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The Commercial Storage of Fruits, Vegetables, and Florists' Stocks

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Division of Fruit and Vegetable Crops and Diseases
Bureau of Plant Industry, Soils, and Agricultural Engineering
Agricultural Research Administration

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CONTENTS

[1] The writers not only have included results of their own investigations but also have drawn freely on published and unpublished results of other staff members, whose assistance and cooperation have done much to make possible this publication in its present form. Acknowledgment for unpublished information furnished on refrigeration or commodities indicated is due the following present or former members of this Division: W. R. Barger, dates and dried fruits; C. O. Bratley, limes and pineapples; Fisk Gerhardt, A. L. Ryall, and W. H. English, pears; C. W. Mann, lemons; W. T. Pentzer, refrigeration, garlic, olives, pears, and peppers; Edwin Smith, refrigeration, apricots, and pears; Morris Lieberman, lima beans, cabbage, celery, and cucumbers; M. H. Haller, spinach; E. B. Lambert, mushrooms. Acknowledgment is also due J. N. Kelley, Fruit Dispatch Co., for information on bananas. Special acknowledgment is made to D. F. Fisher, of this Division, for valuable suggestions and criticisms throughout the preparation of this and earlier editions of the circular.

829965—49——1

INTRODUCTION

The purpose of this circular is to present a series of brief summaries of the essential average storage requirements of most of the more important varieties of fresh fruits, vegetables, cut flowers, and certain other perishable commodities that enter the market on a commercial scale. Many details are of necessity omitted, as the work is intended primarily for general practical reference. The conditions given should not be considered as 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, etc., intended for storage should be as free as possible from skin breaks, bruises, and decay. They should be neither immature nor overmature, because in either case it may be difficult to keep them from too rapid deterioration, and even if they do not change appreciably in storage, they will not be commercially desirable when removed. The proper degree of maturity in each case can usually be determined by consulting the various sections of this circular, or the publications listed in Literature Cited (p. 54), or 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 one 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 discussed very generally in connection with various fruits and vegetables covered by this circular and in greater detail in other publications (*8, 14, 22, 38, 45, 53, 72, 77, 78, 79, 80, 82, 83, 84, 85, 86, 88, 95, 98, 109, 110, 112*).[2]

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 in this circular are derived from the best commercial practice at the present time and from scientific experimentation. The term "cold storage" as used in this circular refers to storage where temperatures in the approximate range of 25° to 45° F. are maintained by mechanical means or by the use of ice and salt; "freezer storage" to temperatures ranging from about 15° to −20°, usually close to zero; "cool storage" to temperatures ranging from about 50° to 65°, or possibly 70°; "unrefrigerated storage" to temperatures that are allowed to fluctuate with outside temperature; and "common storage" to storage in which the temperature best suited to the commodity is obtained as nearly as possible by insulation and ventilation only.

All of the 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 humidity should be 85 percent, this means that the air should be at approximately 85 percent of complete saturation 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 in most cases too large. They can usually be avoided if the storage rooms are well insulated throughout and have adequate coil surface 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,

[2] Italic numbers in parentheses refer to Literature Cited, p. 54.

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 5. Storage rooms should be equipped either with reliable, accurate thermostats or with means for manual control which are given frequent personal attention by someone charged with that duty. Even when reliable automatic controls are used, they should be checked periodically by some responsible person.

In commercial cold-storage rooms thermometers are usually placed at a height of about 5 feet, sometimes slightly lower, for convenience in reading. It is important, however, to take temperatures frequently at the floor and the ceiling also, and at any other places where they might be expected to be undesirably high or low. 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 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 can be corrected by wider spacing of packages and the use of portable fans and baffles for the direction of air currents to the centers of the piles. The installation of such equipment will also be useful in preventing dead-air pockets that are hard to cool, especially in rooms cooled by direct-expansion coils or by brine coils and without means for air circulation.

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 circular. In addition, there is always the possibility that fluctuations in temperature will cause condensation of moisture on stored products, which in itself 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 "fly-wheel" 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 generally will 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. With only a few exceptions (see especially onions), the most desirable condition is that in which the humidity of the air in the storage room is kept at approximately the moisture content of the produce stored therein. If it is too low, wilting is likely to occur in most fruits, vegetables, cut flowers, etc.; 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, however, and in the past was not often attempted in commercial-storage warehouses. However, at the present time new plants are being designed and old ones changed over in such a way that a foundation for humidity control in cold storage is being developed. Sufficient refrigeration, whether coils or brine spray, is provided so that the room can be operated with only a small difference in temperature between the refrigerant and the air of the room, thus raising the dew point of the air and its relative humidity. This permits the maintaining of high humidity. For low humidity the temperature of the refrigerant is lowered. To build up humidity quickly in cold-storage rooms some operators evaporate water from insulated open-top tanks equipped with insert electrical heaters. Others use a fan to beat water into very fine particles and to blow this spray into the room. These humidifiers are sometimes made automatic, connecting with humidistats. However, if the coil temperature is too low, that is, if the spread between the temperature of the refrigerant and that of the room is too great, the effect of these various measures will be short-lived. The relative humidity will soon become undesirably low, and harmful drying out of the stored product will occur.

When warm products are placed in a cold room the spread between commodity temperature and refrigeration temperature is wide at first. Such a condition hastens cooling and shortens the time during which undesirable changes can occur in the commodity. 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. If it could be successfully managed under commercial conditions, a temporary reduction in refrigerant temperature below what is desired or safe for long-time operation would be extremely helpful in shortening the initial cooling period.

Operators of certain large cold-storage houses have found that when a room is filled with apples or celery, for example, the relative humidity soon becomes constant at a fairly definite level, which fortunately is about the optimum for the particular commodity concerned. The same result has been observed with other commercially important fruits and vegetables and probably is obtained in many of the larger well-constructed cold-storage warehouses of the country. This is probably due to the fact that when a storage room is nearly full and there is comparatively little air space left the pull on the moisture in the produce is less, and it is easier to maintain the desired humidity. In these cases, however, it must be assumed that the spread between coil temperature and air temperature is kept narrow.

For most fruits that are stored commercially the statement is true that a relative humidity of 80 to 90 percent gives the best results. Exceptions are discussed at various places in the text. For leafy vegetables and root crops the relative humidity should be about 90 to 95 percent; for other vegetables, except as noted in the text, 85 to 90 percent. If it seems necessary to increase the relative humidity in rooms used for common, or air-cooled, storage, this can best 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 calls for an increase in relative humidity if wilting of the stored commodity is to be avoided. Allen and Pentzer (*2*) 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.

Evolution of Heat by Commodity

In any consideration of the storage of fresh fruits and vegetables, cut flowers, etc., it should be remembered that these commodities are alive and that by virtue of that fact they carry on within themselves many of the processes characteristic of all living things. Unless the relative humidity is high, they give off moisture to the surrounding air and most of them, in time, become shriveled or wilted, even at 32° F. The enzymes, or ferments, they contain act on various substances in their tissues and gradually bring about changes in color, texture, and chemical composition which ripen the commodity and may result in serious deterioration or even complete break-down. The most important of these changes are produced by respiration, the process in 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°. This heat is always a part of the refrigeration load which must be considered in handling fruits, vegetables, and cut flowers in cold-storage rooms or refrigerator cars. The approximate rate of evolution of heat by various commodities is given in table 1.

TABLE 1.—*Approximate rate 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	(55)
	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	(62)
	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	([d])
	40	4, 060	
	60	7, 240	
Broccoli (variety unknown)	32	7, 450	([b])
	40	11, 630	
	60	33, 870	
	70	47, 340	
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 rate of evolution of heat by certain fresh fruits and vegetables when stored at the temperatures indicated*—Con.

Commodity	Temperature	Heat evolved per ton of fruits or vegetables per 24 hours [a]	Literature reference
	° F.	*B. t. u.*	
Cherries (sour)	32	1, 320 to 1, 760	(*41*)
	60	11, 000 to 13, 200	
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	32	460	(*34*)
	40	1, 070	
	60	2, 770	
	80	4, 180	
Grapes:			
Concord	32	602	(*48*)
	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	580	(*34*)
	40	810	
	60	2, 970	
	80	6, 200	
Lettuce	32	11, 320	([d])
	40	15, 990	
	60	45, 980	
Mushrooms (cultivated)	32	6, 160	
	50	22, 000	
	70	58, 000	
Onions (Yellow Globe)	32	660 to 1, 100	
	50	1, 760 to 1, 980	
	70	3, 080 to 4, 180	
Oranges	32	690 to 900	(*34*)
	40	1, 400	
	60	5, 000	
	80	8, 000	
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	(*53*)
	60	8, 800 to 13, 200	

See footnotes at end of table, p. 9.

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

Commodity	Temperature	Heat evolved per ton of fruits or vegetables per 24 hours [a]	Literature refeence
	° F.	*B. t. u.*	
Peas: Improved Pilot	32	8, 160	([d])
	40	13, 220	
	60	39, 250	
	80	75, 500	
Laxtonian	32	8, 360	
	40	16, 020	
	60	44, 510	
	80	82, 920	
Peppers	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	36	4, 400 to 6, 600	(*29*)
	60	15, 400 to 17, 600	
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	(*34*)
	40	5, 130 to 6, 600	
	60	15, 640 to 19, 140	
	80	37, 220 to 46, 440	
Sweet corn (Golden Bantam cross; not husked)	32	6, 560	([d])
	40	9, 390	
	60	38, 410	
	80	61, 950	
Sweetpotatoes (Nancy Hall): Not cured	32	2, 440	
	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	
Turnips (topped)	32	1, 940	
	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 work by T. M. Whiteman.

[c] Unpublished work by Morris Lieberman.

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

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

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

829965—49——2

It will be noted that lettuce, Bartlett pears, peaches, and cherries have a much higher respiration rate than potatoes, apples, and onions. This means that the first group require considerably more refrigeration than the second to keep them at a specified temperature. Less pronounced differences occur between other commodities in the list and are important to a lesser degree in determining the amount of refrigeration necessary to cool them and keep them in sound, usable condition.

It is interesting to note that the storage life of apples (as represented by the three varieties with short, medium, and long storage periods, table 1) varies inversely as the rate of evolution of heat. The same relation holds true if one considers broccoli, lettuce, peas, spinach, and sweet corn in comparison with carrots, onions, storage varieties of grapes, and potatoes.

