Cold Storage Chart & Reference Guide

Robert Hadad – Regional Vegetable Specialist, CCE Cornell Vegetable Program

Vegetable	**Recommended Temp**	**Recommended Relative Humidity**	**Max Time Held**
------------------------	(° F)	(%)	(Weeks)
Asparagus	32	90-95	1-2
Bean	45-50	85-90	1-2
Beet, topped	**32**	**90-95**	**7-8**
Broccoli	**32**	**90-95**	**1-2**
Brussels sprouts	**32**	**90-95**	**4**
Cabbage	**32**	**90-95**	**12-16**
Carrot, topped	**32**	**90-95**	**16-20**
Cauliflower	**32**	**90-95**	**3-4**
Chinese cabbage	**32**	**90-95**	**8-12**
Greens	**32**	**90-95**	**1-3**
Kohlrabi	**32**	**90-95**	**4-8**
Lettuce, head	**32**	**90-95**	**2-4**
Honey Dew	50-55	85-90	2-4
Muskmelon	45-50	85-90	1-2
Onion, dry	32	70-75	28
Parsnip, topped	**32**	**90-95**	**24-26**
Pea	32	85-90	1-2
Pepper, sweet	45-50	85-90	1-6
Potato	**38-40**	**85-90**	**24-26**
radish, spring, bunched	32	90-95	1-2
Radish, winter	**32**	**90-95**	**8-16**
Rutabaga, topped	**32**	**90-95**	**8-16**
Spinach	**32**	**90-95**	**1-3**
Squash, winter	50-55	70-75	24-26
Tomato, mature green	55-60	85-90	1-4
Turnip, topped	**32**	**90-95**	**16-22**
Watermelon	**50-55**	**85-90**	**1-6**

Adapted from: USDA bulletin #66 - **The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks**

Asparagus

There are two forms of marketed asparagus, namely white (blanched) and green. White asparagus is more common in Europe and Asia (Lipton 1990); green asparagus is popular in the United States and is produced predominantly in California and Washington. Asparagus has a high metabolic rate after harvest and is among the most perishable crops.

Quality Characteristics and Criteria

High quality asparagus spears are dark green and firm with tightly closed and compact tips (Suslow 1998a,b). Spears are straight, tender, and glossy in appearance. Spears with green butts are preferred over the spears with white butts, as the latter are associated with increased toughness. However, a small amount of white tissue at the butt will delay decay development under typical commercial distribution conditions (Lipton 1990, Suslow 2001).

Horticultural Maturity Indices

Asparagus spears are harvested as they emerge through the soil from the underground crowns. Typically, spears are cut when they reach 10 to 25 cm (8 to 10 in) in length, with spear tips still tightly closed. Tender, immature (that is, shorter) asparagus may be harvested for special markets.

Grades, Sizes, and Packaging

Harvested spears are prepared for market by grading, sizing, and bunching. Grades are based on freshness, length and diameter of the stalks, color of spears, tightness of the spear tips, and the extent of bruising. Sizing is based on spear diameter with U.S. No. 1 having a diameter >1 cm (>0.5 in) and U.S. No 2 having a diameter >0.8 cm (>5/16 in). Spears of larger diameter are considered to be superior in quality with less fiber (Peirce 1987). Spears are tied in bunches weighing 0.45 to 1.1 kg (1 to 2.5 lb) and trimmed to a standard length of 18 to 25 cm (7 to 10 in). Color is also important, with U.S. No. 1 spears being green for more than 2/3 their length, while U.S. No. 2 are green for more than half their length. After trimming the butt-end, the bunches are packed upright in trapezoidal

-shaped crates to minimize geotropic bending (curving away from gravity) in transit. The container should include a wet pad in contact with the butt end to maintain turgidity. Headspace is provided in the carton to prevent tip curvature or breakage during spear elongation.

Precooling conditions

Asparagus is highly perishable and must be cooled immediately to 0 to 2 °C (32 to 36 °F). A 4-hr delay in cooling resulted in an average 40% increase in shear force due to tissue toughening. Asparagus is typically partially cooled during the washing, selection, and packing operation, and then hydrocooled to near 0 °C (32 °F) after packing.

Optimum Storage Conditions

The recommended conditions for commercial storage of asparagus are 0 to 2 °C (32 to 36 °F) with 95 to 99% RH, yielding 14 to 21 days of storage life. Maintaining a low storage temperature is critical to delay senescence, tissue toughening, and flavor loss. High RH is essential to prevent desiccation and to maintain freshness. Typically, asparagus is packed and shipped with water saturated pads in the bottom of the containers to maintain high RH and to replenish water lost by the spear or water used during spear elongation; this practice maintains spear turgidity. Excessive free water at elevated storage or shipping temperatures may lead to increased decay.

