew	45 to 50	85 to 90	2 to 3 weeks	[9] 29.0 [10] 28.8
Casaba	45 to 50	85 to 90	3 to 6 weeks	
Crenshaw and Persian.	45 to 50	85 to 90	1 to 2 weeks	
Mushrooms, cultivated	[2] 32	85 to 90	3 to 5 days [2]	30.2
Okra	50	85 to 95	2 weeks	30.1
Onions	32	70 to 75	6 to 8 months	30.1
Onion sets	32	70 to 75	do	29.5
Parsnips	32	90 to 95	2 to 4 months	30.0
Peas, green	32	85 to 90	1 to 2 weeks	30.0
Peppers:				
Chili, dry	([2])	65 to 70	6 to 9 months	
Sweet	45 to 50	85 to 90	8 to 10 days	30.1
Potatoes:				
Early-crop	([2])	85 to 90	([2])	
Late-crop	([2])	85 to 90	([2])	28.9
Pumpkins	50 to 55	70 to 75	2 to 6 months [2]	30.1
Radishes:				
Spring, bunched	32	90 to 95	10 to 14 days	29.5
Winter	32	90 to 95	2 to 4 months	
Rhubarb	32	90 to 95	2 to 3 weeks	28.4
Rutabagas	32	90 to 95	2 to 4 months	29.5
Salsify	32	90 to 95	do	28.4
Spinach	32	90 to 95	10 to 14 days	30.3
Squashes:				
Summer	32 to 40	85 to 95	do	29.0
Winter	50 to 55	70 to 75	4 to 6 months	29.3
Sweetpotatoes	55 to 60	85 to 90	do	28.5
Tomatoes:				
Ripe	50	85 to 90	8 to 12 days	30.4
Mature-green	[2] 55 to 70	85 to 90	2 to 6 weeks [2]	30.4
Turnips	32	90 to 95	4 to 5 months	30.5
Vegetable seeds	32 to 50	50 to 65	([2])	
Dried vegetables	([2])	70	1 year	
Frozen vegetables	([2])		([2])	

[1] These figures, except for summer squash, represent actual commodity temperatures recorded when freezing occurred in tests. They are based on previous publication by Wright (*207*). The freezing point for summer squash was obtained from list on p. 11 of this handbook.

[2] See text.

[3] See text and table 4.

[4] Green: Flesh, 30.2°; peel, 29.8°. Ripe: Flesh, 26.0°; peel, 29.4°.

[5] Eastern sour, 28.0°; eastern sweet, 24.7°; California sweet, 24.2°.

[6] Flesh, 28.0°; peel, 27.4°.

[7] Winter Nelis, 27.2°; Anjou, 26.9°.

[8] Persian (English) walnuts, 20.0°; pecans, 19.6°; chestnuts (Italian), 23.8°; peanuts, 13.4°; filberts, 14.1°.

[9] Flesh.

[10] Rind.

Fresh Vegetables

By R. C. WRIGHT

The recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of vegetables are given in table 6 (see pp. 31–32). Detailed descriptions of these requirements are given in the text.

Artichokes

Globe

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

The true artichoke, a member of the thistle family, is known to the trade as the globe artichoke. The edible bud, made up of a cone of short, thick-stemmed leaves, apparently is seldom stored; but for temporary holding a temperature of about 32° F. is used with a relative humidity of 90 to 95 percent to prevent wilting or drying. This product should keep for at least 30 days in storage.

Jerusalem

(Temperature, 31° to 32° F.; relative humidity, 90 to 95 percent)

Jerusalem-artichokes, which are not true artichokes but belong to the sunflower family, are tubers which, if held in storage at a temperature of 31° to 32° F. in a relative humidity of 90 to 95 percent, may be expected to remain in good condition 2 to 5 months. At low humidities they shrivel badly and are more likely to decay than if kept in a moist atmosphere. They are sometimes stored in barrels or in paper-lined bags in which they keep longer with less wilting and decay than if left in open containers.

Asparagus

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

Fresh asparagus deteriorates rapidly at temperatures above 32° F. It is not usually stored except temporarily when the market is overstocked. Experiments have shown, however, that it can be kept successfully for 3 to 4 weeks at a temperature of 32°. At this temperature, growth of the stalks, which takes place at higher temperatures, is practically nil. The original tenderness of fresh asparagus, which at ordinary room temperatures is lost soon after cutting owing to the formation of woody tissue, is preserved at the lower temperature. Furthermore, the sugar content, to which asparagus owes some of its flavor and which after cutting rapidly diminishes at higher temperatures, remains practically the same as when the asparagus is cut, if it is put in storage at 32° immediately after cutting. Therefore, the sooner asparagus is placed in proper storage after harvesting the better will be its condition when used. The loss of water while in storage or transit is likely to be great if the stalks are not stood on wet moss or other moist, absorbent material placed in the bottoms of the crates. In storage, asparagus bunches are sometimes set in water in shallow trays or pans. After a long haul to market, asparagus should not be expected to keep in storage for more than 3 to 6 days, although the preservation of quality will depend largely on how

the product was handled before being received for storage. Asparagus that has been precooled immediately after being packed will arrive at the market in better condition than if not so treated. The principal decays of asparagus in storage are bacterial soft rot and gray mold rot.

(See *120.*)

Beans

Green, or Snap

(Temperature, 45° to 50° F.; relative humidity, 85 to 90 percent)

Snap beans should be stored only for short periods. When held at 40° F. or lower they are subject to definite chilling injury. Pitting develops in 32° storage after 3 to 5 days. After removal from storage of 3 to 5 days at 32° to 40°, russeting usually develops in about 1 day during warm weather. This condition, which is caused by condensation of moisture especially at the centers of the containers, detracts seriously from salability. Snap beans can be stored at about 45° for 8 to 10 days, but the marketing should be completed in 1 or 2 additional days. To prevent wilting, the humidity should be not lower than 85 percent; and the hampers or other containers should be so stacked as to allow abundant air circulation. If the containers are packed close together, the temperature may rise somewhat because of the heat given off by the commodity, and more or less rapid decay may be expected. If the beans are stored too long, the pods may become moldy or slimy and stick or "nest" together. The principal kinds of decay favored by a too high storage temperature or a too long holding period are watery soft rot, slimy soft rot, rhizopus rot, gray mold rot, and anthracnose.

Lima

(Temperature, 32° to 40° F.; relative humidity, 85 to 90 percent)

Shelled lima beans are sometimes stored in quart baskets and, if fresh and sound when stored, can be expected to keep in good salable condition for about 15 days at 32° F. and about 4 days at 40°. If stored too long, the beans tend to fade to a light color and become sticky. Unshelled lima beans can be stored at 32° for 14 to 20 days, and at 40° for 10 to 14 days. Containers should be stacked to allow air circulation. Storage diseases are similar to those of snap beans.

Beets

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Late beets stored at 32° F. can be expected to keep 1 to 3 months under suitable storage conditions. Either cold storage or cool-cellar storage is suitable, provided the humidity is kept sufficiently high to prevent wilting. Cellar storages often have a higher average temperature range than is recommended, and under these conditions the period of successful storage will be comparatively shorter. The temperature in such storage should not go above 45°. Beets are subject to wilting because of the rapid loss of water and should be kept where the humidity is sufficiently high to prevent excessive evaporation.

Before going into storage, beets should be topped and well sorted to remove all diseased specimens and those showing mechanical injury,

in order to prevent undue shrinkage because of storage decay. Beets can be stored in ventilated barrels or, better still, in slat crates. Storage in large bulk should be avoided.

Bunched beets can be stored at 32° F. for 10 days to 2 weeks. See discussion of bunched carrots (p. 36), as the same conditions apply to bunched beets.

Broccoli (Italian, or Sprouting)

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Italian, or sprouting, broccoli does not keep well in storage and is usually held for only very short periods. The best storage temperature to retain the maximum salable condition and to preserve the vitamin C content is 32° F. If in good condition and stored with sufficient ventilation between the packages, broccoli should keep satisfactorily for a week or 10 days. Longer storage is undesirable because the leaves are likely to discolor and the buds may drop off.

(See *108*, *128*.)

Brussels Sprouts

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Brussels sprouts are stored only occasionally, but when stored they require the same conditions as broccoli. They should be held in small containers to prevent yellowing and the development of mold. The maximum storage period is probably not longer than 3 to 4 weeks.

Cabbage

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

A large percentage of the late crop of cabbage is stored and sold during the winter and early spring, or until the new crop from the Southern States appears on the market. If stored under proper conditions, the late cabbage should keep for 3 to 4 months. The longest keeping varieties belong to the Danish Ballhead class. Early-crop cabbage, especially southern grown, has a limited storage life of 3 to 6 weeks.[5] Cabbage is most successfully held in common storage in the Northern States, where a fairly uniform inside temperature of 32° to 35° F. can be maintained. Many such storage houses are to be found, principally in New York, Pennsylvania, Michigan, and Wisconsin. Cabbage in quantity is not usually held in cold storage because its value does not justify the expense.

Storehouses should be insulated sufficiently to prevent freezing, for although slight freezing does no harm, hard freezing is likely to cause considerable loss. More ventilating capacity than is required for most other vegetables should be provided to carry away the excessive moisture given off by this product and to obtain the maximum advantage of the cold night air during mild weather. Cabbage wilts quickly if held under too dry storage conditions; hence, the humidity should be high enough to keep the leaves fresh and turgid. Bin storage is common, the bins usually being 4 to 5 feet wide, 10 to even 20 feet long, and about 5 feet deep. They are best separated by tight board

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[5] Refrigeration Research Foundation. cabbage. *In* Commodity Storage Manual. Refrig. Res. Found., 3 pp. 1951. [Processed.]

partitions and slat floors for ventilation. Tiers of such bins may be built as high as it is convenient to elevate the cabbage, and ample air space between the tiers should be allowed for ventilation. The use of slat shelves, with heads piled 1 or 2 layers deep, is considered the best method, but it is too expensive when large quantities are to be stored.

Cabbage should be handled carefully from field to storage. Before it is stored, the roots and all loose leaves should be trimmed away, and damaged and misshapen heads should be culled. On being removed from storage, the heads should be trimmed again to remove loose and damaged leaves.

The most common decay found in stored cabbage is slimy soft rot.

Carrots

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Carrots are stored in fairly large quantities during the winter. The marketing period for stored carrots extends to late winter or early spring. They are usually held in common storage in those sections where the storage temperature can ordinarily be held sufficiently low. In the larger markets stored carrots must be sold in competition with fresh stock, which is being shipped practically the year around from either southern or western producing sections. Carrots are sometimes held in cold storage, although the prices obtained for them do not usually justify this kind of treatment.