It is difficult to determine the heat to be removed in cooling fruits and vegetables to cold-storage temperatures. This depends mainly on the following factors: 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 only the number of British thermal units (B. t. u.) or calories 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 of the product in pounds or kilograms. 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.

In order to determine the amount of this additional heat it is necessary to know the rate of heat production at any temperature 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. When fruits and vegetables cool, the rate at which they produce heat decreases, and the total heat produced depends not only upon the time required for cooling but also upon how long the commodity stays in each temperature range.

Table 2 shows the approximate amounts of sensible heat and of heat produced by respiration which must be removed from eight varieties of five kinds of fruit in cooling them from various temperatures to a temperature of 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 (*53*, *55*), and the remainder from data reported by Haller et al. (*34*). The figures for Bartlett pears are based on the maximum values given by Magness and Ballard (*53*). The figures given in this table have been obtained by assuming that the heat of respiration is produced by oxidation of a hexose sugar and 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, and this assumption seems to be the best available basis for calculating heat production at any given temperature. Recent investigations (*30*) 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 at any given time during cooling is proportional to the difference between room temperature and fruit temperature at that time. 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.[3]

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[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: Winesap	80	8, 000	11, 000	14, 000	16, 000	22, 000	27, 000	80, 000
	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
Grimes Golden	80	12, 000	16, 000	20, 000	24, 000	32, 000	40, 000	80, 000
	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: Elberta	80	13, 000	18, 000	22, 000	26, 000	35, 000	44, 000	80, 000
	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
Carman	80	16, 000	22, 000	27, 000	32, 000	43, 000	54, 000	80, 000
	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: Bartlett	70	16, 000	22, 000	27, 000	33, 000	44, 000	54, 000	61, 000
	60	13, 000	17, 000	22, 000	26, 000	35, 000	43, 000	43, 000
Strawberries: Chesapeake	80	30, 000	39, 000	49, 000	59, 000	79, 000	99, 000	83, 000
	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
Howard 17	80	38, 000	51, 000	64, 000	77, 000	102, 000	128, 000	83, 000
	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: Florida seedling[2]	80	9, 000	12, 000	15, 000	18, 000	24, 000	30, 000	81, 000
	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.

[3] The authors wish to acknowledge the valuable assistance given by W. V. Hukill, Division of Farm Buildings and Rural Housing, Bureau of Plant Industry, Soils, and Agricultural Engineering, in making the calculations and in preparing this statement on the production of heat by fruits and vegetables.

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 (*88*).

Column 1 of table 2 shows the kind and variety of fruit and column 2 the temperature of the fruit at the time cooling started, in a room held at 32° F. The next column shows the amount of heat evolved by respiration if the fruit reaches 35° at the end of 3 days. The next five columns show the amount of heat if cooling to 35° requires 4, 5, 6, 8, or 10 days, respectively. The last column is the sensible heat (obtained by multiplying the specific heat of the fruit by the difference between initial and final temperatures and this result by the number of pounds in a ton). For any one kind of fruit at a given initial temperature, the specific heat is assumed to be the same for all the cooling periods included in the table.

The values given in table 2 are only approximate. However, in view of the results of the investigations mentioned on page 10, it is believed that the two assumptions that have been made—namely, (1) that the heat of respiration is produced only by the oxidation of a hexose sugar and can be computed from observed amounts of carbon dioxide produced and (2) that the rate of temperature drop is always proportional to the difference between fruit temperature and room temperature—probably 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 be 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.

EFFECT OF COLD STORAGE ON SUBSEQUENT BEHAVIOR OF FRUITS AND VEGETABLES

The belief is rather common among those concerned with the marketing of fresh fruits and vegetables that commodities of this kind that have been in cold storage deteriorate more rapidly after removal from the low temperature than if they had been held at ordinary temperatures. It is difficult, however, to find a basis for judging whether or not they actually do so because there is no means known other than the use of low temperature for checking the ripening and decay so largely responsible for their deterioration—that is, it is impossible in the present state of knowledge to obtain fruits and vegetables that have not been refrigerated but still have not changed in any way since harvest, for comparison with similar lots that have been in cold storage and are eventually removed. However, so far as is now known, it is correct to say that for many fruits and vegetables cold storage at or near 32° F. is beneficial. Important exceptions are bananas, sweetpotatoes, tomatoes, cucumbers, melons, and certain other horticultural products mentioned herein, the behavior of all of which in storage is discussed later under appropriate headings.

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 is more marked the higher the relative humidity of the outside air. 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, as in the British practice with eggs and certain other commodities, by allowing the fruits or vegetables to warm up gradually. Under commercial conditions in the United States this is rarely practicable, however, and the best thing to do in very damp weather is to realize the risk, handle the product carefully, and get it into consumption without undue delay.

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. Its value for both of these products lies in the fact that it not only improves their appearance but also prevents shrinkage by restricting the loss of water.

Waxing has been tried on a number of other products. In the case of cucumbers and carrots it gives considerable promise and may come into general use. It has been tried on cantaloups but did not prove to be beneficial.

(See *75*.)

CHOICE OF STORAGE CONDITIONS

The storage conditions recommended herein for certain commodities represent either a compromise between two undesirable extremes of temperature or humidity or a choice of the least harmful of two such extremes. Grapefruit, for example, suffers less from decay at low humidities than at high; on the other hand, at low humidities it is subject to a pitting which, in fruit from regions where stem-end rot is not prevalent, is usually more damaging to the market value of the fruit, because it is more common than decay. Therefore, it is recommended that grapefruit from all producing regions be held at 85 to 90 percent relative humidity in storage in order to reduce pitting.

The Jonathan variety of apple suffers less from soft scald if stored at 34° to 36° F. than if stored at 32°. It is susceptible, however, to the more common and more serious condition known as internal breakdown and also to Jonathan spot and decay if held continuously at temperatures above 32°; hence this latter temperature should usually be chosen as safer than any higher one.

Investigations in New York State (*91*) have shown that one lot of apples may have a stimulatory effect on the ripening of another lot stored with it. In some tests as much as 50 percent or more of the storage life of a lot of apples was lost because of exposure to the emanations from other apples. The agent causing the stimulation is presumed to be ethylene, but it was not identified as such. The most effective absorbent for removing the stimulatory agent was activated coconut-shell carbon.

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. Under various commodities additional undesirable combinations are discussed.

FRUITS AND NUTS

By DEAN H. ROSE, *senior physiologist*

The recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of fresh, dried, and frozen fruits, and nuts are given in table 3. Detailed descriptions of these requirements are given in the text.

APPLES

(Temperature, 30° to 32° F.; relative humidity, 85 to 88 percent)

There is a wide variation in the storage quality of the different varieties of apples and of the same variety grown in different regions. For example, McIntosh grown in the Middle Atlantic States is practically an early-fall apple not suitable for more than 2 or 3 weeks' storage, whereas if grown in northern New York or New England it can be held for as long as 4 or 5 months. Such varieties as Northern Spy, Baldwin, and Rhode Island Greening grown in the Cumberland-Shenandoah Valley district or in the hot, irrigated valleys of the Pacific Northwest behave like fall varieties and are short-lived in storage, although suitable for winter storage when grown in New England, New York, Michigan, and other northern producing districts.

The keeping quality of apples in storage is also definitely related to the cultural and orchard sanitation practices of the grower, who alone is responsible for the production of sound, properly matured fruit. To have good keeping quality, apples should be mature and well-colored. When they have reached this stage, they are less likely to scald in storage and are in better condition generally to be held in storage for the maximum period than if they are either immature or overmature (*55*, *56*).

TABLE 3.—*Recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of fresh, dried, and frozen fruits, and nuts, and the average freezing points*

Commodity	Temperature	Relative humidity	Approximate length of storage period	Average freezing point [1]
	° *F.*	*Percent*		° *F.*
Apples	[2] 30 to 32	85 to 88	(2)	28. 4
Apricots	31 to 32	80 to 85	1 to 2 weeks	28. 1
Avocados	(3)	85 to 90	(3)	27. 2
Bananas	(4)	(4)	(4)	(5)
Blackberries	31 to 32	80 to 85	7 to 10 days [4]	28. 9
Cherries	31 to 32	80 to 85	10 to 14 days	(6)
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. 3
Dates	(4)	(4)	(4)	−4. 1
Dewberries	31 to 32	80 to 85	7 to 10 days [4]	
Figs (fresh)	31 to 32	85 to 90	10 days	
Grapefruit	(4)	85 to 90	6 to 8 weeks	28. 4
Grapes:				
Vinifera	30 to 31	85 to 90	3 to 6 months	24. 9
American	31 to 32	80 to 85	3 to 8 weeks [4]	27. 5
Lemons	55 to 58	85 to 90	1 to 4 months	28. 1
Limes	45 to 48	85 to 90	6 to 8 weeks	29. 3
Logan blackberries	31 to 32	80 to 85	7 to 10 days	29. 5
Olives (fresh)	45 to 50	85 to 90	4 to 6 weeks	28. 5
Oranges	(4)	85 to 90	8 to 10 weeks	(7)
Peaches	31 to 32	80 to 85	2 to 4 weeks	29. 4
Pears:				
Bartlett	29 to 31	85 to 90	(4)	28. 5
Fall and winter varieties	29 to 31	85 to 90	(4)	(8)
Pineapples:				
Mature green	50 to 60	85 to 90	3 to 4 weeks	29. 1
Ripe	40 to 45	85 to 90	2 to 4 weeks	29. 9
Plums (including prunes)	31 to 32	80 to 85	3 to 8 weeks [4]	28. 0
Quinces	31 to 32	80 to 85	2 to 3 months	28. 1
Raspberries	31 to 32	80 to 85	7 to 10 days	29. 9
Strawberries	31 to 32	80 to 85	do	29. 9
Dried fruits	(4)	(4)	9 to 12 months	
Frozen fruits	(4)	(4)	6 to 12 months	
Nuts	[4] 32 to 45	65 to 75	8 to 12 months	(9)

[1] These figures are based on previously published work by Wright (*116*) and are subject to revision whenever further investigation makes this necessary.
[2] See text and table 4.
[3] See text and table 5.
[4] See text.
[5] Green: Flesh, 30.2°; peel, 29.8°. Ripe: Flesh, 26.0°; peel, 29.4°.
[6] Eastern sour, 28.0°; eastern sweet, 24.7°; California sweet, 24.2°.
[7] Flesh, 28.0°; peel, 27.4°.
[8] Winter Nelis, 27.2°; Anjou, 26.9°.
[9] Persian (English) walnuts, 20.0°; pecans, 19.6°; and chestnuts (Italian), 23.8°.