Chilling Sensitivity

Asparagus is subject to chilling injury after about 10 days at 0 °C (32 °F). Symptoms include loss of sheen and glossiness and graying of tips. A limp, wilted appearance may be observed. Severe chilling injury may result in darkened spots or streaks near the tips.

Ethylene Production and Sensitivity

Ethylene production is low to intermediate, increases with time after harvest, and varies with where the spears are cut relative to the soil surface (Lipton 1990). For spears cut at the soil surface and held at 20 °C (68 °F) for 45 and 90 min, ethylene production changes from 2.1 and 3.1 $\mu L\ kg_{-1}h$

Exposure to ethylene accelerated the lignification (toughening) of asparagus spears (Hennion et al. 1992). Prompt cooling and maintaining optimal shipping temperatures minimizes ethylene - induced toughening.

Physiological Disorders

Elongation and Tip Bending.

Asparagus continues to grow and elongate after harvest if not immediately cooled and stored at temperatures below 5 °C (41 °F). Holding the butt in contact with water (the moist pad) promotes spear growth and elongation. Tip bending occurs as the result of upward growth of the tips when the spears are horizontal. If spears are held in an upright position, tip bending may still occur if the tips reach the top of the package and are physically deflected. Postharvest treatment of asparagus spears in heated water at 45 to 50 °C (113 to 122 °F) for 2 to 5 min reduces tip bending (Paull and Chen 1999).

Spear Toughening.

Tissue lignification and fiber development, which progresses from butt to tip, cause spear toughening. It develops at >10 °C (50 °F), rapidly above 15 °C (59 °F), and is accelerated by ethylene.

Feathering.

Feathering is the appearance of bracts of spear tips, which have opened due to outgrowth of the underlying buds. Tip feathering is a sign of senescence, often observed following extended storage at higher than optimal temperature or harvesting of overmature spears.

Freezing Injury.

Water -soaked appearance and tissue softening occur at temperatures below -0.5 °C (31 °F).

Postharvest Pathology

The most prominent postharvest disease on asparagus is bacteria soft rot, caused by Pectobacterium carotovora or Pseudomonas spp. Decay may occur anywhere on the spears in the form of “soft rot pits,” most frequently found on the tips or the butts. Spears with green butts are more susceptible to this decay than spears with white butts. Storing asparagus at <5 °C (41 °F) controls this disease. In some production areas, the fungi such as Fusarium, Penicillium, and Phytophthor are associated with postharvest decay or spoilage of asparagus (Snowdon 1992).

Bean

Quality Characteristics and Criteria

Beans should be well -formed and straight, bright in color with a fresh appearance free of defects, and tender (not tough or stringy) but firm. The diameter of the pod, rather than length, is a good indicator of quality. Buyers prefer pods with no or only slight bulges indicating tender, young seeds. As the name implies, snap beans should break easily when the pod is bent, giving off a distinct audible snap. Poor quality is most often associated with overmaturity, broken beans, water loss, chilling damage, and decay.

Cooling

Snaps beans can be hydrocooled. This is especially beneficial in dry climates where dehydration is a concern and in situations where evaporation of surface moisture occurs rapidly after cooling (for example, beans packed in wire-bound crates).

Hydrocooling is very rapid, but significant postharvest decay can occur if the product remains wet after cooling. Forced-air cooling is the method of choice if beans have been packed. Efficient cooling is achieved without leaving free moisture on beans, but high relative humidity must be maintained to reduce excessive water loss.

Optimum Storage Conditions

Snap beans should be stored at 5 to 7.5 °C (41 to 46 °F) with 95 to 100% RH. At 5 to 7.5 °C (41 to 46 °F), a storage life of 8 to 12 days is expected. Good quality can be maintained for a few days at temperatures below 5 °C (41 °F), but chilling injury will be induced (see Chilling Sensitivity). Some chilling may occur even at the recommended storage temperature of 5 °C (41 °F) after 7 to 8 days, depending on cultivar. Quality rapidly decreases above 7.5 °C (46 °F) due to yellowing, seed development, and water loss. Waxed cartons and plastic film liners reduce water loss. The perishability and rates of water loss of immature beans are higher than for mature beans. Long beans have postharvest requirements similar to those of snap beans with similar responses to chilling.