It is generally considered that very light freezing causes practically no injury, but carrots should be protected from severe freezing and are best stored at a temperature of 32° F. They are subject to wilting or drying out if the humidity is not fairly high; for this reason, they are more easily kept in a well-ventilated cellar or bank storage than in an aboveground storage. The relative humidity should be maintained at 90 to 95 percent or slightly higher.

Before being placed in storage, carrots should be topped and all misshapen or injured specimens sorted out. The latter are especially objectionable, because their presence in a storage lot favors the development of two serious diseases of stored carrots—watery soft rot and bacterial soft rot. Topped carrots keep best in slat crates or ventilated barrels, and provision should be made for air circulation between the containers. Under good conditions they should keep 4 to 5 months.

Bunched carrots may be stored at 32° F. for 10 days to 2 weeks, and the tops will still retain a fresh appearance if they are not crowded. If cold storage is not available, bunched carrots from distant production sections may be packed in crushed ice and should keep 10 days to 2 weeks. If it is desired to carry over such carrots for only a day or two, icing may not be necessary. Under these conditions, however, the crates or containers should be opened and the contents loosened so as to allow air to circulate through; otherwise, heating will take place, and the foliage will soon become yellow or discolored.

Cauliflower

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

Cauliflower is not usually kept in cold storage; however, an oversupply on the market can be stored for a short time to await more

favorable selling conditions. If in good condition, cauliflower can frequently be held satisfactorily for 2 to 3 weeks at 32° F. Successful storage depends not only on preventing decay but also on retarding the maturing of the head, or curd. Overmaturity is marked by a browning of the otherwise white curd and the development of a ricey appearance. The leaves also become yellowish and may drop off. It has been reported (77) that spraying with certain growth regulators has proved effective in preventing the dropping of the leaves during storage.

During storage or transportation the crates should be stacked with the flower heads down to protect the curds from discoloration by dirt and moisture. When it is desirable to hold cauliflower temporarily out of cold storage, packing in crushed ice will aid in keeping it fresh. Freezing causes a grayish-brown discoloration and softening of the curd, accompanied by a water-soaked condition.

Celeriac

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Celeriac should be stored under the same conditions as those for topped carrots and should keep 3 to 4 months.

Celery

(Temperature, 31° to 32° F.; relative humidity, 90 to 95 percent)

Much of the late celery grown in the Northern States, notably New York and Michigan, is put in cold storage to supply the market up to the period in late winter when the competition of new celery from California and the South renders further holding unprofitable. Considerable celery from the South and West is also put in cold storage toward the end of the shipping season and held to supply the market during the summer, or until supplies of early, northern-grown stock appear on the market. Northern-grown celery is usually stored in field crates and washed and packed on removal. Southern- and western-grown stock is mostly washed and packed as it comes from the field.

Celery is a rather perishable commodity and under unsuitable storage conditions is especially subject to watery soft rot. This disease originates in the field and is caused by a fungus that is able to develop to some extent even at temperatures of 34° to 36° F. For this reason celery intended for storage should be as free as possible from infection. If held in rooms where a uniformly low temperature can be maintained, it should keep for 2 to 4 months. It is best stored at a temperature of 31° or 32° with a relative humidity high enough to prevent wilting (90 to 95 percent), and with sufficient air circulation to keep the temperatures at the top and bottom of the room as nearly equal as possible. Considerable heat is given off by celery because of active respiration, and the air at the top of a storage room is likely to be 3° to 4° warmer than at the bottom unless special precautions are taken to avoid such a condition. Air circulation can be maintained around the crates by using dunnage strips between the crates and leaving air channels between the rows. If wall or ceiling refrigerating coils are used, fans should be located at positions that will insure adequate air circulation. If the storage period is long, celery will keep better in small crates than in large ones.

Celery should not be piled more than four crates high in storage not provided with forced-air circulation; otherwise, there is danger of overheating, even with stock that is in prime condition. If it is piled 5 to 8 crates high, as is sometimes done, the room should be watched carefully to see that overheating does not occur.

Some growth takes place in celery while in storage. The central stalks lengthen considerably, obtaining their food at the expense of the outer stalks and the roots. Blanching of the stalks also takes place in most varieties that are put into storage. Some celery is trimmed and washed as it comes from storage, but probably the larger part is moved out in the original crates in which it was received.

(See *173.*) [6]

Corn, Sweet

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

Green sweet corn is seldom stored, although there are occasions during the southern shipping season when it may be desirable to put an excess supply of this commodity temporarily in cold storage. However, storage for more than a few days results in serious deterioration. The sugar content, which so largely determines quality in this product and which decreases rapidly at ordinary temperatures, decreases less rapidly if the corn is cooled quickly and kept at about 32° F. Cooling is sometimes done by submerging the corn in tanks of ice water immediately after removal from the field to reduce the temperature to as near 32° as possible.

Sweet corn should not be handled in bulk unless copiously iced, because of its tendency to heat throughout the pile. It should be packed in baskets or crates, which allow air circulation and more rapid removal of field heat and heat produced by respiration. During transit, containers should be kept covered with crushed ice. Ice within the package would help to keep the corn well refrigerated. This commodity as it usually arrives on the market should not be expected to keep in marketable condition in cold storage for more than 4 to 8 days.

Cucumbers

(Temperature, 45° to 50° F.; relative humidity, 85 to 95 percent)

Cucumbers are usually held in storage for only short periods and cannot be expected to keep satisfactorily for much more than 2 to 3 weeks. The most favorable storage temperature range seems to be between 45° and 50° F., with a relative humidity of 85 to 95 percent. When cucumbers are held at 45° or below for longer periods than recommended, surface pitting or dark-colored watery areas appear. These blemishes indicate low-temperature or chilling injury. Such areas soon become infected, and they decay rapidly on removal of the cucumbers to warmer temperatures. Slight chilling injury has been noted at 32° in 2 days, and severe injury within 6 days. If the cucum-

[6] THOMPSON, H. C. CELERY STORAGE. [Refrig. Res. Found.] TRRF Fact File Sheet, 2 pp. October 1947. [Processed.]

bers are held at 50°, little or no breakdown develops, but they tend to ripen rather rapidly, the color changing from green to yellow, and there may be some shriveling and surface pitting (*109*).[7]

Cucumbers grown in the semitropics seem to be somewhat less subject to chilling than those grown in the temperate zones (*185*). Waxing is practiced commercially, usually with a paraffin-carnauba emulsion containing approximately 7 percent solids. This treatment reduces weight loss and improves appearance.

Eggplants

(Temperature, 45° to 50° F.; relative humidity, 85 to 90 percent)

Eggplants cannot be expected to keep satisfactorily in storage for more than about 10 days.

The optimum storage temperature for eggplants seems to be 50° F. or slightly lower. Slight surface pitting and bronzing, especially near the stem end, have been noted at 40° or lower in 4 to 8 days. The pits sometimes occur in groups that coalesce into larger sunken areas on longer exposure.[8] [9]

Endive, or Escarole

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Endive, or escarole, is a leafy vegetable and under commercial conditions is not adapted to long storage. Even at 32° F., which is considered to be the best storage temperature, it cannot be expected to keep satisfactorily for more than 2 or 3 weeks. The storage requirements for endive are practically the same as for lettuce. Like lettuce it should keep somewhat longer than the period just mentioned if it is stored with cracked ice in or around the packages. The relative humidity in rooms where endive is held should be kept at 90 to 95 percent to prevent wilting.

A certain amount of desirable blanching usually occurs in endive that is held in storage.

Garlic, Dry

(Temperature, 32° F.; relative humidity, 70 to 75 percent)

Garlic is best stored under the temperature and humidity conditions required for onions. If in good condition and well cured when stored, this product should keep at 32° F. for 6 to 8 months. In California, where considerable garlic is grown, it is frequently put in common storage, where it may be held for 3 to 4 months or sometimes longer if the building can be kept cool, dry, and well ventilated. Garlic is stored in loose mesh bags, which are piled 2 layers deep in stacks separated by air spaces. It is essential that garlic be well cured in the field before going into storage.

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[7] MORRIS, L. L., and MANN, L. K. STORAGE OF CUCUMBERS. Refrig. Res. Found. Fact File Sheet, 1 p. December 1948. [Processed.]

[8] MORRIS, L. L., and MANN, L. K. STORAGE OF EGGPLANT. Refrig. Res. Found. Fact File Sheet, 1 p. January 1949. [Processed.]

[9] Unpublished report by R. C. Wright and T. M. Whiteman.

Horseradish

(Temperature, 30° to 32° F.; relative humidity, 90 to 95 percent)

Horseradish should keep satisfactorily for 10 to 12 months at 30° to 32° F. under the relative humidity and storage conditions recommended for topped carrots. Roots dug when the plant is in active growing condition do not keep so well as those conditioned by cold weather before they are dug. Frequent inspection is advisable.

Kohlrabi

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Kohlrabi should keep 2 to 4 weeks if stored under the conditions recommended for topped carrots.

Leeks, Green

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Green leeks are crated and stored under conditions similar to those suitable for celery. If properly handled, they should keep satisfactorily for 1 to 3 months in storage.

Lettuce

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Lettuce is sometimes put in cold storage when there is a surplus on the market, or in certain sections when the fall crop is threatened by approaching cold weather. If in good condition when stored, it can be expected to keep for 2 or 3 weeks. When lettuce is held temporarily out of cold storage, crushed ice aids greatly in keeping it fresh. Even when it is held in cold storage, ice tends to keep this product fresh by preventing drying or wilting. Lettuce is generally packed between layers of crushed ice in the crates. Ice that has previously been stored at a very low temperature sometimes causes severe freezing injury to lettuce if used too soon after removal from storage.

One of the most troublesome diseases of lettuce in transit and storage is the type of tipburn that develops in the interior of the head. This injury appears in the field, but in the later stages of the marketing process it is frequently followed by a slimy bacterial decay which may result in serious damage. Frequent inspection of stored lots is desirable.

Melons

Cold storage is used very little for most kinds of melons. When it is used, the storing is generally done at the terminal markets to avoid temporary adverse market conditions.

Watermelons

(Temperature, 36° to 40° F.; relative humidity, 85 to 90 percent)

The ordinary commercial varieties of watermelons cannot usually be expected to keep in storage for more than 2 or 3 weeks. Experimental lots held at 32° F. did not develop decay so rapidly as at the recommended temperatures, but the melons tended to become pitted or dented and to take on an objectionable flavor after 1 week.