To insure soundness and good keeping quality, apples must be not only properly grown and at the proper stage of maturity, they should also be handled in all the operations of picking, grading, packing, and hauling with that degree of care necessary to prevent serious bruising, skin punctures, or other mechanical injuries; and they should be stored as quickly as possible after they are picked.

Apples should not be handled while frozen, if such handling can possibly be avoided. Water core does not develop or spread in storage, and in varieties such as Yellow Newtown and Winesap it may actually disappear after a few months' storage, especially if originally present only in mild form. When large portions of the flesh are affected, especially in soft-textured varieties like Jonathan, Delicious, Stayman Winesap, and Rome Beauty, there is danger of subsequent break-down and prompt disposal of the fruit is advisable. The diseases of apples in storage are discussed in Farmers' Bulletin 1160 (*8*) and Miscellaneous Publication 168 (*84*).

For the storage of most varieties of apples the best results are obtained by maintaining a temperature of 30° to 32° F. and a relative humidity of 85 to 88 percent. However, as the storage temperature approaches the freezing point of the fruit the hazard of freezing increases unless the temperature is well controlled and there is good air circulation. Yellow Newtown apples from the Pajaro Valley, Calif., and McIntosh and Rhode Island Greening apples from New York should be held at 35° to 38° rather than at 32° to prevent the development of internal browning or brown core. Grimes Golden apples should be held at 34° to 36° instead of at lower temperatures (*71*) in order to avoid soggy break-down. It should be remembered, however, that at these higher temperatures the fruit cannot be held as long as when stored at 30° to 32°, because of the possible development of Jonathan spot and internal break-down.

(See *9, 21, 36, 43, 71, 72, 73, 74.*)

If air-cooled storage is used, the temperature obtainable will usually not be much lower than the average of the prevailing outside temperatures. The nearer this is to 32° F. the better.

The length of time apples can be held successfully in cold storage will vary with the variety and with the district where grown, as well as with their condition when harvested. Table 4 shows the normal or average storage period and the maximum storage period for the more important apple varieties when picked at proper maturity and stored immediately at 30° to 32° F.

TABLE 4.—*Normal and maximum storage periods for important apple varieties*

Variety	Storage period: Normal	Storage period: Maximum	Variety	Storage period: Normal	Storage period: Maximum
	Months	*Months*		*Months*	*Months*
Jonathan	2 to 3	4	Arkansas (Black Twig)	4 to 5	6
Grimes Golden	2 to 3	4	Delicious	4 to 5	6
McIntosh	2 to 3	4 to 5	Northern Spy	4 to 5	6
Golden Delicious	3 to 4	5	Baldwin	4 to 5	6 to 7
Cortland	3 to 4	5	Rome Beauty	4 to 5	6 to 7
Rhode Island Greening	3 to 4	6	Ben Davis	4 to 5	8
Stayman Winesap	4 to 5	5 to 6	Winesap	5 to 7	8
York Imperial	4 to 5	5 to 6	Yellow Newtown	5 to 7	8

In determining when to remove apples from storage the dealer must, of course, consider the market, but he must also allow for the more rapid softening that takes place at the higher temperatures to which they will usually be removed. Investigations by the United States Department of Agriculture (*55*) have shown that apples soften approximately twice as fast at 70° as at 50° F., twice as fast at 50° as at 40°, and about twice as fast at 40° as at 32°, whereas at 30° the rate is about three-fourths that at 32°.

Apples in cold storage should be inspected frequently, in order that they may be removed and sold while still in good condition. It is highly desirable that apples intended for storage be wrapped in oiled paper or packed in shredded oiled paper, in order to reduce damage by scald as much as possible (*22*). Apples should not be stored in the same room with potatoes because of the danger that the former will absorb undesirable odors. On the other hand, the odors given off by apples are readily absorbed by dairy products; consequently the two should not be stored in the same room. (See also p 14.)

(See *8*, *81*, *90*, *19*.)

Apricots

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

Apricots are not stored commercially to any extent, although they will keep well for 1 to 2 weeks at 31° to 32° F. When harvested at a firmness permitting storage and shipping, the fruit lacks flavor and has poor dessert quality after ripening but is satisfactory for canning purposes (*1*).

Avocados

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

Investigations in California (*63*) on the storage of avocados have shown that the best temperature for all varieties grown there, except the Fuerte, is about 40° F. The Fuerte discolors internally at this temperature but holds up well at 45°. At temperatures below 40° all the varieties investigated are likely to become discolored internally and do not soften when removed to a higher temperature. When properly stored, the Dickinson, Royal, Taft, and Queen are said to hold up well for about 2 months, the Spinks, Sharpless, and Challenge for 5 to 6 weeks, and the Rey, Fuerte, and Kist for about 4 weeks. Most of these varieties are of the Guatemalan race.

No general recommendations can be made concerning the storage of varieties of avocados grown in Florida, Central America, or the West Indies, because of the wide variation among them in susceptibility to injury by low temperatures. Many varieties of the West Indian race are injured by exposure to temperatures of 50° to 53° F. for 15 days (*99*, *100*), whereas others (Pollock, Trapp) remain in good condition for 3 weeks when held at 42° (*52*). Varieties of the Guatemalan race are more resistant to cold, and those of the Mexican race are the most resistant of all. Some of the varieties that are least affected by cold (Lula, Taylor) can safely be held at 37° to 42° for 4 weeks (*52*). Wolfe, Toy, and Stahl (*115*), in their work on the storage of Florida-grown avocados, obtained the results given in table 5.

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TABLE 5.—*Effect of storage of various avocado varieties at different temperatures on their marketable life* [1]

Variety [2]	Optimum temperature for storage	Period held at optimum temperature	Period thereafter at room temperature for softening	Period marketable after softening	Gain in marketable life due to storage
	° F.	*Days*	*Days*	*Days*	*Days*
Pollock (WI)	42	21	3	3	17–19
Trapp (WI)	42	21	4–6	2–5	18–20
Waldin (WI)	(3)				
Collinson (G × WI)	42–48	14	4–6	3–4	7–8
Booth 8 (G × WI)	42	14	4–6	1–4	7–9
Lula (G × M)	37	28	3–6	2–3	20–24
Taylor (G)	37	28	4–6	2–3	23–26

[1] Adapted from Wolfe, Toy, and Stahl (*115*).
[2] WI, West Indian; G, Guatemalan; M, Mexican; G × M, Guatemalan × Mexican; G × WI, Guatemalan × West Indian.
[3] Cold injury noted even at 48° storage.

At the higher temperatures mentioned, in the text, anthracnose, a fungus disease of avocados, will probably be an important factor in the storage of this fruit. At the lower temperatures decay is not likely to be troublesome after long storage.

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 banana shipments 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 ripened at a temperature of about 64° F., with a relative humidity of 90 to 95 percent or higher. If it is desired to hasten the ripening process, a higher temperature can be used (up to 70°) for the first 18 to 24 hours, but temperatures should then be reduced to about 66°. In any case the relative humidity should be kept at 90 to 95 percent or higher until the fruit becomes thoroughly colored. After this it should be reduced slightly, but not below about 85 percent. Prolonged exposure to high temperatures will cause poor color and flavor and weak necks and will hasten decay.

The lowest temperature at which green bananas can safely be held in order to delay ripening is about 56° F.; below this they suffer an injury known as chilling—a form of peel injury to which both green and ripe bananas are susceptible, 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 will develop a dull-brown color when later exposed to higher temperatures and is very susceptible to handling marks, the slightest bruising causing discoloration.

The best holding temperature for ripe bananas is generally considered to be between 56° and 60° F. At this temperature they will retain their good appearance and flavor and remain edible for a week or 10 days, although ordinarily they will not keep firm enough for shipment more than half that time.

(See *25*, *103*.)

Blackberries

Short storage only. See Raspberries.

Cherries

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

The extreme limit for the successful commercial cold storage of fresh 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 (*28*). In fact, the treatment has proved to be so beneficial in this respect that it is now being used commercially for shipments of cherries from the West and Northwest to eastern markets.

The sweating discussed on page 13 is particularly troublesome on cherries, because of the dull appearance that it produces on the fruit when displayed for sale soon after removal from iced cars.

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 artificially refrigerated warehouses. The storage period is usually not longer than about 3 months and for that length of time the range from 36° to 40° F. (whether obtained in air-cooled storage or under artificial refrigeration) has been found to be the most desirable. Occasional lots of poorly colored fruit may be held at 45° to 50° for a few weeks in order 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, which can develop at low temperatures (*118*). Shrinkage of the berries as a result of water loss is also a limiting factor. Further facts that need to be kept in mind are that keeping quality depends to some extent on the maturity of the fruit, that some varieties keep better than others, and that there may be a difference in keeping quality from year to year in crops from the same bog.

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 for 5 to 8 weeks if held at a temperature of 32° F., but fruit held for a longer time at that temperature is likely to develop a "low-temperature break-down." 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 has disappeared. Such berries closely resemble those that have been frozen. Fruit held at 36° to 40° is less likely to discolor and become rubbery, but if it has been cleaned and sorted it is more likely to suffer from decay than if held at 32°.

(See *4*, *23*.)

Dates

(Temperature, see text; relative humidity, 65 to 75 percent; or 28° F. and no humidity control for cured grades)

Dates absorb moisture and odors readily 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.

Dates are of two different types, and fruits of each type are likely to 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 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. If such dates are not cured, a temperature of 0° to 10° is necessary for even short-time storage (*89*).

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° (*5*).

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.

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 are favorable to pitting, and higher ones 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. For fruit grown in sections where stem-end rot is prevalent, this disease is likely to be the determining factor; it will generally be advisable to use a comparatively low temperature range (32° to 34°). On the other hand if the fruit is grown in sections where stem-end rot is not prevalent, the limiting factors are likely to be storage pitting and watery break-down, which develop most seriously at temperatures of 40° or lower. For fruit from these sections a temperature of 45° to 55° is 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 as objectionable on such fruits 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 6 weeks without serious spoilage at the higher temperature mentioned above, and this storage period can sometimes be doubled with satisfactory results. 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 or sodium metaborate, pulled from the tree instead of being clipped (*112*), 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.