Chilling Sensitivity

Snap and pod beans are chilling sensitive, and visual symptoms depend on the storage temperature. Below 5 °C (41 °F), chilling injury produces a general opaque discoloration of the entire bean. A less common symptom is pitting on the surface and increased water loss. Discrete rusty brown spots appear at 5 to 7.5 °C (41 to 46 °F). These lesions are very susceptible to attack by common fungal pathogens. Beans can be held about 2 days at 1 °C (34 °F), 4 days at 2.5 °C (37 °F), and 6 to 10 days at 5 °C (41 °F) before chilling symptoms appear (Cantwell and Suslow 2008). No discoloration occurs on beans stored at 10 °C (50 °F), but undesirable seed development, water loss, and yellowing will occur. Different varieties differ substantially in susceptibility to chilling injury.

Freezing Injury

Freeze damage occurs at -0.7 °C (30.7 °F) or below and appears as water -soaked areas that subsequently deteriorate and decay.

Ethylene Production and Sensitivity

Beans produce only very low amounts of ethylene

Ethylene exposure promotes chlorophyll loss, increases browning, and reduces green bean storage life by 30 to 50% at 5 °C (41 °F) (Wills and Kim 1996).

Respiration Rates

Beans are rapidly growing when harvested and have high respiration rates.

Physiological Disorders See Chilling Sensitivity.

Postharvest Pathology

Various decay organisms may attack fresh pod beans as a result of chilling injury, surface moisture, or mechanical damage. Common decay-causing fungi are those causing “nesting decays” (cottony leak caused by Pythium spp. and Rhizopus spp), gray mold (Botrytis cinerea), and watery soft rot (Sclerotinia spp.). Water - soaked spots may be due to lesions caused by bacterial infections (Pseudomonas spp. And Xanthomonas spp.)

Beet

Quality Characteristics and Criteria

Quality criteria include root shape, root size (diameter), color, firmness (turgidity), smoothness, cleanness, trimming of rootlets, and freedom from defects. Intensive and uniform color with minimum zoning is the most important quality criterion.

Horticultural Maturity Indices

Fresh -market bunched beets (with tops) are harvested as early as 50 to 70 days after planting; whereas roots (without tops) are usually harvested later but before they reach full maturity, especially when they are intended for long-term storage.

Grades, Sizes, and Packaging

Grades U.S. No. 1 and U.S. No. 2 are based primarily on external appearance. Unless otherwise specified, the diameter of each beet shall not be less than 2.5 to 3.8 cm (1 to 1.5 in). Standard bunches shall be fairly uniform in size, and each bunch of beets shall not weigh less than 0.5 kg (1.1 lb) and must contain at least 3 beets. Fresh-market bunches are packed in small crates of 10 to 15 kg (22 to 33 lb) capacity, whereas beets intended for storage are packed in 20 kg (44 lb) polyethylene-lined crates or bins of 500 to 600 kg (1,100 to 1,320 lb) capacity.

Precooling Conditions

Bunched beets should be precooled to below 4°C (39 °F) within 4 to 6 hof harvest. Hydrocooling, forced-air cooling, and package icing are common cooling methods. Proper precooling and packaging retard subsequent discoloration of the leaves, weight loss, and decay. Mature harvested beets should be precooled within 24h after harvest to below 5°C (41 °F) with forced-air cooling.

Optimum Storage Conditions

Bunched beets can be kept for about 10 to 14 days at 0°C (32 °F) and above 98% RH. Topped beets should be stored at 1 to 2°C (33 to 36 °F) and 98% RH. During storage at 0 to 1°C (32 to 34°F), more black spot and rot occur than at higher temperatures (Schouten and Schaik 1980). Red beets can be in air-ventilated storage for 4 to 6 mo and in mechanical refrigerated storage for as long as 8 to 10 mo.Before storage, beets should be topped and sorted to remove all diseased or mechanically damaged roots. Large roots keep much better than small ones because they lose water and shrivel more slowly. Red beets can be stored in pits and trenches, especially where winter temperatures are low for prolonged periods. Insulation of pits (clamps) and trenches is needed to avoid injurious temperature fluctuations. The temperature in pits (clamps) and cellars should not drop below -0.5°C (31 °F) or exceed 5°C (41°F) to minimize losses caused by freezing, sprouting, and rotting.

Controlled Atmosphere (CA) Considerations

Chilling Sensitivity

Beet roots are not sensitive to chilling and should be stored in temperatures as low as possible without freezing.

Ethylene Production and Sensitivity

Beet roots produce very low amounts of ethylene, and are not particularly sensitive to ethylene exposure.

Physiological Disorders Death of shoots and breakdown of the top part of roots are common problems during long-term storage at 0 ºC (32 °F). Physiological disorders can appear quickly during subsequent shelf –life at 20 ºC (68 °F) after storage.