Cantaloups; Honey Dew, Casaba, Crenshaw, and Persian Melons

(Temperature: Cantaloups, full-slip, 40° to 45° F.; half-slip, 45° to 50°; Honey Dew, Casaba, Crenshaw, and Persian melons, 45° to 50°. Relative humidity, 85 to 90 percent)

Cantaloups (half-slip), Crenshaw melons, and Persian melons, picked at the shipping-ripe stage (not table-ripe) and shipped under refrigeration, cannot be expected to keep in cold storage at the recommended temperatures for more than 1 to 2 weeks after arrival at the market. Cantaloups picked in the full-slip stage keep only about 4 to 8 days. Honey Dew melons can be kept for 2 to 3 weeks, and Casaba melons, 3 to 6 weeks. When melons are stored too long or at too low temperatures, breakdown or decay develops so rapidly on removal that they soon become worthless. Cantaloups are sometimes shipped with contact ice, but it is doubtful whether this practice is to be recommended for other melons. Unripe melons are best stored at the higher temperature given; otherwise, they may fail to ripen satisfactorily. Symptoms of deterioration are softening, decay, surface breakdown, and off-flavors.

(See *121*, *133*, *195*, *196*.)[10]

Mushrooms, Cultivated

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

Fresh mushrooms do not keep well in storage and are therefore only stored temporarily for short periods. Deterioration is marked by brown discoloration of the surfaces and by opening of the veils. Freshly picked mushrooms will keep in prime condition at 32° F. for 5 days, at 40° for 2 days, and at 50° for only 1 day. Allowing a marketing period of 1 day at higher temperatures immediately after storage, they should be kept at 32° for only 3 to 4 days and at 40° for up to 2 days. While being transported or displayed for sale, mushrooms should be kept under refrigeration.[11]

Okra

(Temperature, 50° F.; relative humidity, 85 to 95 percent)

Okra, if in good condition, can be kept satisfactorily in storage for a maximum of 2 weeks at a temperature of 50° F. A relative humidity of 85 to 95 percent is desirable to prevent wilting. At temperatures below 50° okra is subject to chilling injury, which is manifested by surface discoloration, pitting, and decay.[12] After 3 days at 70° about 5 percent of the pods will be decayed or shriveled; but at 32° nearly all the pods will be badly chilled as indicated by severe pitting. At 40° okra may keep in salable condition for 7 days. Contact or top ice has caused water spotting in 3 days at all temperatures.[12 13]

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[10] MORRIS, L. L., and MANN, L. K. STORAGE OF CANTALOUPES & OTHER MELONS. Refrig. Res. Found. Fact File Sheet, 1 p. January 1949. [Processed.]

[11] Unpublished report by R. C. Wright and T. M. Whiteman.

[12] MORRIS, L. L., and MANN, L. K. STORAGE OF OKRA. Refrig. Res. Found. Fact File Sheet, 1 p. December 1948. [Processed.]

[13] Unpublished report by H. B. Johnson.

Onions and Onion Sets

(Temperature, 32° F.; relative humidity, 70 to 75 percent)

Onions are held in either common or cold storage. In the northern onion-growing States, strongly flavored varieties, mostly of the globe type, are generally held in common or dry storage. The principal northern onion-producing States have an average winter temperature sufficiently low so that onions can be successfully held in common storage there during the winter months. About one-fourth of the onion crop of these States, however, is put in cold storage for consumption late in the spring. About the first of March is considered as late as onions should be held in common storage, because after this time there is danger of sprouting. The mild, or Bermuda, types, such as those produced in Washington, southern California, Texas, and other States where the climate is not suitable for common storage, are usually consumed soon after harvest. These onions can be, and limited quantities are, held in cold storage, but usually for much shorter periods than the globe varieties because of their poorer keeping qualities. Onions of the Spanish type grown in this country are often stored and, if well-matured, are considered capable of storage until January or early February.

A comparatively low relative humidity (70 to 75 percent) is very desirable for the successful storage of onions. However, humidities as high as 85 percent with forced-air circulation have given satisfactory results. At higher humidities, in which many other vegetables keep best in storage, onions are disposed to root growth and decay. The commonest form of the latter is gray mold rot occurring at the top of the bulb, whence its name "neck rot" (*181*). The fungus causing it can develop to some extent even at 32° F.; hence, onions intended for storage should be carefully sorted to remove all diseased bulbs. A uniform temperature of 32° is found to be sufficiently low to keep onions dormant and reasonably free from decay provided they are in good sound condition and well cured when stored.

Onions are not perceptibly injured by slight freezing if allowed to thaw out slowly and without rough handling. In cold storage they are usually held in bags of 50 or 100 pounds each, which are best piled in pairs laid crosswise in stacks 5 or 6 sacks high. The stacks should be set a few inches off the floor on 2- by 4-inch strips and the individual stacks separated by a few inches of space to allow air circulation. When kept in common storage, onions are generally stored in slat field crates holding about 1 bushel, rather than in bags. Before being placed in storage, onions should be well dried, or cured, in the field for 4 to 6 weeks, and all decayed onions or those showing thick, or "bottle," necks should be sorted out.

Recently some large growers have been storing their onions in large bulk bins 6 to 8 feet deep. The onions are mechanically harvested and elevated into trucks which deliver them to common storages where they are conveyed into the bins. These bins are constructed so that the onions are cured by forcing air up through the bottoms. This method is considered more efficient and economical than curing and storing in crates.

Onion sets are usually held in common storage. They require nearly the same conditions as large onions and are best stored in shallow slat-bottom crates or trays not over 4 inches deep and about 5 by 5 feet in

some districts or 2 by 3 feet in others. The corner posts of the crates should project about an inch above the side pieces to prevent the crates from resting tightly on each other when stacked and to allow air circulation between them. Because of their size, onion sets tend to pack closely in the crates; hence it is essential to allow as much air circulation as possible and to maintain a comparatively low humidity. If good stock is provided and is held under proper storage conditions, it should keep 6 to 8 months.

(See *104*.)

Parsnips

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Parsnips have nearly the same storage requirements as topped carrots and should keep for 2 to 4 months. They are not injured by slight freezing while in storage but should be protected from hard freezing and should be handled with great care while in a frozen condition. Parsnips dry out readily in storage; hence, it is essential that the humidity of the storage place be kept relatively high. Parsnips are sometimes stored in sand or clean soil to prevent wilting, but they keep in good condition in barrels or crates if the proper humidity is maintained. Waxing is effective in preventing wilting.

Peas, Green

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

Storage conditions required for green peas are somewhat different from those for beans. Green peas tend to lose part of their sugar content, on which much of their flavor depends, unless they are promptly cooled to near 32° F. soon after picking. They cannot be expected to keep in salable condition for more than 1 to 2 weeks unless packed in crushed ice, in which condition the storage period may be extended perhaps a week. Peas keep better unshelled than shelled.

Peppers

Chili Peppers, Dry

(Temperature, see text; relative humidity, 65 to 70 percent)

Chili peppers are usually picked when ripe and then dried and allowed to equalize in moisture content in covered piles. Water is usually added to the peppers after drying, and as a result they become less brittle. They are then packed tightly by tamping into sacks holding 200 to 300 pounds or in bales of about 600 pounds, and are generally stored in nonrefrigerated warehouses for 6 to 9 months.

The temperature of the warehouses depends to some extent on their construction and the way in which they are managed but chiefly on the outside temperature. In southern California, where a large part of the commercial crop of Chili peppers is produced, the outside temperature ranges from 50° to 80° F. during the usual storage period.

The moisture content of Chili peppers when stored is usually low enough (10 to 15 percent) to prevent mold growth; the chief storage trouble is insect infestation. Manufacturers of Chili-pepper products hold part of their supply of the raw material in cold storage at 32° to 35° F., but they prefer to grind the peppers as soon as possible and

store them in the manufactured form in airtight containers. When put in cold storage, the sacks or bales of peppers should be cooled before final stacking; otherwise, they may "crawl" while cooling and the stacks will fall down.

Sweet Peppers

(Temperature, 45° to 50° F.; relative humidity, 85 to 90 percent)

Sweet, bell, or bullnose peppers are subject to chilling injury at temperatures below 45° F. The symptoms of injury are surface pitting and discoloration near the calyx which develop in a few hours after removal from storage. After about 5 days of storage at 32°, peppers usually show serious deterioration, marked by pitting and decay, after 1 day at ordinary room temperatures. For the maximum storage of 8 to 10 days, a temperature range of 45° to 50° is recommended. This should allow 3 to 4 days for marketing. When stored at a temperature above 50°, ripening (red color) and development of decay are rapid.

Potatoes

Early-Crop

(Temperature, see text; relative humidity, 85 to 90 percent)

Early and intermediate potatoes are not often stored. However, if need arises in the production area (usually southern), this crop can be kept satisfactorily for several weeks in common unrefrigerated storage in the locality where the potatoes are grown (*85*). The potatoes should be sorted carefully before storage to remove all that are decayed, seriously bruised, or cracked. Investigations in Oklahoma (*29*) indicated that refrigerated storage at 50° F. after a curing period is best for the early crop. Some evidence has been obtained, however, that if early potatoes are to be used for chipping, a storage temperature of 60° to 70° is better than one of 50° (*214*). The relative humidity should be the same as for the late crop (85 to 90 percent).

If refrigeration is not available, an underground storage cellar or cave is next best if the temperature can be held below 70° and a fairly moist atmosphere maintained to avoid excessive shrinkage. (See also *95*). Early-crop potatoes should always be considered as perishable. The storage period is never so long as is possible with late-crop potatoes.

Late-Crop

(Temperature, see text; relative humidity, 85 to 90 percent)

Late potatoes are stored in either cold or common storage, but the greater part of the stored crop is held in common storage (*38*). Like most other vegetables that can be held for relatively long periods in common storage, potatoes can be kept successfully through the winter and spring months only where the winter climate is sufficiently cold. In either cold or common storage a temperature of 40° F. is as low as table or seed stock need be kept. At temperatures below this, there is a tendency for potatoes to become undesirably sweet. However, if sweetening occurs, 1 to 3 weeks holding at ordinary living-room temperature restores the natural flavor (*215*). Potatoes should always be kept in the dark to prevent greening. At 40° potatoes remain dormant 5 to 8 months after harvest, depending on the variety. If it is desired to keep them longer than this, as is often the case with

seed stock, the temperature may be lowered to 38°, at which they should remain dormant indefinitely. A storage temperature as low as 32° is not only unnecessary but often detrimental.