(See *10*, *24*, *92*, *93*, *94*, *111*, *112*, *113*.)

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 Vendemian, Malaga, Sultanina (Thompson Seedless), Cornichon, and Alphonse Lavallee (Ribier) are also occasionally stored. All of these have low freezing points, lower in fact than the freezing point of any other important fruit, largely because of their high sugar content. Although for most varieties there is no danger of freezing injury at temperatures as low as 28° F. (*13*), they are usually held at temperatures of 30° to 31°. At low air velocities a humidity of 85 percent prevents excessive wilting of stems and berries without favoring the formation of mold growth. At air velocities of 100 to 150 feet per minute a humidity of 90 percent is desirable (*2*, *67*).

California grapes for cold storage are packed in kegs or drums in sawdust or in various types of lidded lugs with or without sawdust. Good results are usually obtained, although if the fruit or the sawdust is damp at packing time or becomes so in storage there is danger of damage by mold. Mold may develop also if the grapes have been handled carelessly and if there are numerous cracked or loosened berries scattered through the pack. 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) seem to keep better than any of the other storage varieties. Treating grapes with sulfur dioxide has helped to reduce spoilage in storage. In recent years the display type of lug has grown in favor for storage, because grapes packed in it can be refumigated. 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 10 days. Under these conditions fruit has been held fully as long in this type of package as in the more expensive sawdust chests or kegs. 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 (*66*).

Storage quality varies considerably from season to season and seems to be adversely affected by rain just before and during harvest. Grapes picked before rains usually keep better than those picked after rains.

(See *13*, *65*.)

AMERICAN

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

The eastern, or American, varieties of grapes, the most important of which is Concord, are not adapted to long storage; and most of them do not hold up well under storage conditions for more than 3 or 4 weeks, depending on the variety. After that time they begin to deteriorate in flavor and may suffer heavily from decay if the temperature is not kept close to 32° F. The Catawba keeps 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.

Too low humidity is undesirable for grapes, since it causes shriveling, especially of the stems. Stock intended for storage should be handled carefully to avoid cracking of the berries or loosening at the cap stem, because such injuries allow juice to exude and thus furnish favorable conditions for the beginning of 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 *2*, *48*.)

LEMONS

(Temperature, 55° to 58° F.; relative humidity, 85 to 90 percent)

From the standpoint of preventing decay (blue mold rot, green mold rot, and alternaria rot) in stored lemons, the lowest temperature that can be used without freezing the fruit would seem to be the most desirable. The difficulty is that at low temperatures certain nonparasitic troubles which are fully as serious as decay develop; among these are red blotch, pitting, and membranous stain. With proper humidity and at temperatures above 50° F. red blotch and pitting practically never occur and membranous stain is greatly reduced. The best results are usually obtained by storage at 55° to 58° in a relative humidity of 85 to 90 percent. Under such conditions lemons can be expected to hold up satisfactorily for periods of 1 month to as long as 4 months, depending on their maturity and condition when stored (*11*). Tree-ripened lemons, which are yellow when picked, do not keep well in storage.

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 latter is able to penetrate the uninjured skin of lemons but is likely to cause more loss if the skin of the fruit is broken at numerous places. 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 danger 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.) Lemons in storage should be examined frequently to avoid loss from the development of decay or other deterioration.

(See *11*, *16*, *39*, *42*.)

Limes

(Temperature, 45° to 48° 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 45° to 48° F. for 6 to 8 weeks, provided that 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.

Logan Blackberries

Short storage only. See Raspberries.

Olives (Fresh)

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

The best storage temperature for fresh olives (*67*) 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.

Oranges

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

Although oranges are ordinarily stored at about 38° F., experimental results have shown that for long storage (8 to 10 weeks) a range of 34° to 38° gives better results. However, within this range some decay, chiefly blue mold rot or green mold rot, may occur during storage of 2 months or more, and some fruit may begin to show pitting and brown stain of the rind. If stored for longer periods, decay increases and the spotted fruit may gradually turn brown over all or most of the surface. Watery break-down may develop, as in grapefruit. Stem-end rot is likely to develop in Florida fruit if the storage temperature is higher than about 34°. Among California varieties, Washington Navel oranges are more subject to decay (blue mold or green mold rots) than Valencia oranges. The Washington Navel is also subject to alternaria rot.

Careful handling is necessary at all times to avoid injury to the fruit. Decay, chiefly blue mold rot or green mold rot, frequently follows injuries.

A free circulation of air around the boxes is desirable for oranges as for other citrus fruit. A relative humidity of 85 to 90 percent is sufficient to hold the shriveling of packed oranges to a minimum and retards decay more than does a higher humidity.

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 regularly and often to avoid 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 may increase rapidly after the fruit is removed to higher temperatures.

(See *12*, *92*, *93*, *94*, *111*, *113*.)

Peaches

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 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. The 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 break-down develops sooner at 36° and 40° than at either lower or higher temperatures. The best storage varieties and the periods they can ordinarily be held in storage are Tuskena (Tuscan), 8 weeks; Early and Late Crawford, and Salwey, 4 weeks; Elberta and J. H. Hale, 3 to 4 weeks. Belle, Champion, Hiley, and Carman 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.

(See *1*, *29*, *33*, *37*, *38*.)

Pears

(Temperature, 29° to 31° F.; relative humidity, 85 to 90 percent)

BARTLETT PEARS

The successful storage of Bartlett pears (*43*, *53*, *54*) depends not only on the temperature and humidity in the storage room but also on the condition of the fruit when stored. If the highest quality is to be obtained, Bartlett pears for storage should not be removed from the tree until the ground color begins to lighten and the lenticels have corked over. If picked before reaching that stage, they have a marked tendency to wilt, scald, and break down in storage. They also tend to break down in storage if picked when too ripe. The most desirable temperature for the storage of Bartlett pears is 29° to 31° F. The relative humidity should range from 85 to 90 percent. The maximum

829965—49——4

period for storage for canning and local fresh markets is about 90 days, and for storage at shipping point and at terminal markets, 45 to 60 days.

FALL AND WINTER PEARS

For fall and winter varieties of pears (*43*, *67*, *68*), such as Anjou, Bosc, Clairgeau, Comice, Easter Beurré, Hardy, Seckel, and Winter Nelis, the most desirable storage temperature is 29° to 31° F. A relative humidity of 85 to 90 percent is most commonly used. However, a relative humidity of 90 to 95 percent is maintained in some pear storage rooms in order to prevent shriveling. Such humidities are maintained in connection with air velocities of 100 to 200 feet per minute. The length of time for which it is safe to store these pears depends on the variety and when it is picked and also on whether the fruit is shipped directly to a consuming center and there stored or is stored at the shipping point for a time and later shipped to market. Information on these points is given in table 6. 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 (*27*). For best ripening after storage these and most other varieties of fall and winter pears should be held at a temperature somewhere in the range from 65° to 70°, preferably about 65°.

TABLE 6.—*Length of time at 30° to 31° F. for safe storage of certain varieties of pears at shipping point and after shipment to market (68)*

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.
Clairgeau	6	February.
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.
Clairgeau	3 to 6	November to February.
Winter Nelis	6 to 7	March to May.

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 (*14*). 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.

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 (*50*) by the United States Department of Agriculture have proved that a ripening temperature of 60° to 65° F. is essential for the attainment of maximum quality in Kieffer pears for either dessert or canning purposes.

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 *102*, *110*.)

Plums (Including Prunes)

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

Plums and prunes (fresh) are not stored extensively and are not adapted to long cold storage. Such varieties as Wild Goose and those of the damson type store better than the softer fleshed plums, such as Santa Rosa, Beauty, Wickson, and Duarte. The storage period, at 31° to 32° F., ranges from 3 to 8 weeks depending on the variety. After that time the soft-fleshed varieties are likely to become too soft for commercial handling, may suffer some darkening of the flesh, and lose somewhat in flavor.

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 prevented by partly ripening the fruit prior to storage at 31° to 32° or by holding it at 40° to 45°.

(See *1*, *26*, *97*.)

Quinces

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 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 80 to 85 percent)

Fresh raspberries, blackberries, Logan blackberries, and dewberries are not adapted to storage and are usually not stored commercially. For short periods, 7 to 10 days, most of them can be kept in fair condition by storage at 31° to 32° F. in a relative humidity of about 80 to 85 percent. Young and Boysen dewberries cannot be stored satisfactorily for more than 3 to 4 days.

Strawberries

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 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 which causes leather rot; 31° to 32° is still better. After about 10 days, sometimes sooner, the fruit loses its fresh bright color, shrivels more or less, and deteriorates in flavor (*114*).

Dried Fruits

(Temperature and relative humidity, see text)

For the preservation of natural color in storage, cut dried fruits and dried berries that are not subject to sugaring are held at 26° F. with no humidity control or at 32° with a relative humidity of 70 to 75 percent.

Figs and prunes are best stored at 40° to 45° F. The relative humidity should not be over 70 to 75 percent, to prevent excessive absorption of moisture. Dried apples, apricots, and peaches keep best at 26° to 32°. Raisins should be stored at 40° to 45° and require a relative humidity of 50 to 60 percent to keep them from absorbing moisture. The holding of dried fruit in high humidity at temperatures above 32° is likely to result in mold. The dried fruits mentioned can be kept in marketable condition for 9 to 12 months at the temperatures and humidities specified.

Dried fruit can be tightly stacked, without stripping, in large solid blocks in storage rooms without injurious effect, and this method of handling the packages minimizes the absorption of moisture from the storage-room air. When nonventilated packages, such as those used for dried fruit and dates, are removed from cold rooms, the sweating that results 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 (*6*).

Frozen Fruits and Vegetables

(Temperature, see text)

Frozen fruits should be held at −10° to 0° F. if they are to be stored for several months.

For the freezing of fruits a temperature of 0° F. or lower is desirable for both 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 (*17*, *18*, *96*).

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 if ample provision is made for rapid cooling until the product reaches the freezing point.