Postharvest Pathology

The most common decay during storage is gray mold (Botrytis cinerea Pers.) Beet roots are also affected by black rot caused by Phoma betae. Water-soaked and brown lesions become black and affect mostly the tip of the root. Good air circulation and optimal storage conditions retard development of black rot.

Broccoli (handling similar for Cauliflower)

The crop is annual and grows to maturity in about 75 to 95 days, depending on cultivar, season, and planting date. The whole immature influorescence (head) is the edible portion, with the floret tissue most often preferred by consumers. It grows best in cool climates and is available year.

Quality Characteristics and Criteria

High-quality broccoli is either a dark or bright green with closed flower buds (termed “beads”). The head should be firm to hand pressure and compact, and the stalk cleanly cut to the appropriate length for a particular grade standard or for “crowns” (dissected portions of the whole influorescence).

Horticultural Maturity Indices

Ideal maturity is based on head diameter, compactness, and tightly closed flowers (beads). Overmature heads are characterized by open flower buds or enlarged buds on the verge of opening, resulting in a loose head.

Grades, Sizes, and Packaging

There are three grades: U.S. Fancy, U.S. No. 1, and U.S. No. 2. They are based on external appearance, level of damage, trimming, and stalk diameter. Two or three heads are normally bunched together for the fresh market. Such bunches are packed 14 to 18 units in waxed cardboard boxes and weigh approximately 10 kg (21 lb) (Boyette et al. 1996). Larger heads may have the stem trimmed to produce “crowns,” and these are packed loose in 9 kg (20 lb) boxes. Individual florets are also cut and packed in 2.5 to 5 kg (5.5 and 11 lb) film bags for hotel, restaurant, and institutional use.

Precooling Conditions

Field-packed broccoli is commonly cooled by injecting liquid ice into waxed cartons. Ice maintains the proper temperature and RH for transport and distribution. Hydrocooling and forced-air cooling are also options, but good temperature management is required during transport (Cantwell and Suslow 1999).

Optimum Storage Conditions

Broccoli can be kept in excellent condition for 2 to 3 weeks at 0ºC (32ºF) with 98 to 100%RH. Package icing is required if storage or transport conditions cannot maintain the recommended temperature or RH (Shewfelt et al. 1983). Use of ice is not necessary if temperature can be maintained (Kleiber et al. 1993). Perforated plastic film packaging is recommended to minimize wilting (Toivonen 1997). Loss of quality during prolonged storage is caused by wilting, yellowing of buds and leaves, loosening or opening of buds, and decay.

Chilling Sensitivity

Broccoli is not sensitive to chilling and should be stored as cold as possible without freezing.
Ethylene Production and Sensitivity Broccoli produces very little ethylene, but it is extremely sensitive to ethylene, with floret yellowing being the most prevalent symptom. Exposure to ethylene halves shelf-life

Physiological Disorders

Bead (bud) yellowing may occur in overmature broccoli when stored at higher-than-optimal temperatures or in response to exposure to ethylene. Presence of yellow beads ends the commercial marketability of broccoli. There is sometimes confusion between senescence associated yellow bead and yellow – to –light -green marginal areas of floret that occur due to shading by adjacent floret tissue. This is normal for tissue that is not exposed to light during head growth. A disorder called black speck on stems occurs in stored broccoli, and certain cultivars are more sensitive than others (DeEll and Toivonen 1998).

Postharvest Pathology

Grey mold rot (Botrytis cinereaPers.:Fr.) is the most commonly reported mold in shipped broccoli (Ceponis et al. 1987). Erwinia carotovora and Pseudomonas spp. bacterial head rots are found on shipped and stored broccoli. Injury to the bead tissue during handling may enhance development of these rots (Liao and Wells 1987). While Erwinia carotovora decay seldom develops below 5 °C (41 °F), decay caused by Pseudomonas spp. Can be severe (Liao and Wells 1987) since it grows relatively well even at low storage temperatures.

Freezing injury may occur during liquid-ice cooling if excessive salt is used in the slurry mixture or if the broccoli is stored below -1 ºC (30 ºF). Thawed buds will be very dark and translucent and can later turn brown or may serve as sites for development of bacterial decay. Rough handling during harvest and packing can damage floret tissue and lead to increased levels of damage.

Brussels Sprouts

Quality Characteristics and Criteria

High-quality brussels sprouts are about 2.5 cm (1 in) in diameter, firm with green outer leaves, and a white cut end. The inner leaves are light yellow, fairly tightly arranged, and without large air pockets between them.

Horticultural Maturity Indices

Harvest maturity is based on sprout size and compactness. Sprouts should be 2.5 cm (1 in) or more in diameter but not more than 7 cm (2.75 in) in length Stem elongation, resulting in space between older leaves, is a sign of overmaturity.