Investigations have indicated that potatoes stored at 50° to 60° F. have better texture, color, and flavor when cooked or made into chips than the same stock stored at lower temperatures (*210*), although the higher temperatures are not suitable for long-time storage. When potatoes are stored at these higher temperatures, sprouting occurs more quickly. A limited amount of sprouting does not injure potatoes for food, but it makes the stock difficult to market because usually only dormant potatoes are wanted. If sprouting has started it can be checked by lowering the storage temperature (*213*). Commercial sprout inhibitors are sometimes used to prevent sprouting where the storage temperatures are too high to prevent it. When used as directed, these are effective at temperatures even as high as 70° and apparently do not affect the table quality.

Potatoes that have been kept at 40° F. for a long time are seldom suitable for processing, such as chip making, french frying, or dehydrating, without first being conditioned to reduce the quantity of sugar that has accumulated. This is accomplished by holding the potatoes at 70° to 80° until trial cooking tests show that they have recovered sufficiently for use. The length of the conditioning period will depend on the variety and the amount of sugar that has accumulated; usually this will be 1 to 3 weeks.

Not all varieties of potatoes are suitable for chipping or for french frying (*215*).

The relative humidity of a potato-storage house should be 85 to 90 percent, to prevent undue shrinkage through loss of water. In cold storage, potatoes are generally kept in sacks holding 50 to 100 pounds net; in common storage they are usually placed in bins holding 150 to 1,000 bushels or more. In Maine and northern New York, where the average temperature is sufficiently low, the large-bin storage is used with success, but in the milder climate of States in the latitude of Pennsylvania potatoes should not be stored in such large units. Potatoes are readily injured by even slight freezing, which takes place at about 29° F. or slightly below; hence, common-storage buildings should be sufficiently insulated to prevent freezing. Insulation also prevents the condensation of moisture on the walls and ceilings and the consequent undesirable wetting of stored stock, which favors the development of decay. Common storages should be provided with sufficient ventilation to take advantage of the cool night air in mild weather; this will aid in removing excess moisture that often accumulates soon after potatoes are stored in the fall, and it will also maintain a lower average temperature. It is desirable to ventilate just enough during the first 2 weeks of storage to keep the work-alley temperature at 55°. This will result in a potato temperature of about 60° which will encourage wound healing, or "curing." Ventilators should never be opened, however, when the outside temperature is higher than that inside the storage house. In addition to damage to potatoes, condensed moisture caused by improper ventilation or inadequate insulation may also cause serious impairment of the building structure (*37*).

Potatoes intended for storage should be handled carefully to prevent bruises and cuts; otherwise, they are likely to be damaged by various forms of decay before the end of the storage period (*135, 148*).

Potatoes from fields infected by late blight are usually not suitable for storage, as the blight fungus will spread in storage even if all obviously diseased tubers have been sorted out. If the field infection occurs late in the season, no evidence may be apparent on the tubers but extensive rot may develop soon after storage. If infected tubers can be quickly cooled below 40° F., the development of the rot may be delayed for a short time.

For a complete digest of potato handling, storage, and transportation literature, see Bibliographical Bulletin 11 (*140*).

Pumpkins and Squashes

(Pumpkins and winter squashes: Temperature, 50° to 55° F.; relative humidity, 70 to 75 percent. Summer squashes: Temperature, 32° to 40°; relative humidity, 85 to 95 percent)

In general most varieties of pumpkins do not keep in storage so long as the usual storage varieties of squash. Such varieties as Connecticut Field and Cushaw are relatively poor keepers and cannot be expected to hold in good condition more than 2 to 3 months. Varieties like Large Cheese and and Table Queen keep 3 to 6 months.

Hard-shell squashes, such as the Hubbards, can be successfully stored for 6 months or longer.

All stock should be well matured, carefully handled, and free from injury or decay when put in storage. The best storage temperature for pumpkins and winter squashes seems to be 50° to 55° F., with a relatively low humidity of about 70 to 75 percent. A preliminary curing at 80° to 85° for about 2 weeks is of benefit in ripening immature specimens and in healing mechanical injuries incidental to harvesting. Less rot will occur in storage if stems are removed before curing.

Summer (yellow crookneck) squashes keep best at a temperature of about 32°to 40° F. and a relative humidity of 85 to 95 percent. Under these conditions, they may show increase in the yellow color, pitting, and some wilting at the necks after approximately 2 weeks, but they are not likely to be seriously damaged by decay (*90*).[14]

Radishes

Spring, Bunched

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Bunched spring radishes require the same storage conditions as bunched carrots.

Winter

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Winter radishes require the same storage conditions as topped carrots and should keep in good condition for 2 to 4 months.

Rhubarb

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Rhubarb stalks, if fresh and in good condition, may be stored for 2 to 3 weeks. The bunches should be packed in crates, which are stacked

[14] MORRIS, L. L., and MANN, L. K. STORAGE OF SUMMER SQUASH. Refrig. Res. Found. Fact File Sheet, 1 p. December 1948. [Processed.]

to allow ample air circulation on all sides; otherwise, there is danger of heating and mold growth.

Rutabagas

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Rutabagas require the same storage conditions as topped carrots and should keep satisfactorily under such conditions for 2 to 4 months. Probably most of the rutabagas that now appear on the market have been waxed. This treatment improves the appearance and is reported to prevent wilting and loss of weight.

Salsify

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Salsify has the same storage requirements as topped carrots. The roots are not injured by slight freezing but should be carefully handled while frozen. Under the conditions specified, they should keep for 2 to 4 months.

Spinach

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Spinach is usually stored for only short periods. It should keep fairly well for 10 to 14 days after being cut. If crushed ice is used in the packages, this period can be extended somewhat.

Squashes

See Pumpkins and Squashes.

Sweetpotatoes

(Temperature, 55° to 60° F.; relative humidity, 85 to 90 percent)

The requirements for the successful storage of sweetpotatoes differ from those recommended for most other vegetable crops. When freshly dug sweetpotatoes are to be stored for any length of time, they should be given a preliminary curing treatment at a relatively high temperature and humidity, to permit the healing of all wounds or abrasions incidental to harvesting and handling. This helps prevent the entrance of decay organisms.

The curing and storing are done in the same house so that the roots do not have to be moved after the curing treatment. When commercial lots are handled, the storage house is generally of special construction with sufficient insulation to maintain a uniform temperature and some means of ventilation that will insure the desired humidity. Provision should be made for heating the building during the curing process and for holding the proper storage temperature afterward.

The curing process ordinarily takes about 10 days, during which the house is kept at a temperature of 85° F., with a relative humidity of 90 percent or higher. After the curing period the temperature is allowed to drop to about 55°, with a humidity of 85 to 90 percent. Short periods of a few hours at temperatures somewhat lower than 55° need not cause alarm, but longer periods of low temperature should

be avoided because of possible chilling injury or possible damage from certain types of decay which may soon develop in the injured tissues and which are more likely to develop at temperatures below the range given (*86, 87, 94, 96, 132, 192*). Noncured sweetpotatoes are more susceptible to cold injury or chilling than cured ones. Noncured roots left at a temperature of 50° or lower for only a few days may be seriously damaged, principally by pitting. There is a varietal difference in sensitivity to low temperatures. The Big Stem Jersey, Little Stem Jersey, Orange Little Stem, and Maryland Golden are the most sensitive commercial varieties, followed by Nancy Hall, and the Porto Rico is most resistant.[15] The general symptoms of cold injury are increased decay and internal discoloration which may show up before or after cooking. Under the recommended conditions, properly cured stock should keep satisfactorily for 4 to 6 months.

Only well-matured stock that is free from mechanical injury or decay should be stored. Sweetpotatoes are usually stored in slat crates of about a bushel capacity or in bushel baskets. Shallow bins are sometimes used. The roots should be handled as little as possible during storage.

Sweetpotatoes are frequently waxed to improve their market appearance. It is not advisable to wax the roots that are to be stored, however, as this may increase susceptibility to decay. The wax treatment should be delayed until they are being prepared for the market.

Tomatoes

(Temperature: Ripe, 50° F.; mature-green, 55° to 70°. Relative humidity, 85 to 90 percent)

Ripe tomatoes are held in storage only temporarily and, except for short storage (3 to 5 days), should not be stored at temperatures lower than 50° F. At 50°, if not already soft ripe, they may keep in good condition for 8 to 12 days; at temperatures lower than this, they sometimes show a tendency to break down.

Except for local use, only tomatoes in the mature-green state are usually shipped to large markets where they are ripened and repacked for consumer use. For satisfactory ripening they should be held at a temperature of 55° F. or above. At 55° they will ripen slowly and remain in good salable condition for 2 to 6 weeks. They may be ripened rather rapidly at 70° for immediate demand, but a temperature range of 60° to 65° is preferable and is used most by the industry. At this range ripening is slower than at 70° or above, but the fruit is firmer when ripe and usually has less loss from decay. The relative humidity for storage and ripening should be 85 to 90 percent.

Storage or ripening temperatures lower than those given may weaken the fruit and therefore encourage decay. Short exposures of 3 to 5 days at 32° to 40° F. may cause little or no injury, but longer exposures may inhibit ripening and increase decay in proportion to the exposure time.

(See *98, 99, 134, 147, 185, 209, 211.*)

[15] Unpublished data by J. S. Cooley.

Turnips

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Turnips require the same storage conditions as topped carrots, except that the relative humidity need not be so high. They can be expected to keep for 4 to 5 months.

Vegetable Seeds

(Temperature, 32° to 50° F.; relative humidity, 50 to 65 percent)

Successful seed storage requires a comparatively low temperature and relative humidity to prolong viability. A storage temperature of 32° F. is most desirable, but 50° is satisfactory for practical purposes provided the relative humidity can be kept at near 50 percent. Under these conditions most seeds will keep a year, and some kinds much longer.

A combination of high temperature and high relative humidity will cause more rapid loss of viability than the same temperature with a low relative humidity. At the higher relative humidity seeds take up moisture, and this speeds the changes that finally lead to loss of viability. If it is impractical to maintain the desired low humidity, the seeds while still sufficiently dry should be sealed in airtight containers. There is considerable inherent variation in the storage life of different kinds of vegetable seed.

(See *15*, *174*, *175*.)

Dried Fruits and Vegetables

Dried fruits differ from dried vegetables in that dried fruits contain 15 to 25 percent moisture and a high percentage of sugar whereas vegetables contain 8 percent or less moisture and a low sugar content. Preservation of quality in dried fruits depends on a relatively low storage temperature. This is not so marked with dried vegetables, but these also deteriorate at high temperatures and undoubtedly retain their quality longer at low temperatures.