Nuts

(Temperature, 32° to 45° F.; relative humidity, 65 to 75 percent)

Most of the commercial nut crop, including walnuts of all kinds, filberts, almonds, Brazil nuts, peanuts, and sometimes pecans, is usually held in ordinary warehouse storage through the winter following harvest. The portion of the crop (except pecans) that is to be kept through the following summer should be placed in cold storage early in March. 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. shortly after harvest. Brazil nuts can usually be kept satisfactorily in warehouse storage during the winter, but that portion to be held over summer should be stored at 32° before warm weather. Brazil nuts should be carefully inspected before being accepted for storage to see that they are well dried out, or cured. Walnuts, filberts, and almonds usually need not be stored below 40° to 45°. Chestnuts are rarely held in any other way than in cold storage at 32° to 40°.

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. If cold storage is not available, common storage can be used, but the peanuts should be stored in the shell and shelled out as needed, because if stored shelled 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 for any considerable time.

As all varieties of nuts keep better unshelled than shelled, it is usually the best practice to store nuts in the shell and crack them as needed unless the kernels can be sealed in vacuum, which will permit them to be kept even longer than in the shell. Generally nut kernels should be stored at 32° F.

The relative humidity of the storage room should be 65 to 75 percent. At higher humidities there is danger of mold growth, and at lower humidities there will be undue drying.

(See *117.*)

VEGETABLES

By R. C. Wright, *physiologist*

The recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of vegetables are given in table 7. Detailed descriptions of these requirements are given in the text.

Table 7.—*Recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of various vegetables, and the average freezing points*

Commodity	Temperature	Relative humidity	Approximate length of storage period	Average freezing point [1]
	° F.	Percent		° F.
Asparagus	32	85 to 90	3 to 4 weeks	29. 8
Beans:				
Green, or snap	32 to 40	85 to 90	2 to 4 weeks	29. 7
Lima:				
Unshelled	32	85 to 90	do	30. 1
	40	85 to 90	10 days	
Shelled	32	85 to 90	15 days	
	40	85 to 90	4 days	
Beets:				
Topped	32	95 to 98	1 to 3 months	26. 9
Bunch	32	85 to 90	10 to 14 days	
Broccoli (Italian, or sprouting).	32 to 35	90 to 95	7 to 10 days	29. 2
Brussels sprouts	32 to 35	90 to 95	3 to 4 weeks	------
Cabbage	32	90 to 95	3 to 4 months	31. 2
Carrots:				
Topped	32	95 to 98	4 to 5 months	29. 6
Bunch	32	85 to 90	10 to 14 days	
Cauliflower	32	85 to 90	2 to 3 weeks	30. 1
Celeriac	32	95 to 98	3 to 4 months	------
Celery	31 to 32	90 to 95	2 to 4 months	29. 7
Corn (green)	31 to 32	85 to 90	(2)	28. 9
Cucumbers	45 to 50	85 to 95	10 to 14 days	30. 5
Eggplants	45 to 50	85 to 90	10 days	30. 4
Endive	32	90 to 95	2 to 3 weeks	30. 9
Garlic (dry)	32	70 to 75	6 to 8 months	25. 4
Horseradish	32	95 to 98	10 to 12 months	26. 4
Jerusalem-artichokes	31 to 32	90 to 95	2 to 5 months	27. 5
Kohlrabi	32	95 to 98	2 to 4 weeks	30. 0
Leeks (green)	32	85 to 90	1 to 3 months	29. 2
Lettuce	32	90 to 95	2 to 3 weeks	31. 2
Melons:				
Watermelon	36 to 40	75 to 85	do	[3] 29. 2 [4] 28. 8
Muskmelon (cantaloup)	32 to 34	75 to 78	7 to 10 days	[3] 29. 0 [4] 28. 4
Honey Dew and Honey Ball.	36 to 38	75 to 85	2 to 4 weeks	[3] 29. 0 [4] 28. 8
Casaba and Persian	36 to 40	75 to 85	4 to 6 weeks	------
Mushrooms (cultivated)	32 to 35	80 to 85	2 to 3 days	30. 2
Okra	50	85 to 95	2 weeks	30. 1

See footnotes at end of table, p. 31.

TABLE 7.—*Recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of various vegetables, and the average freezing points*—Continued

Commodity	Temperature	Relative humidity	Approximate length of storage period	Average freezing point [1]
	° *F.*	*Percent*		° *F.*
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	28.9
Peas (green)	32	85 to 90	1 to 2 weeks	30.0
Peppers:				
Chili (dry)	(2)	70 to 75	6 to 9 months	
Sweet	32	85 to 90	4 to 6 weeks	30.1
Potatoes:				
Early	(2)	85 to 90	(2)	
Late	38 to 50	85 to 90	(2)	28.9
Pumpkins	50 to 55	70 to 75	2 to 6 months	30.1
Radishes (winter)	32	95 to 98	2 to 4 months	
Rhubarb	32	90 to 95	2 to 3 weeks	28.4
Rutabagas	32	95 to 98	2 to 4 months	29.5
Salsify	32	95 to 98	do	28.4
Spinach	32	90 to 95	10 to 14 days	30.3
Squashes:				
Summer	40 to 50	85 to 95	2 to 3 weeks	
Winter	50 to 55	70 to 75	4 to 6 months	29.3
Sweetpotatoes	[2] 50 to 55	80 to 85	do	28.5
Tomatoes:				
Ripe	40 to 50	80 to 85	7 to 10 days	30.4
Mature green	[2] 55 to 70	80 to 85	3 to 5 weeks	30.4
Turnips	32	95 to 98	4 to 5 months	30.5

[1] These figures are based on previously published work by Wright (*116*) and are subject to revision whenever further investigation makes this necessary.
[2] See text. [3] Flesh. [4] Rind.

ASPARAGUS

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

Fresh asparagus 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° F. 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 this temperature 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 *69*.)

Beans

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

GREEN, OR SNAP

Green beans are usually stored for only short periods. When held at 32° F. they may be expected to keep 2 to 4 weeks provided they are in good condition and are placed in storage promptly. At 40° the storage period will be about a week shorter. The humidity should not be lower than 85 percent, to prevent wilting, 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 too high storage temperature or too long holding period are watery soft rot, slimy soft rot, rhizopus rot, and gray mold rot.

LIMA

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 held satisfactorily for 2 to 4 weeks at 32° and 10 days at 40°.

Beets

(Temperature, 32° F. Relative humidity: topped, 95 to 98 percent; bunch, 85 to 90 percent)

Late beets stored at 32° F. may 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 may be stored in ventilated barrels or better in slat crates. Storage in large bulk should be avoided.

Bunch beets may be stored at 32° F. for 10 days to 2 weeks. See discussion of bunch carrots (p. 34), as the same conditions apply as for bunch beets.

Broccoli (Italian, or Sprouting)

(Temperature, 32° to 35° 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 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 (*76*).

Brussels Sprouts

(Temperature, 32° to 35° 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, cabbage should keep for 3 to 4 months. The longest keeping varieties belong to the Danish Ballhead class. Cabbage is most successfully held in common storage in the Northern States, where a fairly uniform inside temperature from 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 usually is not held in cold storage because its value does not justify the expense of handling.

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 the active respiration of 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 and 10 to even 20 feet long and about 5 feet deep. They are best separated by tight board partitions and ventilating slat floors. Tiers of bins may be built as high as it is convenient to elevate the cabbage, and while the bins are being filled ample air space between the tiers of bins should be allowed for ventilation. The use of slat shelves with the heads piled one or two 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 the field to the storage. Before it is stored, the roots and all loose leaves should be trimmed away and the damaged and misshapen heads should be culled. On

829965—49——5

being removed from storage, the heads should be trimmed again to remove loose and damaged leaves.

Early cabbage, especially southern-grown, should not be expected to keep over 3 to 6 weeks even at 32° F.

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

Carrots

(Temperature, 32° F. Relative humidity: topped, 95 to 98 percent; bunch, 85 to 90 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 above-ground storage. The relative humidity should be maintained at 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, namely, watery soft rot and bacterial soft rot. Carrots are best kept 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.

Bunch 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 in storage. If cold storage is not available bunch carrots from distant production sections may be packed in crushed ice and should keep at least a week. 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; this, of course, is undesirable.

Foliage will discolor sooner if kept warm and wet than if kept cool and dry.

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 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. 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 it 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, 95 to 98 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.

Celery is a rather perishable commodity and under unsuitable storage conditions may suffer severely from 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 1- by 2- or 2- by 2-inch dunnage strips between the crates, which should be stacked so as not to touch at the sides. If wall or ceiling refrigerating coils are used, fans should be located at such positions as 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; otherwise there is danger of overheating even with stock that is in prime condition. If it is piled five to eight 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 *95*.) [4]

Corn (Green)

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

Green 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 will result in serious deterioration. The sugar content, which so largely determines quality in this product and which rapidly decreases at ordinary temperatures, is reduced very little if the corn is quickly cooled and kept at a relatively low temperature. In order to keep this loss of sugar to a minimum and preserve the flavor, corn in the husks as it comes from the field for consumption in the fresh state should be cooled as quickly as possible. This is sometimes done by submerging it in tanks of ice water immediately after removal from the field to reduce the temperature to as near 32° F. as possible.

Corn should not be handled in bulk because of its tendency to heat but should be put in baskets or crates, which allow air circulation and the more rapid removal of field heat and heat produced by respiration. 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 over 10 to 14 days. 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 dark-colored watery areas, which are an indication of low-temperature injury, appear. These areas soon become infected, and mold growth develops. If the cucumbers are held at 50° little or no break-down develops, but they tend to ripen, the color changing from green to yellow, and there may be some shriveling and surface pitting. [5]

Waxing is practiced commercially, usually with a paraffin-carnauba emulsion containing approximately 7 percent solids. This treatment reduces weight loss and improves appearance.

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[4] Thompson, H. C. celery storage. [Refrig. Res. Found.] TRRF Fact File Sheet. 2 pp. October 1947. [Processed.]

[5] Morris, L. L., and Mann, L. K. storage of cucumbers. Refrig. Res. Found. Fact File Sheet. 1 p. December 1948. [Processed.]

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.

Endive, or Escarole

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

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 in order 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 two layers deep in stacks separated by air spaces. It is essential that garlic be well cured in the field before going into storage.