Precooling Conditions

Effective cooling methods include vacuum cooling, hydrocooling, icing, and forced-air cooling. Vacuum cooling is most effective when sprouts are premoistened to reduce wilting and can be an effective method of cooling even when sprouts are packaged, as long as the packaging material is ventilated.

Hydrocooling is also an efficient method to rapidly cool sprouts from 20 to 2 °C (68 to 36°F) in about 15 min. Package or top -icing can also be used, especially if storage or transport conditions cannot maintain recommended temperature or RH.

Forced-air cooling effectively cools sprouts if packaging is properly vented to allow good air movement about the product.

Optimum Storage Conditions

Quality can be maintained for 3 to 5 week at 0 °C (32 °F) and 95 to 100%RH.
Storage life is half as long at 5 °C (41 °F) and only 10 days at 10 °C (50 °F).

Brussels sprouts do not produce severe off odors when held in low O_2 as do other Brassica vegetables such as broccoli (Forney and Jordan 1999).

Chilling Sensitivity

Brussels sprouts are not sensitive to chilling and should be stored as cold as possible without freezing.

Ethylene Production and Sensitivity

Brussels sprouts produce low to moderate levels of ethylene. Brussels sprouts are extremely sensitive to ethylene, with leaf yellowing and abscission being the most prevalent symptoms.

Physiological Disorders

Internal browning, or “tipburn,” is the margins of inner leaves in buds turning brown and is caused by inadequate transport of calcium to young expanding leaves. Growing conditions that favor rapid growth promote internal browning.

Postharvest Pathology Diseases of importance during storage are bacterial soft rots (Erwinia sp. and Pseudomonas, bacterial leaf spot (Pseudomonas syringae, black or gray leaf spot (Alternaria sp), and grey mold (Botrytis cinerea

Special Considerations

Brussels sprouts can be stored attached to their stem to prolong storage life. Packaging in vented poly-bags or over wrapped cups reduces wilting. Sprout freeze at -0.8 °C (30.6 °F).

Cabbage

Quality Characteristics and Criteria

Cabbage leaves should be green, dark purple, or crinkly, depending on the cultivar. The head should be firm and heavy for its size. The heads are crisp and fresh if they squeak when rubbed together. The presence of a waxy bloom on the leaves is desirable. Yellow leaves on green cultivars suggest extensive trimming of the outer leaves. The presence of a seedstalk is undesirable.

Horticultural Maturity Indices

Determination of maturity in brassicas is not simple and no one index of maturity is reliable. At maturity, a cabbage head should be firm and weigh 0.5 to 3 kg (1 to 6.6 lb), depending on cabbage type and cultivar. Immature heads, besides being smaller and softer, have an excessive tendency to wilt and a less characteristic odor (Pritchard and Becker 1989). Overmature heads are more susceptible to splitting, pathogens, physiological disorders, and seed stalk formation.

Precooling Conditions

Cabbage should be cooled as soon as possible after harvest to preserve quality and reduce wilting. If cabbage is harvested under cool conditions, it can be placed in storage and cooled without precooling. Hydrocooling before storage or forced air-cooling in storage can be used to rapidly remove field heat (Boyette et al. 2008a).

Optimum Storage Conditions

Cabbage should be stored at 0 °C (32 °F) with 98 to 100%RH. Storage at -1 °C (31 °F) may cause freezing, while storage at 1 °C (34°F) may promote senescence-related storage losses, especially if held in long-term storage. The presence of light in the storage room reduces physiological disorders such as leaf yellowing and weight loss. Cabbage is stored in bins or in bulk (IOS 1991). Only three to six wrapper leaves should be left on the head (Hardenberg et al. 1986). All loose leaves should be trimmed before storage because they will interfere with air circulation between heads. Air circulation in the storage should be sufficient to maintain constant and uniform temperature and RH around all cabbage heads. Bulk stored cabbage should be ventilated in a vertical direction and the depth should not exceed 3 m (9.8 ft). Bin-stored cabbage should be arranged to maximize uniform air flow around each bin. Storage life depends on cultivar (for example, early-maturing cultivars tend to have shorter storage life than late -maturing cultivars), quality (for example, freedom from decay), and storage conditions (Pritchard and Becker 1989, IOS 1991, Boyette et al. 2008a). The end of storage life is signaled by increased respiration rate, core elongation, and sometimes rootlet development on the core butt.