For the preservation of natural color in storage, dried fruits that are not subject to sugaring may be held at about 26° F. without humidity control or at 32° to 40° with a relative humidity of close to 55 percent. A storage temperature of 32° is superior to 40° in preventing browning, in retaining ascorbic acid and carotene, and in retaining sulfur dioxide when it has been used to retain color. In general, dried fruits should keep for a year at 32° and for 6 to 8 months at 40°. For storage of dates, see p. 20.

Dried apples, figs, peaches, and pears stored at 40° F. are subject to browning after 5 to 8 months of storage. Apples and prunes at 32° can tolerate a relative humidity as high as 75 to 80 percent, but at 40° mold develops at this humidity. In most products a humidity above 55 percent at 40° permits mold growth because of the moisture absorbed. With raisins, low humidity is more important than low temperature. They usually contain 15 to 20 percent moisture. For long-time storage (more than a year), a lower moisture content helps prevent sugaring. Clingstone peaches if dehydrated after scalding keep better than freestone peaches. At 40° with a moderate humidity, freestones pick up too much moisture and tend to darken.

Dried or dehydrated vegetables in airtight containers should keep for about a year at 68° to 70° F. If the containers are not airtight, the temperature should be kept at 50° or below to delay deterioration and also to prevent insect infestation. Under these conditions the relative humidity should be kept at about 70 percent to prevent absorption of moisture (*12*).

When nonventilated packages, such as those used for dried fruit and dates, are removed from cold rooms, sweating occurs mostly on the outside of the package and the moisture can be prevented from penetrating into the fruit by allowing the packages to warm up before they are opened (*12*).

Frozen Fruits and Vegetables

Frozen fruits can be held at −10° F. for a period of about 6 to 12 months. For a shorter period, up to 6 months, a temperature of 0° would probably be satisfactory.

For the freezing of fruits, a temperature of 0° F. or lower is desirable when in small containers and barrels. If freezing takes place too slowly, the same undesirable conditions may develop that are encountered if the fruit is stored at too high a temperature after being frozen. For best results, frozen fruits should be held in airtight containers.

The best temperature for freezing vegetables is from −10° to −5° F. For storage after freezing, −10° to 0° is satisfactory, and containers may be compactly stacked. If frozen vegetables are to be kept as long as a year, a temperature of −10° would be preferable to 0°.

(See *22*, *30*, *35*, *82*, *176*, *180*.)

Nuts

Much of the commercial nut crop, including walnuts of all kinds, filberts, almonds, Brazil nuts, peanuts, and sometimes pecans, is usually held in ordinary unrefrigerated warehouse storage through the winter following harvest. The part of the crop (except pecans) that is to be kept through the next summer should be placed in cold storage early in March. Some kinds of nuts are frequently stored from one harvest to the next. Pecans become stale and rancid much sooner than most other kinds of nuts, and it is safer to put them in cold storage at 32° F. soon after harvest. Brazil nuts can usually be kept satisfactorily in warehouse storage during the winter, but any that are to be held over the summer should be stored at 32° before warm weather. Brazil nuts especially should be carefully inspected before being accepted for storage, to make certain that they are well dried, or cured, and free from decay. Walnuts, filberts, and almonds usually need not be stored below 40° to 45°. Chestnuts are rarely held in any way other than in cold storage at 32° to 40°, preferably 32°, with a relative humidity of about 85 percent.

Shelled and unshelled peanuts can be held at common warehouse temperature during the winter; but during spring and summer, shelled peanuts should be kept in cold storage both for protection against insects and to prevent development of rancidity. Some manufacturers of peanut products find it most satisfactory to shell their entire year's supply in the fall and store it at about 32° F. If cold

storage is not available, common storage can be used; but the peanuts should be stored in the shell, otherwise they are likely to darken and become rancid. In common storage, care should be taken to prevent infestation by insects. Fumigation is desirable for both shelled and unshelled peanuts if they are to be held in common storage during the summer. Freezing damage has been reported in newly harvested peanuts high in moisture, but there is no evidence of such damage in well-dried nuts having 6 percent or less moisture.

All varieties of nuts keep better unshelled than shelled, unless the kernels can be sealed in vacuum, which permits them to be kept even longer than in the shell. Generally, nut kernels should be stored at 32° F. Cashew nuts usually arrive in this country sealed in cans with an inert gas. These and other nuts so packed keep longer at 32° to 40° than at room temperature.

Nuts should not be stored with foods having pronounced odors such as apples, onions, or potatoes. Pecans are especially susceptible to ammonia injury which causes severe discoloration of the kernels.

The relative humidity of the storage room should be 65 to 75 percent for most kinds. At higher humidities there is a possibility of mold growth, and at lower humidities there is undue drying.

(See *16*, *172*, *206*.)

(See also table 6, p. 31.)

Florist and Nursery Stocks

By T. M. Whiteman

The recommended temperature, relative humidity, and approximate length of storage period for cut flowers, florist greens, and cuttings are given in table 7. Further details of storage requirements are given in the text. Storage and packing recommendations and related information for rhizomes, tubers, roots, bulbs, corms, and nursery stocks are given in table 8.

Cut Flowers

In the storage of cut flowers, at least four viewpoints should be considered—that of the grower, the wholesale commission man, the retailer, and the consumer.

Many growers have one or more storage rooms (possibly kept at about 45° to 50° F.), which they use for holding the cut blooms in good condition until enough stock has accumulated to warrant shipment. As a rule, this would not take more than 24 hours. If a grower is interested in longer storage, he should have a separate room kept at a temperature considered minimum for the particular crop.

The wholesale commission man is interested in turning over the stock as soon as possible; this involves holding it for only a few hours to a few days. He often has two or more refrigerated rooms providing temperatures of 33° to 35° and of 40° F.

The retailer is interested in moving flowers to his customers as rapidly as possible. Because of his short-storage viewpoint, he sometimes buys in quantity the quick-moving items used in maintaining the necessary store displays. However, he should avoid buying so heavily that his storage facilities are overtaxed, necessitating keeping at room temperature stock that should be refrigerated, or risking in-

jury to stored stock by crowding. The retailer usually has at least one display refrigerator and, frequently, additional refrigerated space in conjunction with this; or he may have a separate walk-in refrigerated box. The temperature controls of these refrigeration units should be adjusted as often as necessary to take care of the entrance of warm air during periods of most frequent use. The most desirable temperature to use is about 40° F.

Consumers, of course, prefer flowers that are freshly cut. Cut flowers should therefore be kept for the shortest possible storage periods, to meet this customer requirement.

TABLE 7.—*Recommended temperature, relative humidity, and approximate length of storage period for cut flowers, florist greens, and cuttings*

Commodity	Temperature [1]	Approximate length of storage period
Cut flowers: [2]	° *F.*	
Acacia	40	3 to 4 days.
Anemone [3]	45	1 to 2 days.
Anthurium [3] [4]	55	2 to 3 days.
Aster (China)	40	1 week.
Babysbreath	40	1 to 2 days.
Bird-of-paradise-flower [3]	45	2 to 3 days.
Bouvardia, sweet	35	1 week.
	40	4 days.
Butterflybush, orange-eye	40	1 to 2 days.
Calendula (pot marigold)	40	3 days.
Calla, common and golden	40	7 days.
Camellia [5]	45	3 to 6 days.
Candytuft	40	3 days.
Carnation	33	1 week.
	40	4 days.
Chrysanthemum	35	2 weeks.
Clarkia	40	3 days.
Columbine	40	1 to 2 days.
Cornflower	40	3 days.
Crocus	33	1 week.
Daffodil (See Narcissus.)		
Dahlia	50	2 days.
Daisy, English	40	3 days.
Delphinium:		
Hardy larkspur	40	1 to 2 days.
Annual larkspur	40	Do.
Eucharis [5]	45–50	7 to 10 days.
Feverfew	40	3 days.
Forget-me-not, true	40	1 to 2 days.
Foxglove, common and common white	40	Do.
Freesia	33	2 weeks.
	36	1 week.
Gaillardia, common perennial	40	3 days.
Gardenia [5]	45	3 to 6 days.
Gerbera	35	2 weeks.
	40	5 to 7 days.
Ginger [3]	55	3 to 4 days.
Gladiolus	35	1 week.
Godetia [3]	50	Do.
Heath	40	Do.
Heliconia [3]	55	3 to 4 days.

See footnotes at end of table, p. 54.

TABLE 7.—*Recommended temperature, relative humidity, and approximate length of storage period for cut flowers, florist greens, and cuttings*—Continued

Commodity	Temperature [1]	Approximate length of storage period
	° *F.*	
Cut flowers [2]—Continued		
Hyacinth	33	2 weeks.
	36	1 week.
Iris, Dutch	33	Do.
Laceflower, blue	40	3 days.
Larkspur (See Delphinium.)		
Lilac, forced	40	4 to 6 days.
Lily:		
Easter	35	2 weeks.
Goldband	35	Do.
Regal	35	Do.
Speciosum rubrum	35	Do.
Lily-of-the-valley	35	1 week.
	40	3 days.
Lupine	40	Do.
Narcissus:		
Daffodil	33	2 weeks.
	36	1 week.
Paperwhite	40	2 to 4 days.
Orchid: [4]		
Cattleya	55	2 to 3 days.
Cymbidium	55	Do.
Cypripedium	55	Do.
Vanda (Joaquim) [3]	55	Do.
Peony, Chinese and common:		
Tight buds	35	6 weeks.
Loose buds	35	3 to 4 weeks.
Phlox, garden	40	1 to 2 days.
Poinsettia	60	2 to 3 days.
Primrose, baby	40	1 to 2 days.
Ranunculus [3]	40	2 to 3 days.
Rose:		
Tight buds	40	4 to 5 days.
Loose buds	40	2 to 3 days.
Snapdragon, common	40	3 days.
Snowdrop	40	2 to 4 days.
Squill	33	2 weeks.
	36	1 week.
Statice (sea-lavender)	35	6 weeks.
	40	3 weeks.
Stephanotis [5]	40	1 week.
Stevia	40	3 days.
Stock, common	40	Do.
Strawflower	35	6 weeks.
	40	3 weeks.
Sweetpea	50	1 to 2 days.
Sweet-william [3]	45	3 to 4 days.
Tulip	33	1 week.
Violet, sweet	40	3 days.
Florist greens: [6]		
Anthurium	40–45	----------
Boxwood	32	----------
Camellia	40	----------
Cedar (Oregon, or Port Orford, and desert) [7]	32	----------
Croton, branches	35–40	----------

See footnotes at end of table, p. 54.