Horseradish

(Temperature, 32° F.; relative humidity, 95 to 98 percent)

Horseradish should keep satisfactorily for 10 to 12 months if stored under the conditions recommended for topped carrots.

Jerusalem-Artichokes

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

Jerusalem-artichokes, 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.

Kohlrabi

(Temperature, 32° F.; relative humidity, 95 to 98 percent)

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

Leeks (Green)

(Temperature, 32° F.; relative humidity, 85 to 90 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 will greatly aid in keeping it fresh. Even when it is held in cold storage, ice tends to keep this product fresher by preventing drying or wilting.

One of the most troublesome diseases of lettuce in transit and storage is tipburn of the type 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, 75 to 85 percent)

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

MUSKMELONS (CANTALOUPS)

(Temperature, 32° to 34° F.; relative humidity, 75 to 78 percent)

The common commercial varieties of cantaloups can be expected to keep about 1 week in cold storage at the recommended temperatures after arrival on the market and, under favorable conditions, for a few days longer but not as long as 2 weeks. The riper the melons are on arrival, the shorter the storage period should be. When they are held too long in storage, decay develops so rapidly on removal that they soon become practically worthless.

(See *70.*)

HONEY DEW AND HONEY BALL MELONS

(Temperature, 36° to 38° F.; relative humidity, 75 to 85 percent)

Honey Dew and Honey Ball melons can usually be kept a little longer in storage than cantaloups. At 36° to 38° F. or slightly lower, such melons can be expected to keep for 2 to 4 weeks and still reach the consumer in good condition. If held for a longer time at temperatures below 36°, low-temperature break-down marked by a watery discoloration of the rind, followed by fungus decay, will probably result; at 36° to 38°, decay, which will seriously discolor the rind, may occur. All blemishes show more plainly on these melons because of their light-colored, smooth surfaces.

CASABA AND PERSIAN MELONS

(Temperature, 36° to 40° F.; relative humidity, 75 to 85 percent)

Casaba and Persian melons are relatively good keepers. They will remain in good condition in storage for at least 4 weeks and have been reported to keep as long as 6 weeks.

MUSHROOMS (CULTIVATED)

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

Mushrooms do not keep well in storage and are therefore stored only temporarily for periods of 2 to 3 days or slightly longer. They are easily injured by freezing.

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.[6]

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 a sufficiently low average winter temperature 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 pro-

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

duced in Washington, southern California, Texas, and other States where the climate is not suitable for common storage, are usually consumed shortly after being harvested. 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. The Spanish, or Valencia, type of onions grown in this country are often stored and, if well-matured, are considered capable of storage for practically as long as the globe type.

A comparatively low relative humidity (70 to 75 percent) is very desirable for the successful storage of onions. 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" (*98*). The fungus causing it can develop to some extent even at 32° F.; hence onions intended for storage should be carefully sorted over 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 five or six 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 for air circulation. When kept in common storage, onions are best 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 a period of 4 to 6 weeks, and all decayed specimens or those showing thick, or "bottle," necks should be sorted out.

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 in order 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 *57*.)

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 very carefully handled 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 will keep in good condition when held in barrels or crates if the proper humidity is maintained.

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. shortly after being picked. 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, 70 to 75 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 and 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 generally low enough (10 to 15 percent) to prevent mold growth; the chief storage trouble is insect infestation. Sometimes manufacturers of Chili pepper products hold part of their supply of the raw material in cold storage, but they prefer to grind the peppers as soon as possible and store them in the manufactured form in airtight containers.

SWEET PEPPERS

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

Sweet, bell, or bullnose peppers, if in good condition may readily be kept fresh in storage for a month to 6 weeks at a temperature of 32° F. A relative humidity of 85 to 90 percent is desirable to prevent shrinkage (*46*).

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 in common unrefrigerated storage through the summer in the locality where it is grown (*44*). The potatoes should, of course, be sorted over carefully before storage to remove all those decayed and seriously bruised and cracked. Investigations in Oklahoma (*15*) 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 purposes, a storage temperature of 60° to 70° is better than one of 50°. The relative humidity should be the same as that for the late crop. 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 *49*.)

It almost goes without saying that under the conditions suggested the storage period would never be so long as is possible with late-crop potatoes.

LATE CROP

(Temperature, 38° to 50° F.; relative humidity, 85 to 90 percent)

Potatoes are stored either in cold or common storage, but the greater part of the crop that is stored is held in common storage (*20*). Like most other vegetables that can be held for relatively long periods in common storage, potatoes can be successfully kept through the fall and winter months only in those sections where a sufficiently cold winter climate prevails. In either cold or common storage a temperature of 40° F. is as low as table or seed stock need be kept during the first few months after harvest. At temperatures below this, there is a tendency for potatoes to become undesirably sweet. However, if sweetening occurs, a few days' exposure to ordinary living-room temperature will partly restore the natural flavor. Potatoes should always be kept in the dark to prevent greening. At 40° potatoes will 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 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 (*64*, *120*), although the higher temperatures are not suitable for long-time storage. When potatoes are stored at these higher temperatures, sprouting will occur more quickly. A limited amount of sprouting does not injure potatoes for food purposes, 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.

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, however, this will be 1 to 3 weeks (*123*).

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 or 100 pounds net; in common storage they are usually placed in bins holding from 150 to as much as 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 will also prevent 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, accumulating especially soon after potatoes are stored in the fall, and will maintain a lower average temperature. 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 to the building structure (*19*).

Potatoes intended for storage should be handled carefully to avoid bruises and cuts; otherwise they are likely to be damaged by various forms of decay before the end of the storage period.

Pumpkins and Squashes

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

In general most varieties of pumpkins will not keep in storage as 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 Table Queen will 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 appears to be 50° to 55° F. with a relatively low humidity of about 70 to 75 percent. Investigations have shown that a preliminary curing at 80° to 85° for about 2 weeks is of benefit in ripening immature specimens and in healing mechanical injuries incident to harvesting.

Summer (yellow crookneck) squashes keep best at a temperature of about 40° to 50° F. and a relative humidity of 85 to 95 percent. Under these conditions, they may show some increase in the yellow color, pitting, and some wilting at the necks after approximately 3 weeks; but they are not likely to be seriously damaged by decay.[7]

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[7] Morris, L. L., and Mann, L. K. STORAGE OF SUMMER SQUASH. Refrig. Res. Found. Fact File Sheet. 1 p. December 1948. [Processed.]

Radishes (Winter)

(Temperature, 32° F.; relative humidity, 95 to 98 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 to allow ample air circulation on all sides; otherwise there is danger of heating and mold growth.

Rutabagas

(Temperature, 32° F.; relative humidity, 95 to 98 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, 95 to 98 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 a week or two after being cut. If crushed ice is used in the packages, this period can be extended somewhat.

Squashes

See Pumpkins and Squashes.

Sweetpotatoes

(Temperature, 50° to 55° F.; relative humidity, 80 to 85 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 to permit the healing of all wounds or abrasions incident to harvesting and handling, in order to prevent the entrance of decay organisms.

The curing and storing are done in the same house so that the potatoes 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 85 percent. After the curing period the storage temperature is allowed to drop to about 55°, with a humidity of 80 to 85 percent. Short periods of a few hours at temperatures somewhat lower than 50° need not cause alarm, but prolonged periods of low temperature should be avoided because of the danger from certain types of decay, which are more likely to develop at temperatures below the range given (*45*, *51*). Under the recommended conditions, properly cured stock should keep satisfactorily for 4 to 6 months.

Only well-matured stock that is practically free from mechanical injury or decay should be used for storage. 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.

(See *40*.)

Tomatoes

(Temperature: ripe, 40° to 50° F.; mature green, 55° to 70°. Relative humidity, 80 to 85 percent)

Ripe tomatoes are held in storage only temporarily and, except for short storage, should not be stored at temperatures lower than 40° F. At 40° to 50°, if not already soft ripe, they will keep in good condition for a week to 10 days; at temperatures lower than this they sometimes show a tendency to break down.

Green tomatoes are best kept at a temperature not lower than 55° F. At this temperature ripening progresses slowly but satisfactorily, and mature green tomatoes can be kept for 3 to 5 weeks before becoming overripe. At temperatures much below 55° green tomatoes do not ripen well and if kept there more than about 8 days and then moved to a warmer place usually do not ripen satisfactorily; on the other hand, if they are to be kept for less than 8 days they can be held at 40° or even somewhat lower. If fairly rapid ripening is desired, temperatures from 60° to 70° should be used. At 70° or slightly above, ripening is accelerated, but so also is the development of decay, which will be found difficult to control. At about 80° coloring will be uneven since the development of the red pigment is inhibited at this temperature or above. The relative humidity of tomato-storage or tomato-ripening rooms should be from 80 to 85 percent.

(See *101*, *119*, *121*.)

Turnips

(Temperature, 32° F.; relative humidity, 95 to 98 percent)

Turnips require the same storage conditions as topped carrots. They can be expected to keep for 4 to 5 months.

Frozen Vegetables

For treatment of frozen vegetables see page 29.

CUT FLOWERS, FLORISTS' GREENS, RHIZOMES, TUBERS, CORMS, AND BULBS

By T. M. Whiteman, *associate horticulturist*

The recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of cut flowers, florists' greens, rhizomes, tubers, corms, and bulbs are given in table 8. Detailed descriptions of these requirements are given in the text.

Table 8.—*Recommended temperature, relative humidity, and approximate length of storage period for cut flowers, florists' greens, rhizomes, tubers, corms, and bulbs*

Commodity	Temperature	Approximate length of storage period
Cut flowers: [1]	° F.	
Babysbreath	40	3 to 4 days.
Bouvardia, sweet	40	7 to 10 days.
Butterflybush, orange-eye	40	3 to 4 days.
Calendula (pot marigold)	40	3 to 6 days.
Calla, common and golden	40	10 days.
Candytuft	40	3 to 6 days.
Carnation:		
Full bloom	33–40	7 to 10 days.
Buds	33–40	10 to 15 days.
China-aster	40	7 to 10 days.
Chrysanthemum	35	2 weeks.
Clarkia	40	3 to 6 days.
Columbine	40	3 to 4 days.
Cornflower	40	3 to 6 days.
Crocus	33–36	1 to 2 weeks.
Dahlia	40	7 to 10 days.
Daisy, English	40	3 to 6 days.
Delphinium:		
Hardy larkspur	40	Do.
Annual larkspur	40	3 to 4 days.
Feverfew	40	3 to 6 days.
Forget-me-not, true	40	3 to 4 days.
Foxglove, common and common white	40	Do.
Freesia	33–36	1 to 2 weeks.
Gaillardia, common perennial	40	3 to 6 days.
Gardenia	45–50	1 week.
Gladiolus	35	2 weeks.
Heath	40	7 to 10 days.
Hyacinth	33–36	1 to 2 weeks.
Iris, Dutch	33	1 week.
Laceflower, blue	40	3 to 6 days.
Lily:		
Easter	35	1 month.
Goldband	35	Do.
Regal	35	Do.
Speciosum	35	Do.
Lily-of-the-valley	40	1 week.
Lupine	40	3 to 6 days.