Chilling Sensitivity

Cabbage is not chilling sensitive. The freezing point is -0.9 to -0.83 °C (30.4 to 30.5 °F). Even though cabbage with core temperature of -1.1 °C (30 °F) before harvest can show no evidence of freeze damage, storage at -1.0 °C (30.2 °F) is not advisable because it can produce freeze damage, especially on outer leaves (R. Prange, unpublished data). Temperature oscillations during cycling of mechanical refrigeration may expose tissue to freezing temperatures if the setpoint is too low or if the hystersis is too large.

Ethylene Production and Sensitivity

Cabbage produces very little ethylene. Cabbage should not be exposed to ethylene after harvest. Ethylene increases respiration and accelerate senescence and quality loss (for example, leaf yellowing, wilting, and abscission more in air.

Physiological Disorders

The physiological cause is unknown for some disorders of stored cabbage (for example, black midrib, black speck of cabbage [pepper spot, spotted necrosis], gray speck, and necrotic spot) (Bérard 1994). The occurrence of these disorders is influenced by cultivar and cultural practices, especially mineral nutrition. Some storage disorders are clearly frost-induced (for example, black blotching, black spot, epidermal detachment, frost blemishing, and redheart). Bérard (1994) also describes storage disorders caused by dormancy, ethylene, and head maturity.

Postharvest Pathology

The major cause of postharvest decay in cabbages is the gray mold fungus (Botrytis cinerea). Gray mold can be minimized by using resistant cultivars, using preharvest fungicides, practicing strict hygiene, avoiding mechanical or frost damage, rapid cooling to 0 °C (32 °F), and using CA storage (Snowden 1991). Alternaria rot, also known as dark, black, or gray leaf spot and caused by Alternaria spp., infects a wide range of cruciferous vegetables and can cause significant storage losses. Since this disease is commonly transmitted through infected seed, it can be minimized by using disease -free seed, rotation with noncruciferous crops, applying preharvest fungicides, destruction of diseased material before storage, and using rapid cooling to 0 °C (32 °F). There are other fungi (such as ring spot), bacteria (bacterial rots and watery soft rot, for example), and a virus (tobacco mosaic virus) that cause significant losses.

Carrot (Handle Parsnips similarly)

Quality Characteristics and Criteria

Quality criteria vary with use. High - quality carrots are firm, straight from “shoulder” to “tip,” smooth with little residual “hairiness,” sweet with no bitter or harsh taste, and show no signs of cracking or sprouting.

Horticultural Maturity Indices

Harvest maturity varies with the market outlet and use. Fresh market carrots are harvested partially mature, when the roots are about 1.8 cm (0.75 in) or larger in diameter at the upper end. Late harvesting may improve storability by reducing decay during extended storage. Fresh-cut processing carrots are harvested immature to ensure they are tender and sweet.

Precooling Conditions

Prompt washing and hydrocooling to under 5 °C (41 °F) are essential to maintain carrot freshness and crispness. Typically, carrots pass through several wash and flume steps that remove field heat and are then hydrocooled in chlorinated water before packing.

Optimum Storage Conditions

Storage at 0 to 1 °C (32 to 34°F) is essential to minimize decay and sprouting during storage. High RH is required to prevent desiccation and loss of crispness. Mature topped carrots can be stored for 7 to 9 mo at 0 °C (32 °F) with 98 to 100% RH. However, commercial storage and distribution conditions rarely achieve the optimum storage conditions and topped carrots are often stored for 5 to 6 mo at 0 to 5 °C (32 to 41 °F) with 90 to 95% RH. Common “Cello-pack” carrots are typically immature and may be stored successfully for 2 to 3 weeks at 3 to 5 °C (37 to 41 °F). Bunched carrots are highly perishable due to the presence of leaves and can be maintained for only 8 to 12 days. Bunched carrots are typically shipped and stored with shaved or flaked ice.

Chilling Sensitivity

Carrots are not chilling sensitive and should be stored as cold as possible without freezing. Their freezing point is -1.2 °C (29.8 °F).

Ethylene Production and Sensitivity

Carrots produce very little ethylene. However, exposure to ethylene induces development of the bitter compound isocoumarin. Induction and accumulation of isocoumarin is greatest in the peel of cut carrot sections. Exposure of peeled carrot to ethylene does not result in development of bitterness. Whole or sectioned carrots should not be exposed to ethylene in storage.

Physiological Disorders

Bruising, shatter-cracking, longitudinal cracking, and tip breakage are signs of excessively rough handling. Nantes type carrots are particularly susceptible to mechanical damage. The severity of shatter - cracking is partially related to varietal background. Wilting, shriveling, and rubberiness are signs of moisture loss. Sprouting may occur on topped carrots if the storage temperature is too high. Bitterness can develop in storage due to the accumulation of isocoumarin, caused by disease or exposure to ethylene. Harsh flavor may be caused by high terpenoid content induced by preharvest water stress. Surface browning or oxidative discoloration often develops during storage, especially on carrots harvested when immature.