TABLE 7.—*Recommended temperature, relative humidity, and approximate length of storage period for cut flowers, florist greens, and cuttings*—Continued

Commodity	Temperature [1]	Approximate length of storage period
	° F.	
Florist greens [6]—Continued		
Dracaena, leaves	40	
Dracaena sanderiana, cut	40	
Eucalyptus, round- and spiral-leaved	35–40	
Fern:		
Adiantum cuneatum (wrightii) [7]	32–40	
Asparagus (*A. plumosus*) [7]	32–40	
Brake [3 7]	32	
Dagger and woodferns (Eastern, Oregon, and others). [7]	30–32	
Leather-leaf (Baker)	35–40	
Staghorn [3]	55	
Woodwardia	32–40	
Galax, brown and green [7]	32	
Groundpine (*Lycopodium*) [7]	32	
Holly, branch or wreaths (*212*) [7]	32	
Huckleberry [7]	32	
Juniper	32	
Laurel, mountain	35–40	
Leucothoe, drooping	35–40	
Magnolia	35–40	
Palm:		
Arizona (coonties)	45	
Cocos	45	
Palmetto	45	
Philodendron radiatum (dubia)	45	
Podocarpus	45	
Pothos [3]	55	
Rhododendron	40	
Salal (lemon leaves) [7]	32	
Scotch-broom	40	
Smilax (southern wild) [7]	40	
Ti (palm-lily) [3]	40	
Cuttings: [8]		
Carnations:		
Nonrooted	31	5 months.
Rooted	31	6 months.
Chrysanthemums, rooted	31–35	2 to 5 weeks.

[1] Where two temperatures are given in braces, the lower temperature is that recommended for storage at warehouse or wholesale commission house; the higher, for shorter holding at the commission house or by the retailer.

[2] Approximately 80 percent relative humidity. The storage periods are given in the interest of satisfactory handling and keeping quality after removal from storage.

[3] The recommended storage temperatures for these items were taken from Claypool and coworkers' report (*25*), but the length of storage period was not.

[4] Orchids and anthuriums should have their stems placed individually in small vials of water.

[5] Camellias, gardenias, eucharis, and stephanotis are not placed in water for handling or storage.

[6] Approximately 90 percent relative humidity. At the retail level, most of the items are held at approximately 40° F., usually only for about a week. Most of these are stored with the butts in water, except where noted.

[7] Usually held in shipping cases.

[8] (See *105* and *171*).

Factors Affecting Keeping Quality

In planning the storage of cut flowers, it is important to know what varieties and species can be expected to keep well under given storage conditions. The best flowers for storage are normally those that have developed under optimum growing conditions and that have received no mechanical or other injury before being cut. Flowers of high quality are said to be "firm" and to have "substance," terms which probably could be justified on the basis of higher total solid matter, as contrasted with "soft" blooms that usually develop under conditions of forced growth. Well-grown flowers do not have hard, or excessively woody, stems for the species; hard stems make water uptake difficult. In selecting cut flowers for storage, the proper maturity discussed under individual species is of prime importance.

Storage Temperature

One of the chief factors influencing the storage life of cut flowers is temperature. No known treatment is nearly so satisfactory in extending the life of cut flowers as storage at comparatively low temperatures. If the proper temperature is used, inherent high quality should not diminish appreciably during short storage. The temperatures and approximate length of the storage periods given here are recommended to insure reasonably long life for flowers after their removal from storage. Cut flowers for which 45° to 55° F. is recommended, when stored at a much lower temperature, as a rule do not keep well after removal from storage. Those for which a storage temperature of 33° is recommended naturally mature more rapidly if stored at any higher temperatures; if held at 33°, they develop slowly. Sometimes the changes occurring during storage are not apparent at the time, but the longer the blooms are stored at 33°, the shorter will be their life when they are used for decorations. On the other hand, if short-lived blooms that keep best at 40° are stored at 33°, the effect of this adverse condition will appear after they are placed at room temperature (70°–75°).

If several types of flowers need to be stored and only one storage room is available, it is suggested that a temperature range of 40° to 45° F. be used. The tolerance of the particular species involved and the length of time that the blooms are to be stored should always be considered. For a number of items, table 7 gives the storage temperature to cover the maximum holding period at a cold-storage warehouse or wholesale commission house, and also the storage temperature for the shorter holding periods at the commission house or retail establishment. Where one temperature is suggested, the range, if any, in the approximate length of the storage period should take care of any differences in maturity or in quality of the stock.

Humidity

The effect of humidity on the storage of cut flowers deserves more consideration than it has had in the past. A relative humidity of 90 to 95 percent is probably too high in that it might promote mold growth, especially if the blooms are somewhat crowded. At low relative humidity, 70 to 75 percent, the petals of certain types of flowers tend to become undesirably dry. A relative humidity of 80 percent is therefore recommended. It has been noted that with certain types of blooms, such as gladiolus, floret development is faster at 36° F. and a high relative humidity than at the same temperature and a lower humidity.

TABLE 8.—*Storage, packing, and commercial information on rhizomes, tubers, roots, bulbs, corms, and nursery stocks*

Commodity	Storage temperature	Period stored [1]	How stored	Is this item specially treated for early flowering (See text.)	Commercial source	Commercial importance	What to check for during storage	Shipping information	
								Type of shipping container	Usual type of packing material
Rhizomes, tubers, roots, bulbs, and corms: [2]	° F.								
Amaryllis	40 to 45	Fall and winter.	Loose in trays	No	Florida	Little		Tight cartons or cases.	None, or dry peat moss.
Begonia, tuber	45	Sept. to Nov.	In paper bags, in trays.	do	Belgium, California.	Considerable	Shriveling	In paper bags, in tight cartons.	Slightly damp peat moss.
Brodiaea		Not held	[3]	do	California	Little		Tight cartons	None.
Caladium, fancy-leaved.	60	Sept. to Oct.	In paper bags, in trays.	do	Florida, California.	Considerable	Shriveling, decay.	In paper bags, in tight cartons.	Dry peat moss.
Calla	36 to 40	Sept. to Dec.	Loose in trays	do	France, Italy, California.	do	Sprouting, decay.	Ventilated wooden crates.	Dry excelsior, peat moss, or sawdust.
Canna	40 to 45	Sept. to May	In shipping container.	do	Many States	Little		Tight cases	Dry peat moss.
Crocus	55 to 60	Sept. to Dec.	In shipping container, or loose in trays.	do	Holland, Washington.	Considerable	Shriveling	Ventilated cartons or cases.	None.
Dahlia (*9, 26*)	40 to 45	Oct. to May	[3]	do	England, Holland; several States, especially New York and New Jersey.	Little		Tight cartons or cases, newspaper-lined in cold weather.	Dry wood shavings, soil, or peat moss.
Eranthis		Not held	In paper bags, in trays.	do	Holland	do		In paper bags, in ventilated wooden crates.	Sawdust or slightly moist peat.
Freesia	55 to 60	Sept. to Oct.	Loose in trays	do	California	Considerable	Shriveling	Ventilated cartons or cases.	None.
Fritillaria	55 to 60	Sept. to Dec.	In shipping container.	do	Holland	Little		do	Do.

Gladiolus (*14, 44, 88*)	40 to 50	Sept. to May	Loose in trays	do	Holland, many States.	Considerable	Shriveling	do	Do.
Gloxinia	50	Sept. to Nov	In shipping container.	do	Belgium, California.	do	Shriveling, decay.	Tight cartons or cases.	Very slightly damp peat moss.
Hyacinth	55 to 60	Oct. to Nov	In paper bags, in wire-bottom trays.	Yes, 84° F. and 75 percent relative humidity for 4 weeks.	Holland, France, Italy, Washington.	do		In paper bags, in ventilated wooden crates.	None.
Iris:									
Dutch	35	Sept. 1 to Oct. 15.	In mesh bags, in trays.	Yes, 50° F. for 6 weeks.	Holland, Oregon, Washington.	do		In mesh bags, in ventilated wooden crates.	Do.
Spanish	35	Sept. to Dec	Loose in trays	No	Holland, Washington.	Little	Shriveling	Ventilated cartons or cases.	Do.
Lily:									
Lilium auratum	32	Dec. to May	In shipping container.	do	Japan, Washington, Oregon.	Considerable		Heavy, tight wooden cases.	Dry sawdust, vermiculite, soil, or peat moss.
L. canadense		Not held	(3)	do	Eastern United States.	Little		Tight cartons or cases.	Moist soil, peat, vermiculite, or sawdust.
L. candidum	32	Aug. to Oct	In shipping container.	do	Holland, France, Washington, Oregon.	Considerable	Sprouting, rooting, shriveling, and decay.	Ventilated cartons or cases.	Dry tissue paper.
L. hansoni	32	Dec. to May	do	do	Japan, Washington.	Little	Sprouting and shriveling.	Tight cartons or cases.	Damp peat moss, soil, vermiculite, or sawdust.
L. longiflorum (Easter lily):									
Ace	31 to 35	Sept. to Nov	do	Yes, 45° to 50° F. for 4 to 6 weeks.	Georgia	Considerable	Sprouting, shriveling, and decay.	Tight cases	Slightly damp peat moss or dry subsoil.
Creole	31 to 35	do	do	do	do	do	do	do	Do.
Croft	31 to 35	do	do	do	California, Oregon, Washington.	do	do	do	Do.

See footnotes at end of table, p. 59.

TABLE 8.—*Storage, packing, and commercial information on rhizomes, tubers, roots, bulbs, corms, and nursery stocks* Con.

Commodity	Storage temperature	Period stored [1]	How stored	Is this item specially treated for early flowering (See text.)	Commercial source	Commercial importance	What to check for during storage	Shipping information	
								Type of shipping container	Usual type of packing material
Rhizomes, tubers, roots, bulbs, and corms [2]—Con.									
Lily—Continued									
L. *longiflorum*—Continued	° F.								
Erabu	31 to 35	Sept. to Nov.	In shipping container.	Yes, 45° to 50° F. for 4 to 6 weeks.	Japan	Considerable	Sprouting, shriveling, and decay.	Tight cases	Slightly damp peat moss or dry subsoil.
								do	
								do	
Estate	31 to 35	do	do	do	Georgia, Oregon	do	do	do	Do.
Georgia type	31 to 35	do	do	do	do	do	do	do	Do.
Giganteum	31 to 35	do	do	do	Japan	do	do	do	Do.
Kenyon-Davidson.	31 to 35	do	do	do	Georgia	do	do	do	Do.
L. philadelphicum	32	All year	do	No	Holland	Little	Sprouting and shriveling.	Tight cartons or cases.	Damp peat moss or soil.
L. regale	32	Late fall and winter.	do	do	Holland, Oregon	Moderate		Tight wooden cases.	Moist peat moss.
L. speciosum rubrum.	32	Sept. to Nov.	do	do	Japan, Oregon, Washington.	Considerable	Sprouting, decay.	do	Damp soil.
Lily-of-the-valley	25 to 28	All year	do	do	Germany, Holland, Belgium.	Little		do	Damp sphagnum moss.
Lycoris		Not held	[3]	do	Japan, California, New York.	do		Tight cartons or cases.	Dry wood shavings.
Muscari	48 to 50	Aug. 15 to Oct. 10.	In paper bags, in wire-bottom trays.	Yes, 48° to 50° F. for 8 weeks.	Holland	do		In paper bags, in ventilated wooden crates.	Do.
Narcissus (*80*):									
Daffodil	55 to 60	Sept. to Nov.	In shipping container.	Yes, 50° F. for 4 to 6 weeks.	Holland, many States.	Considerable		Ventilated cases	None.
Paperwhite	75 to 80	Fall and winter.	Loose in trays	Rarely	France, Florida	do		do	Do.