See footnotes at end of table, p. 47.

TABLE 8.—*Recommended temperature, relative humidity, and approximate length of storage period for cut flowers, florists' greens, rhizomes, tubers, corms, and bulbs*—Continued

Commodity	Temperature	Approximate length of storage period
Cut flowers: [1]—Continued	° *F.*	
Narcissus:		
Daffodil	33–36	1 to 2 weeks.
Paperwhite	33–36	Do.
Orchid	45–50	1 week.
Peony, Chinese and common:		
Tight buds	35	3 to 4 weeks.
Loose buds	35	10 to 14 days.
Phlox, garden	40	3 to 4 days.
Poinsettia	50	Do.
Primrose, baby	40	Do.
Rose	35–40	1 week.
Snapdragon, common	40	3 to 6 days.
Snowdrop	33–36	1 to 2 weeks.
Squill	33–36	Do.
Statice (sea-lavender)	35–40	3 to 6 weeks.
Stevia	40	3 to 4 days.
Stock, common	40	3 to 6 days.
Strawflower	35–40	3 to 6 weeks.
Sweet pea	40	3 to 4 days.
Tulip	33–36	1 to 2 weeks.
Violet, sweet	33–36	3 to 6 days.
Florists' greens: [1]		
Asparagus, fern and smilax	40–45	7 to 10 days.
Ferns:		
Common woodfern	32–45	2 weeks to 4 months.
Dagger	32–45	Do.
Galax	32–45	Do.
Groundpine (*Lycopodium*)	32–45	Do.
Holly (*Ilex opaca*)	32	1 month.
Huckleberry	32–40	3 to 6 weeks.
Leucothoe, drooping	32–40	Do.
Mountain-laurel	32–40	Do.
Rhizomes, tubers, corms, and bulbs: [2]		
Begonia, tuber	45	4 to 6 months.
Caladium, spotted	45	Do.
Calla, common and golden	35	6 to 8 months.
Canna	40–45	6 to 7 months.
Crocus	55–60	4 to 6 months.
Dahlia	40–45	6 to 7 months.
Freesia	55–60	4 to 6 months.
Gladiolus	40–50	7 to 8 months.
Hyacinth	55–60	4 to 6 months.
Lily:		
Easter	32–35	6 to 8 months.
Regal	32–35	Do.
Lily-of-the-valley	25–28	12 to 17 months.
Narcissus:		
Daffodil	55–60	4 to 6 months.
Paperwhite	75–80	5 to 7 months.
Peony	40–45	6 to 7 months.
Snowdrop	55–60	4 to 6 months.
Squill	55–60	Do.
Taro	45	Do.
Tuberose	40–45	6 to 8 months.
Tulip	50–55	4 to 6 months.

[1] Approximately 80 percent relative humidity.
[2] Approximately 75 percent relative humidity; for individual species see text.

The average freezing points of some flower petals, foliage, bulbs, corms, etc., are given in the following tabulation:

	Temperature (°F.)[1]
Foliage:	
Amaryllis	31. 0
Asparagus fern	24. 2
Aspidistra	24. 9
Caladium, spotted	30. 6
Carnation	27. 4
Chrysanthemum	29. 6
Columbine	29. 1
Daisy, Shasta	30. 0
Delphinium (hardy larkspur)	29. 2
Dracaena	28. 0
Fern, 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
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, etc.:	
Calla	27. 5
Dahlia	28. 3
Gladiolus	26. 8
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 previously published work by Wright (*116*) and are subject to revision whenever further investigation makes this necessary.

Cut Flowers

The best prestorage handling of cut flowers not only includes the selection of species and varieties known to be good keepers but also provides for the use of well-grown blooms only. Well-grown flowers are those that have developed under near-optimum water, nutrient, temperature, and light conditions and that have received no mechanical or other damage while on the plant. Flowers of such quality are "firm" and are said to have "substance," terms which probably could be justified on the basis of 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 preparing cut flowers for storage the proper cutting stage, discussed under individual species, is of prime importance. Most cut flowers are benefited by a freshening period of a few hours (in water) at about 50° F. immediately after being cut, unless intended for dry storage. Bunching is usually done before storage. Flowers should be bunched and tied firmly but not too tightly or in too large bunches. Wrapping the bunches with 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; of course, in the case of roses wrapping of the bunches is customary. If intended for storage in water, cut flowers should be stored at the proper temperature soon after they have been freshened at 50°.

One of the chief factors influencing the storage life of cut flowers is temperature. There is no known treatment that is nearly so satisfactory in extending the life of cut flowers as is storage at comparatively low temperatures. If the proper temperature is used, inherent quality should not deteriorate appreciably during a short storage period. The temperatures given here are recommended to insure a reasonably long life for flowers after their removal from storage. Cut flowers for which 45° to 50° F. is recommended, when stored at a much lower temperature, may not keep well after removal from storage. Those for which a storage temperature of 33° is recommended will naturally mature more rapidly if stored at any higher temperature. If held at 33° they develop slowly. Often the changes in storage are not apparent, but the longer the blooms are stored at 33° the shorter will be their life when later they are used for decorations. On the other hand, if short-lived blooms that keep best when held at 40° are stored at 33° they show the effect of the previous adverse conditions after they are placed at ordinary room temperature (70°–75°).

In case a variety of flowers needs to be stored and only one storage room is available it is suggested that a temperature of 40° be used. The length of time that the blooms are to be stored should always be considered. For a number of items table 8 shows the recommended storage temperature as well as the range in the approximate length of the storage period.

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 may 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 may tend to dry to an undesirable degree. A relative humidity of 80 percent is therefore recommended. It has been noted with certain types of blooms, such as gladiolus, that floret development was faster in a room with a temperature of 36° F. and a high relative humidity than in a room at the same temperature and a lower humidity.

In constructing a storage room for cut flowers one of the most important considerations is air circulation. To get good air circulation the vases or buckets of flowers should be set on racks arranged so that air can pass through and back of them. Forced but gentle air movement should be provided, but the blooms should not be in a direct draft. The containers should be spaced so that the blooms are not crowded.

Cut flowers in storage should usually be kept with the stems in water. They should not be crowded in the container because of the danger of mechanical injury and the decay that may result because of insufficient ventilation. In most cases care should be taken not to spill water on the blooms as these usually discolor rather readily. Experiments in which French marigolds and carnations were stored out of water for comparatively long periods have been reported (*60*, *61*). Peonies are known to keep fairly satisfactorily when stored out of water.

Damage to several kinds of cut flowers when stored in the same room or even in the same building with apples, oranges, pears, and other fruits should be emphasized. Such damage is evidenced by premature withering or the rapid aging of the blooms and is thought to be caused by the ethylene gas given off by the ripening fruit. Roses, carnations, snapdragons, stocks, and daffodils have been shown to be affected in this way by the emanations from ripening fruit (*47*, *58*). Since ethylene gas is used at times to defoliate rose bushes and is known to cause premature dropping of foliage from cut sprays of holly, it may also affect such greens as mountain-laurel and huckleberry. Greens therefore should not be stored near the fruits mentioned.

Many kinds of pigmented flowers fade, discolor, or develop an off-color appearance during storage, especially under dark storage conditions. The effectiveness of artificial light in retarding this color change has been demonstrated experimentally (*59*).

Chrysanthemums (*Chrysanthemum hortorum*) and gladioluses (*Gladiolus*) may be stored at 35° F. for 2 weeks and usually remain very salable. Longer storage is possible, though frequently not practicable. These flowers are usually tied in bunches of 12 and 25, respectively, but are not wrapped when placed in storage. Pompons, however, are sold in bunches of various sizes.

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.

Gladioluses should be cut when three or four of the lower buds are partly opened. However, for distant shipments before storage one or two of the lowest florets should show color but should be in the tight-bud stage. Gladiolus spikes should always be shipped and stored in a vertical position (*105*).

Easter lily (*Lilium longiflorum*), Speciosum lily (*L. speciosum*), Regal lily (*L. regale*), goldband lily (*L. auratum*), common peony (*Paeonia officinalis*), and Chinese peony (*P albiflora*) can be held at 35° F. for comparatively long periods, although 30 days is usually the maximum storage period. The lilies in this group should be cut for storage when the corolla is about one-half opened or just before the tips begin to reflex. Lilies forced at relatively high temperatures should be kept at a temperature of about 50° for a preliminary period of about 24 hours before being put at 35°. Peonies showing color in the tight-bud stage may be stored at 35° for 3 to 4 weeks, but they seldom give satisfaction for decorative purposes without special handling; in the loose-bud stage they may be held satisfactorily for 10 to 14 days.

The cut blooms of common and golden callas (*Zantedeschia aethiopica* and *Z. elliottiana*) may be stored when fresh for as long as 10 days at 40° F. and will be in good condition upon removal. Calla blooms should be gathered just before the spathe shows signs of curling downward. Callas that have been subjected to hard forcing should be held for about 24 hours at a temperature of 50° previous to storage at 40°. 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 useless appendage. Although the blooms are sometimes removed from the plant by cutting, the stub left on the plant will probably rot and thus may serve as a place of entrance for disease organisms. Pulling, however, is much easier with potted callas than with those planted in beds or benches. Callas intended for storage should be tied near the end of the stem and also loosely tied below the blooms. They are usually put up in lots of 1 dozen.