Postharvest Pathology

The most prominent storage decays are bacteria soft rot (induced by Pectobacterium carotovora or Pseudomonas marginalis), gray mold rot (Botrytis cinerea), rhizopus soft rot (Rhizopus spp.), watery soft rot (Sclerotinia sclerotiorum), and sour rot (Geotrichum candidum). Good sanitation during packing and storage at 0 °C (32 °F) minimizes postharvest diseases.

Celeriac

The harvest portion is a bulbous tuber with a crisp texture and a white flesh that has a nutty, celerylike flavor. It is also known as celery root or apio and can be used fresh or cooked. It must be peeled to remove the rough, light-brown skin if used fresh.

Quality Characteristics and Criteria

The primary quality characteristics are a firm texture and tender flesh. Roots with a soft, spongy texture should be avoided.

Precooling Conditions

Celeriac can benefit from precooling since it retains quality best when stored at 0 °C (32 °F). However, since celeriac has a relatively low respiration rate, the benefits of precooling must be balanced with the desired storage time before marketing and consumption.

Optimum Storage Conditions

Celeriac can be stored for 6 to 8 mo at 0 to 2 °C (32 to 36 °F) with RH of 97 to 98%. Storage life can be under 4 mo if temperature exceeds 3 °C (38 °F). High RH of 90 to 98 % is needed to prevent moisture loss, which results in shriveling. Freezing injury can occur if celeriac is stored at temperatures below -1 °C (30 °F) and is manifested as water-soaked areas or softening.

Chilling Sensitivity

Celeriac is not chilling sensitive and should be stored as cold as possible without freezing.

Ethylene Production and Sensitivity

Ethylene production is low. However, celeriac may be slightly sensitive to ethylene. Therefore, celeriac should not be stored with other fruit or vegetables that produce high levels of ethylene.

Physiological Disorders

Ethylene exposure may result in toughening of the root.

Postharvest Pathology

Decay may become a problem if celeriac is stored in a warm, humid environment.

Cucumber

Quality Characteristics and Criteria

The rind of slicing cucumbers should be dark green and firm with no pits or wrinkled (pinched) ends. Spine color is associated with mature fruit color and fruit netting. Fruit of white-spined cultivars are light green to yellow when mature and not netted. Black-spined fruit are orange or brown when mature and may be netted. The flesh is crisp and white, except in a few cultivars where it is pale orange.

Horticultural Maturity Indices

Fruit are harvested at various stages of development. Immature fruit are green at the edible stage, except for a few cultivars that are white or yellow. Fruit are generally harvested immature (that is, before the seeds are fully enlarged and hardened) with a diameter of <5 cm (2 in) for picklers and <6 cm (2-3/8in) for slicers. The minimum length is 14 cm (5.5 in) for slicers. Fruit firmness, external glossiness, and formation of jellylike material around the seeds are indicators of proper harvest maturity. Greenhouse-grown parthenocarpic (produced without pollination) fruit are harvested 10 to 14 days after anthesis after they turn bright green (Kanellis et al. 1988). Straight, uniformly cylindrical fruit slightly tapered at both ends are of highest quality. Cucumbers are listed as nonclimacteric, yet there is a burst of ethylene production that precedes a rapid loss of chlorophyll in harvested fruit.

Precooling Conditions

The chilling sensitivity of cucumbers does not preclude precooling with cold water (hydrocooling) or air (forced -air) (Ryall and Lipton 1979). However, even though fruit can tolerate brief exposure to chilling temperatures, they should not be maintained at chilling temperatures for more than 6 h.

Optimum Storage Conditions

Recommended conditions for commercial storage of cucumbers are 10 to 12.5 ºC (50 to 54 °F) at 95%RH. Storage life is generally less than 14 days, with visual and sensory quality rapidly declining thereafter. Chilling sensitivity limits storage temperatures to a narrow range. Storage below 10 °C (50 °F) results in chilling injury in as little as 2 or 3 days, while storage at 15 °C (59 °F) results in rapid yellowing and loss of quality.

Chilling Sensitivity

Cucumbers are chilling sensitive and most fruit will be injured if stored below 10 °C (50 °F) for more than 2 or 3 days. Sensitivity varies greatly with duration of exposure, temperature, cultivar, growing conditions, and storage environment (Cabrera et al. 1992). CA during chilling and high RH after chilling can reduce symptom expression. Intermittent warming to nonchilling temperatures for 12 h every 2 or 3 days can reduce chilling injury of fruit held at 0 to 2 °C (32 to 36 °F). Development of chilling injury symptoms can be avoided if chilled fruit are used immediately after removal from storage.