Soleil d'Or	55 to 60	do	In shipping container.	No	France, California.	Little		Ventilated cartons or cases, paper-lined.	Do.
Nerine	45 to 50	Sept. to Oct.	Loose in trays	do	Holland, Southern States.	do		Tight cases	Dry peat moss.
Oxalis	40 to 45	Fall and winter.	In paper bags, in wire-bottom trays.		Holland	do		In paper bags, in ventilated wooden crates.	Dry wood shavings.
Pancratium		Not held	(3)	No	California	do		Tight cartons or cases.	Do.
Peony	40 to 45	Fall and winter.	Loose in trays	do	Holland, many States.	Considerable		do	Damp peat moss.
Snowdrop	55 to 60	Sept. to Oct.	In paper bags, in trays.	do	Holland, several States.	Little		In paper bags, in ventilated cartons.	None.
Squill	55 to 60	do	do	do	do	do		do	Do.
Sternbergia		Not held	(3)	do	India	do		Tight cartons	None.
Taro	45	Sept. to Oct.	In paper bags	do	California	do		do	Dry peat moss.
Tuberose	40 to 45	Sept. to Dec.	In shipping container.	do	Italy, Mexico, Japan, Florida, North Carolina.	Considerable		Tight cartons or cases.	Do.
Tulip	65 to 70	Sept. 15 to Oct. 15.	In paper bags	Yes, at 50° F. for 4 weeks only.	Holland, England, Japan, Oregon, Washington.	do		In paper bags, in ventilated wooden cases.	None.
Zephyranthes		Not held	(3)	No	India, California	Little		Tight cartons	Do.
Nursery stock: [4]									
Deciduous fruit trees and shrubs.	32 to 35	Oct. to Mar.	In bins	do	Many States	Considerable	Mold	Usually no container, roots often burlapped.	Damp sphagnum moss.
Rose plants	30	Oct. to April	Nursery boxes	do	Several States	do	do	Cartons	Do.
Strawberry plants	30 to 32	Nov. to April	Boxes or bushel baskets.	do	do	Moderate	do	Wooden crates, cartons.	Do.

[1] These periods are mostly those used by bulb dealers. Jobbers and wholesale growers may store for different, and often longer, periods.

[2] Much of the information in this table was supplied by the American Bulb Dealers Association. A relative humidity of 75 percent is recommended for the items included, except when stored under special conditions during preparation for early flowering, and except for the items listed under nursery stock.

[3] Most dealers ship out this item soon after receiving it.

[4] Approximately 85 percent relative humidity.

The average freezing points of some foliage or flower parts are given in the following tabulation:

Foliage:	Temperature (° F.)[1]
Amaryllis	31. 0
Aspidistra	24. 9
Caladium, fancy-leaved	30. 6
Carnation	27. 4
Chrysanthemum	29. 6
Columbine	29. 1
Daisy, Shasta	30. 0
Delphinium (hardy larkspur)	29. 2
Dracaena	28. 0
Fern:	
Asparagus (*A. plumosus*)	24. 2
Dagger	23. 6
Gladiolus	26. 8
Hemerocallis	30. 0
Holly (*Ilex opaca*)	26. 3
Iris:	
Dutch	29. 0
German	27. 6
Japanese	28. 7
Lily, Easter	29. 2
Pandanus	30. 4
Rubber, variegated	30. 3
Violet, sweet	27. 4
Vinca major	28. 6
Petals:	
Anemone	28. 1
Carnation	28. 4
Chrysanthemum	28. 4
Columbine	31. 1
Daisy, Shasta	29. 3
Delphinium (hardy larkspur)	26. 6

Petals—Continued	Temperature (° F.)[1]
Gardenia	28. 3
Gladiolus	28. 7
Heath	28. 7
Hemerocallis	30. 8
Hyacinth	28. 7
Iris, Japanese	30. 5
Lily, Easter	27. 5
Narcissus (daffodil)	30. 1
Orchid (*Cattleya*)	30. 8
Peony, common	29. 0
Poinsettia	29. 2
Ranunculus	28. 6
Rose, hybrid tea	30. 0
Tulip	28. 0
Violet, sweet	28. 5
Bulbs, corms, tubers, and similar products:	
Amaryllis	30. 8
Begonia (tuber)	31. 1
Caladium, fancy-leaved	29. 7
Calla	27. 5
Dahlia	28. 3
Gladiolus	26. 8
Gloxinia	30. 5
Hyacinth	28. 7
Lily, Regal	27. 1
Narcissus:	
Daffodil	26. 1
Paperwhite	28. 9
Tulip	25. 4

[1] Many of these figures are based on previous publication by Wright (*207*).

Air Circulation

In constructing a storage room for cut flowers, one of the most important considerations is air circulation. The containers of flowers should be set on racks and arranged so that air can pass between and behind them. Forced but gentle air movement should be provided, but the blooms should not be in a direct draft.

Effect of Other Products

Certain kinds of cut flowers may be injured if stored in the same room or even in the same building with apples, pears, and other fruits. Such injury is usually evidenced by premature withering or rapid aging of the blooms and is thought to be caused by ethylene gas given off by the ripening fruit. Roses, carnations, snapdragons, stocks, and daffodils are among the flowers that are affected in this way by emanations from ripening fruit (*92*). Since ethylene gas is used at times to defoliate rose bushes (*106*) and is known to cause premature dropping of foliage from cut sprays of holly, it may also affect such florist greens as mountain-laurel and huckleberry. As a precautionary measure, therefore, greens should not be stored near the fruits mentioned. Minute traces of illuminating gas also damage many cut flowers.

(See *33*, *36*, *40*.)

Changes in Flower Color During Storage

Many kinds of pigmented flowers fade, become discolored, or develop an off-color appearance during storage, especially under dark storage conditions. The effectiveness of artificial light in retarding such color changes has been demonstrated experimentally (*110*).

Bunching

Bunching usually precedes storage and is generally done by the grower. Flowers should be tied firmly but not too tight. As a rule, the size of the bunch is determined by custom and does not vary much among markets. Whether 12 or 25 blooms customarily make a bunch probably depended originally on the type of flower. Thus, callas and standard chrysanthemums, because of their size, would be more difficult to handle, pack, and ship without damage if tied 25 in a bunch rather than 12. Other factors that determine the size of the handling or sales unit are high cost of certain flowers and their inherent susceptibility to mechanical injury. Orchids, camellias, and gardenias need special handling and therefore are generally marketed in small units. Some types of flowers may be bunched in miscellaneous sizes, depending on the display quality of the individual flower head or bunch component; such flowers include stevia, babysbreath, statice, and pompon chrysanthemums. Wrapping the bunches in waxed paper with an opening at the top prevents tangling of the blooms during the handling of such species as delphinium, columbine, and lilies-of-the-valley. Bunches of roses are customarily wrapped in water-repellent paper.

Storage in Water

It is the usual commercial practice to store cut flowers with the stems in water. They should not be crowded in the container because of possible mechanical injury, and decay that might result from such injury or from insufficient ventilation. Spilling water on the blooms should be avoided, since this might result in spotting or discoloration. Most cut flowers are benefited by a freshening period of 4 to 6 hours in water in a room temperature of 50° F. immediately after being cut. They should be stored at the proper temperature soon after they have been freshened.

For overnight storage, a crop that develops quickly from bud to open flower (such as daffodils) should be put in a room having a temperature of 40° and in water of about that temperature. If placed at a higher temperature and in warmer water, flower development may be too rapid. A special type of package for storing certain prepackaged cut flowers with their stems in water has been used commercially (*1*).

Storage, Not in Water

Experiments have been conducted with roses, carnations, chrysanthemums, and several other flowers in which the blooms were packaged for long-term storage at a temperature of 31° F. (*129*). This method of storing certain cut flowers, which involves placing them in sealed packages where the relative humidity becomes higher, is sometimes practiced at the production level to avoid marketing during a period of oversupply or to hold the blooms for a particular holiday or other period of increased demand.

Prepackaging

Packing flowers for long-term storage should not be confused with prepackaging. The term "prepackaging" applies to blooms that are packed, often by the grower, for quick movement to the retailer or consumer as fresh flowers. Blooms so handled should be of good quality in every respect. They are usually packed in waxed cardboard boxes or "boats" with overwraps or windows of a material through which the flowers show up to good advantage when on sale. Prepackaged flowers should be adequately refrigerated during the short-storage and marketing periods.

(See *1, 74, 89, 111.*)

Cutting, Storage, and Bunching Details for Certain Flowers

As a rule, the proper cutting stage for the large-flowering types of chrysanthemums is just after the green color in the center of the flower has disappeared. No general rule can be given for pompons, since several varieties—especially some of those in the anemone group—need more development on the plant than the single varieties. Chrysanthemums can be stored at 35° F. for 2 weeks. Longer storage is possible, though frequently not practical. The demand is likely to be greater for chrysanthemums currently in season than for stored blooms that normally were in season several weeks earlier. Chrysanthemums are usually tied in bunches of 12, and are not wrapped when placed in storage. Pompon chrysanthemums are sold in bunches of various sizes.

Gladiolus should be cut when 3 or 4 of the lower buds are partly opened. For distant shipment before storage, however, 1 or 2 of the lowest florets should show color but should be in the tight-bud stage. Gladiolus can be stored at 35° F. for 1 week. Longer storage is possible, though not always practical. The spikes should always be shipped and stored in a vertical position (*190*). These flowers are usually tied in bunches of 12 and are not wrapped when placed in storage.