Lupine (*Lupinus*), clarkia (*Clarkia*), common stocks (*Matthiola incana*), candytuft (*Iberis*), delphinium, or hardy or perennial larkspur (*Delphinium formosum* and hybrids), cornflower (*Centaurea cyanus*), feverfew (*Chrysanthemum parthenium*), common snapdragon (*Antirrhinum majus*), blue laceflower (*Trachymene caerulea*), English daisy (*Bellis perennis*), calendula, or pot marigold, (*Calendula officinalis*), and common perennial gaillardia (*Gaillardia aristata*) should not be held at temperatures lower than 40° F., and cannot be stored with good results for more than a 3- to 6-day period. Sweet violets are usually made up in bunches of 100, supported underneath by a few galax leaves and wrapped with a light waxed paper, and should be stored at 33° to 36°.

Columbine (*Aquilegia*), stevia (*Piqueria trinervia*), babysbreath (*Gypsophila paniculata*), annual larkspur, baby primrose (*Primula forbesii*), sweet pea (*Lathyrus odoratus*), true forget-me-not (*Myosotis scorpioides*), and orange-eye butterflybush (*Buddleia davidii*) all have flowers whose petals shed quickly, almost regardless of temperature. They cannot be held much lower than 40° F. or for longer than 3 to 4 days without impairing the keeping quality after removal. Forced *Buddleia* is sold by the dozen. The others mentioned are bunched in lots of 25. It is not customary to wrap any of these for storage, but, as previously mentioned, certain kinds may be wrapped to prevent tangling with adjacent bunches.

Orchids and gardenias (*Gardenia augusta*, *G veitchi*, and *G. fortunei*) are not customarily stored for long periods. However, they may be kept in storage in good condition for about a week at a temperature of 45° to 50° F. They keep best when cut just after they have reached a salable condition.

Carnations (*Dianthus caryophyllus*) cut in full bloom may be held at 33° to 40° F. for 7 to 10 days. If cut in the bud stage they may be stored at 33° to 40° for 10 to 15 days. Several varieties of carnations, although it is not known how many, will develop satisfactorily when cut in the bud stage, viz, when one or two petals have unfolded from the bud, and will last considerably longer than if cut at a more advanced stage of maturity (*47*).

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 with the variety in question. In the loose-bud stage they may be held at 35° to 40° F. for 1 week; if stored at lower temperatures the subsequent keeping quality is often impaired (*59*). These are often tied loosely in bunches of 25 buds and wrapped with parchment paper.

Dahlias (*Dahlia*), China-asters (*Callistephus chinensis*), sweet bouvardia (*Bouvardia humboltii*), and heath (*Erica*) may be held 7 to 10 days at 40° F. They usually are handled in lots of 1 dozen, tied, but not wrapped.

Statice, including bigleaf and notchleaf sea-lavender (*Limonium latifolium* and *L. sinuatum*, respectively), and strawflower (*Helichrysum bracteatum*) may be kept at 35° to 40° F. for 3 to 6 weeks. They may be dried and will retain their original color and shape;

strawflowers are usually dried instead of being stored to retain their freshness.

Common foxglove (*Digitalis purpurea*), common white foxglove (*D. purpurea* var. *alba*), and garden phlox (*Phlox paniculata*) are not usually satisfactory for storage but may be held for 3 or 4 days at 40° F.

The various forced irises, especially the so-called Dutch irises, may be held for 1 week at 33° F. (*106*).

Cut poinsettias (*Euphorbia pulcherrima*) 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 holding is necessary, storage at about 50° F. is recommended. Any change of environment, such as improper storage, will increase the apparently inherent tendency of poinsettias to shed their foliage. They should be cut when showing sufficient color to be salable. Searing the cut ends with boiling water is a practice usually followed to prevent undue loss of sap before or during storage.

Cut lilies-of-the-valley (*Convallaria majalis*) are kept satisfactorily at 40° F. and may be held for 1 week at this temperature; if they are kept longer the lower bells often become watery in appearance (*104*). The proper cutting stage is just after the terminal bell has lost its deep-green color. It should be of a yellow-green appearance, the lower 3 or 4 bells at this time being well opened. They are usually tied with foliage in bunches of 25 and are better wrapped loosely in heavy waxed paper, leaving the tops and bottoms of the bunches open.

Hyacinth (*Hyacinthus orientalis*), tulip (*107*), narcissus (daffodil and paperwhite), freesias (*Freesia refracta* var. *alba*), squills, snowdrops (*Galanthus nivalis*), and crocuses can usually be held satisfactorily for 1 to 2 weeks at 33° to 36° F.

Spikes, such as snapdragons, should be cut just after the lower five or six flowers have fully opened; umbels, such as blue laceflower, should be cut just after they develop to a salable condition; flowers formed in heads usually should be cut after the outermost petals are fully developed and just before stamens appear in the center of typically single heads or after the center has become closed with petals in double sorts; 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 about two-thirds of the determinate branches are 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 (*87*). With further tests on different types of blooms, the use of such materials may become more extensive as a supplement for cold storage or during shipment.

Florists' Greens

Fern asparagus (*Asparagus plumosus*) and smilax asparagus (*A. asparagoides*) are usually shipped in crates. The turn-over of these greens is rapid and shipments are arranged so that storage for longer than 3 or 4 days is usually unnecessary, but they may be kept in the case for 7 to 10 days at 40° to 45° F. The sprays of *A. plumosus* are tied in bunches of various sizes. Smilax is packed in the crates in various lengths or "strings." The commercial popularity of *A. sprengeri* has declined so much that it is produced and used chiefly by small retail growers.

Drooping leucothoe (*Leucothoe catesbaei*), huckleberry, and mountain-laurel (*Kalmia latifolia*) sprays may be held in good condition at 32° to 40° F. for 3 to 6 weeks. They are usually tied in bunches and kept standing in water.

Galax (*Galax aphylla*), groundpine (*Lycopodium*), dagger ferns, common woodferns, and various other species including *Dryopteris intermedia*, packed in crates, may be held at 32° to 45° F., depending on the length of time it is desired to keep them. At 32° they may be expected to keep 1 to 4 months, whereas at 45° they may be kept for but 2 to 3 weeks in good condition. They are not put in water, but if stored loose they are kept moist by occasional sprinklings. If they are held in wooden cases or packed in such a way as to prevent excessive drying out by direct air currents, no sprinkling is necessary. Galax is usually tied in bunches of 25; the ferns are tied in lots of 50; but both are customarily sold by the hundred. Those who make a business of gathering the greens in this group sometimes store them in coldframes, covering them with about 6 inches of some material such as sphagnum moss or leaves, and shading or using sash as the weather demands. Handled in this way, shipments can be made at any time. Others who might be termed "brokers" have many employees gathering galax and ferns and store their entire holdings in cold-storage warehouses; this is the method commonly employed for storage, and it usually gives satisfaction.

Holly (*Ilex opaca*) sprays or wreaths can usually be held satisfactorily for approximately 1 month at a temperature of 32° F. and a relative humidity of about 80 percent. These should be left in the packing cases to prevent the circulation of air immediately around them (*122*).

A plastic coating has been used on such greens as fern asparagus, dagger fern, and cut branches of several evergreen trees (*35*, *87*).

Rhizomes, Tubers, and Corms

Lily-of-the-valley pips or crowns may be held in cold-storage warehouses at a temperature range of 25° to 28° F. (*104*) up to 17 months, although after about 12 months increasing deterioration in quality becomes noticeable. The pips are tied in bundles of 25 with string or willow ties and are packed with sphagnum moss in wooden cases of various sizes containing 250 to 2,500 pips.

Taro (*Colocasia esculenta*), spotted caladium (*C. neoguineensis*), and tuber begonias (*Begonia tuberhybrida*) may be held at 45° F. and a relative humidity of 75 to 80 percent for 4 to 6 months. They should be packed in dry sawdust, sand, or peat.

Canna (*Canna indica*), dahlia (*Dahlia*) (*3*), and peony (*Paeonia*) may be stored at 40° to 45° F. over a period of 6 to 7 months with a relative humidity of 70 to 80 percent. They are usually packed in dry soil, sand, sawdust, or peat moss.

Gladiolus (mostly hybrids) may be stored at 40° to 50° F. with a relative humidity of 70 to 75 percent for 7 to 8 months. A temperature of 40° will hold these corms dormant during the normal storage season, whereas at 50° sprouting will occur after 4 to 6 months' storage. They should be stored dry in shallow trays with ample ventilation but only after a curing period of 3 to 6 weeks in an open or well-ventilated shed.

Common and golden callas (*Zantedeschia aethiopica* and *Z. elliottiana*) stored at 35° F. and a relative humidity of 70 to 75 percent in dry soil, sand, or peat will keep for many months if it is necessary to store them. The normal rest period in the forcing cycle is during May, June, and July. Unless water is withheld during this period complete dormancy will not exist. Therefore, storage in a dry condition is essential, with sufficient humidity to prevent undue shriveling.

Bulbs

Most varieties of daffodils (*Narcissus*), hyacinths, freesias, squills (*Scilla*), snowdrops (*Galanthus nivalis*), *Crocus*, and similar bulbs may be held at 55° to 60° F. for 4 to 6 months. However, these as well as tulips (*Tulipa*) are usually not stored, because better results are obtained by planting them as soon as they are received. Paperwhite narcissus (*108*) may be stored at 75° to 80° for 5 to 7 months from digging time.

Tulips are usually not stored in any packing material, although the use of such material may be advantageous for long storage. Temperatures of 36° to 38° F., except for short storage, are considered rather low for tulips shipped from the West in which the buds are already formed. The best storage temperature for shipped tulips is between 50° and 55°, at which they may be kept for 4 to 6 months. Tuberoses (*Polianthes tuberosa*) stored at a temperature of 40° to 45° may be expected to keep satisfactorily for 6 to 8 months.

Bulbs of the genus *Lilium*, of which there are approximately 50 species, are like most other bulbs in giving best results if planted when received. However, as Easter lilies are forced during the entire year, it becomes necessary to provide cold-storage conditions suitable for satisfactory holding until they are wanted for planting. The bulbs should be packed in boxes in thoroughly dry soil if rooting and desiccation are to be prevented. A temperature of 32° to 35° F., with a relative humidity of 75 to 80 percent, is recommended; under these conditions they may be held for 6 to 8 months.

The procedure of storing certain bulbs for a time previous to planting at a temperature that will subsequently hasten flowering is in considerable use commercially. Bulbs so handled are said to be "precooled" (*7*, *31*, *32*).

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