Easter, speciosum rubrum, regal, and goldband lilies should be cut for storage when the corolla is about half opened, or just before the tips begin to reflex. Blooms forced at relatively high temperatures should be kept at a temperature of about 50° F. for a preliminary period of about 24 hours before being stored at 35°. These species can be held in storage at 35° for 2 weeks.

Peonies showing color in the tight-bud stage can be stored at 35° F. for about 6 weeks; in the loose-bud stage they can be held satisfactorily for 3 to 4 weeks.

Calla blooms should be gathered just before the spathe shows signs of curling downward. When the blooms are gathered they should be pulled, not cut; otherwise, the stems will split at the cut ends and curl after a few days in storage. The pulling method separates the stem from the rhizome, leaving no superfluous appendage. Moreover, if the blooms are removed from the plant by cutting, the stub left on the plant will probably rot and may permit the entrance of disease organisms. Pulling, however, is much easier with potted callas than with those planted in beds or benches. Freshly cut blooms of common and golden callas can be stored for 7 days at 40° F. Callas that have been subjected to hard forcing should be held for about 24 hours at a tem-

perature of 50° previous to storage at 40°. Callas intended for storage should be tied near the ends of the stems and also tied loosely below the blooms. They are usually tied and sold in lots of 1 dozen.

Lupine, clarkia, stevia, common stock, candytuft, cornflower, feverfew, common snapdragon, blue laceflower, English daisy, calendula or pot marigold, violet, and common perennial gaillardia are not usually held at temperatures lower than 40° F. and cannot be stored with good results for much more than a 3-day period. Sweet violets are usually made up in bunches of 100, supported underneath by a few galax leaves. They are wrapped with a light waxed paper and can be stored at 40° for 3 days. As a rule, they are not stored in water.

Columbine, babysbreath, delphinium (hardy and annual larkspur), baby primrose, true forget-me-not, and orange-eye butterflybush or buddleia, have flowers whose petals shed quickly, almost regardless of temperature. They cannot be stored at temperatures much lower than 40° F. or for longer than 1 to 2 days without impairing the keeping quality after removal. A temperature of 50° and a 1- to 2-day holding period is recommended for sweetpeas. Forced buddleia is sold by the dozen. The others mentioned are bunched in lots of 25 or of various numbers, depending on their quality. It is not customary to wrap any of these flowers for storage, but as previously mentioned, certain kinds may be wrapped to prevent tangling with adjacent bunches.

Camellias and gardenias are not customarily stored for long periods. However, they may be kept in storage in good condition for 3 to 6 days at a temperature of 45° F.

Orchids keep best if cut just as soon as they reach a salable condition (*89*). They can be held at 55° F. for 2 to 3 days.

Carnations should be cut just after the petals have unfolded. They can be held at 33° F. for 7 days, or at 40° for 4 days. They are usually tied 25 to a bunch.

Roses for nearby markets should be cut in the loose-bud stage; if they are to be shipped to distant markets, they should be cut in as tight a condition as is permissible for the variety in question. In the loose-bud stage they can be held at 40° F. for 2 to 3 days; tight buds can be held 4 to 5 days. If they are stored at much lower temperatures, their subsequent keeping quality is often impaired (*110*, *112*). Roses are frequently tied loosely in bunches of 25 buds and wrapped with water-repellent paper; this wrapping is sometimes loosened after 1 or 2 days' holding to preserve quality.

Asters and heath can be held at 40° F. for about 1 week; bouvardia, at 35° for 1 week or at 40° for 4 days. For dahlias, a temperature of 50° is recommended for a period of 2 days. The flowers mentioned in this paragraph are handled in lots of 1 dozen and are tied but not wrapped.

Statice, including bigleaf and notchleaf sea-lavender, and strawflower can be held in the fresh state at 35° F. for 6 weeks or at 40° for about 3 weeks. These flowers are often dried and retain their original color and shape very well.

Common foxglove and garden phlox are not usually satisfactory for storage but they can be held for 1 or 2 days at 40° F.

The various forced irises, especially the so-called Dutch irises, can be held for 1 week at 33° F. (*191*).

Poinsettias should be cut when they show sufficient color to be salable. The cut ends are usually dipped in boiling water to prevent undue loss of sap before or during the holding period. Cut poinsettias sold during the Christmas season usually need not be stored for the few days between their arrival at the wholesale house and the day of sale. If it is necessary to hold them for 2 or 3 days, a minimum temperature of 60° F. is recommended. Any change of environment from greenhouse conditions increases the apparently inherent tendency of poinsettias to shed their foliage.

For lilies-of-the-valley, the proper cutting stage is just after the terminal bell has lost its deep-green color. It should appear yellow-green and the lower 3 or 4 bells should be well opened. Cut lilies-of-the-valley are kept satisfactorily for 1 week at 35° F. or for 3 days at 40°. If kept too long, the lower bells often become watery in appearance (*189*). These flowers are usually tied with foliage in bunches of 25. It is best to wrap them loosely in heavy waxed paper, leaving the tops and bottoms of the bunches open.

Hyacinths, daffodils, freesias, and squills can usually be held satisfactorily for 2 weeks at 33° F. or for 1 week at 36°. Tulips (*193*) and crocus can be held at 33° for 1 week. Paperwhite narcissus and snowdrops can be held at 40° for 2 to 4 days. If hyacinths, tulips, or crocus are stored at 33° in boxes even for a few days, they should be stored in a vertical position with the heads up to prevent any possible curvature of the stem or flower parts.

Spikes, such as snapdragons, should be cut just after the lower 5 or 6 flowers have fully opened. Umbels, such as blue laceflower, should be cut just after they develop to a salable condition. Flowers formed in heads should usually be cut after the outermost petals are fully developed and just before stamens appear in the center of typical single heads or after the center has become closed with petals in the double-flowered types. Corymbs, such as candytuft, are usually best when cut after three-fourths of the lower flowers are opened. Flowers described as thyrses, or corymbose cymes, such as the lilac, should be cut when they are about two-thirds developed. Cymose clusters, such as babysbreath, should be cut after a few of the terminal flowers have developed.

Experiments have been reported on the use of a plastic coating on gardenia blooms (*149*). With further tests on different types of flowers and their foliage, dips or sprays of such materials as water waxes or plastic solutions may become more commonly used for minimizing wilting during shipment and storage (*67*).

Florist Greens

The recommended storage temperatures for most of the florist greens available on the market are listed in table 7. These temperatures are based largely on information obtained from the trade. Practices vary to some extent, depending on the type and size of the business, which in turn determines the desirability of using low temperatures for long-term storage or somewhat higher ones for shorter periods.

The florist greens that are commercially stored and handled in cases (usually waxed-paper-lined) are often those that are collected and packed in the fall for long storage—4 to 5 months or even longer;

these are usually held at about 32° F. When these greens are removed from cold storage and placed in the regular market channels, there is usually no further need to hold them at a temperature below 40°, since they ordinarily move to the retailer within a week or so and are held by him for less than a week. During marketing, the products that are not left in the shipping cases are either stored loose on racks in a room with very high relative humidity, or with the butts in water.

The approximate length of storage period is not given for florist greens because of their extreme variability. It depends on the many factors involved including the maturity, handling, and transportation of the product, as well as the storage temperature used.

Cuttings

Storage of rooted cuttings of chrysanthemums and carnations has been reported by growers of these crops (*105*, *171*). No data were given for holding nonrooted chrysanthemum cuttings, but 31° to 35° F. was recommended for storing rooted cuttings of this crop. Nonrooted and rooted carnation cuttings were stored for 5 and 6 months, respectively, at 31°.

Bulbs, Corms, Rhizomes, Roots, and Tubers

General Storage

The need for cold storage and the period during which bulbs are usually stored depend on where the bulbs are grown and for what purpose. It is therefore not always possible to make hard and fast rules as to the period in storage. With many bulbs, cold storage immediately after digging and curing is unnecessary during the usual period of use or sale, because they normally remain in a dormant condition for a time even at fairly high temperatures and humidities. When the rest period is nearly over, however, it may be necessary to store them at a lower temperature to prevent sprouting, and at a relative humidity low enough to prevent rooting but high enough to retard moisture loss.

Fleshy bulbs, roots, and similar products may be injured by curing at too high temperatures and too low relative humidities. It is desirable to place these commodities in cold storage in dry or slightly damp packing material if they are to be held for later planting. Included in this category are items that do not have a rest period and also those that do not grow well until after a period of low temperature.

For detailed storage conditions for specific bulbs, corms, rhizomes, roots, and tubers, see table 8.

Special Handling To Induce Early Blooming or To Time a Crop

Storing tulips (*13*, *57*), bulbous iris (*56*, *168*, *169*, *170*), lilies (*162*, *163*, *164*, *165*, *166*, *167*), and narcissus (*56*, *91*) under specific temperature and humidity conditions previous to forcing is being practiced commercially. For certain species, holding the bulbs for about 1 month at approximately 50° F., early in the season, hastens flowering; this is known as precooling. Most of the references cited give information on variations in the storage and handling methods necessary to induce early blooming of these bulbs or to time a crop for a

particular holiday. Freesias (*188*) apparently do not respond to precooling as an aid to early blooming. For the forcing of paperwhite narcissus, see (*194*).

Nursery Stock

(See table 8.)

Deciduous Fruit Trees and Shrubs

Although many nurserymen hold fruit trees in common storage under partially controlled conditions, some are now constructing cold-storage rooms to provide a temperature range of 32° to 35° F. As a rule, this type of stock remains dormant in common storage during late fall and early winter, at first because of the normal rest period and later because of a temperature sufficiently low to prevent bud growth. In order to maintain dormancy in late winter and spring, the temperature should be controlled in the 32° to 35° range. A fairly high relative humidity, approximately 85 to 90 percent, should be provided. This is usually accomplished in both common and cold storage by covering the roots with moist shingletow or sphagnum moss and moistening this occasionally. In cold-storage rooms a humidifier may also be used, but strong air movement over the stock should be avoided. It has been reported that ethylene gas from apple fruits in storage injures nursery stock (*32*).

Rose Plants

Rose plants are usually stored in the fall for spring planting. Experiments have been conducted (*216*) in which rose plants have been held in nursery boxes packed with shingletow and granulated peat. These plants were stored for 93 days. The best results were obtained at a temperature of 30° F., with 42 percent moisture in the packing material.

Strawberry Plants

Strawberry plants dug in the late fall or early winter when fully dormant can be stored at 30° to 32° F. (preferably 30°) for planting the following spring. Generally better growth is obtained with stored plants than with plants dug in the spring. Furthermore, digging the plants in the fall and storing them relieves the peak demand for labor in the spring; it also permits shipping the plants both earlier and later than is usually possible with plants dug in the spring.

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