Ethylene Production and Sensitivity

Cucumber fruit produce little ethylene, but they are very sensitive to it.

Physiological Disorders

Chilling injury is characterized by surface pitting, increased yellowing and disease susceptibility, and development of water-soaked areas of the flesh. Bruising and compression injuries are common when careful harvest and handling procedures are not followed.

Postharvest Pathology

Diseases are a significant source of postharvest loss, especially in fruit weakened by chilling injury. The many bacterial and fungal pathogens responsible for postharvest losses include Alternaria spp., Didymella black rot, Pythium cottony leak, and Rhizopus soft rot.

Eggplant

Quality Characteristics and Criteria

A high -quality American eggplant is uniformly egg-shaped or globular and has a fresh green calyx, firm flesh, and dark purple skin. Additional quality indices are size, freedom from growth or handling defects, and decay.
Fruit are harvested immature before seeds begin to significantly enlarge and harden. Firmness and external glossiness are also used as harvest indicators. Overmature fruit become pithy and bitter.

Precooling Conditions

Rapid cooling to 10°C (50°F) immediately after harvest is necessary to retard discoloration, weight loss, drying of calyx, and decay (Ryall and Lipton 1979). Hydrocooling and forced-air cooling are most effective, but room cooling after washing or hydrocooling is common.

Optimum Storage Conditions

Fruit are stored at 10 to 12°C (50 to 54°F) with 90 to 95%RH because they are chilling sensitive. Visual and sensory qualities deteriorate rapidly after 14 days of storage, especially if chilled during storage. Short-term storage or transit temperatures below 10°C (50°F) are often used to reduce weight loss but result in chilling injury after transfer to retail conditions.

Eggplants should never be held in contact with ice. Odor from ginger, and possibly other odor-producing commodities such as onions, can be absorbed by eggplants. Thus, these products should not be placed in close proximity to eggplants.

Chilling Sensitivity

Eggplants will develop chilling injury after storage for 6 to 8 days at 5°C (41°F)

Surface pitting and scald are definite external symptoms (McColloch 1966). Scald refers to brown spots or areas that are first flush with the surface but may become sunken with time. Browning of the flesh and seeds is a conspicuous internal symptom of chilling injury, almost invariably followed by decay caused by Alternaria sp. (Ryan and Lipton 1979). Chilling injury is cumulative and may be initiated in the field prior to harvest. Symptom development can be reduced by storage in polyethylene bags or polymeric film overwraps that retard water loss; however, increased decay from Botrytis is a potential risk.

Ethylene Production and Sensitivity

Rates of ethylene production are low but Eggplant fruit have a moderate to high sensitivity to ethylene exposure. Calyx abscission and increased deterioration, particularly browning, may be a problem if eggplant fruit are exposed to ethylene.

Freezing Injury

Eggplant fruit freeze at -0.8°C (30.6°F). Symptoms include water-soaked pulp that becomes brown and desiccated over time.

Physiological Disorders

Harvesting should be done by cutting the calyx-stem free from the plant rather than by tearing. Cotton gloves are often worn to protect the fruit. Bruising and compression injury is very common when not enough attention is paid to careful harvest and handling practices. Eggplant fruit cannot withstand stacking in bulk containers.

Postharvest Pathology

Postharvest diseases often occur in combination with chilling stress. Common fungal pathogens are Alternaria (black mold rot), Botrytis (gray mold rot), Rhizopus (hairy rot), Phomopsis rot, and Phytophtora (soft rot).

Lettuce and Other Greens

Quality Characteristics and Criteria

Head lettuce should be solid with no seed stem, defects, or decay. In general, high quality lettuce should be clean, free of browning, crisp and turgid, and bright light green.

Horticultural Maturity Indices

Head lettuce is harvested when the heads are well formed and solid. Maturity is based on head compactness, and the firmness of the head is related to its susceptibility to certain postharvest disorders. Soft heads are easily damaged, while fairly firm heads have higher respiration rates. Firm heads have maximal storage life, while hard and extra-hard heads are more prone to develop russet spotting, pink rib, and other physiological disorders.

Precooling Conditions

Vacuum-cooling is the preferred method for precooling all lettuces. For effective vacuum-cooling, containers and film wraps are perforated or readily permeable to water vapor. If heads of lettuce are dry and warmer than 25 °C (77 °F), clean water is sprinkled on them the before closing the cartons to aid cooling. A modification called hydrovacuum reduces water loss during cooling. Thorough precooling is essential because mechanically refrigerated trucks do not have enough cooling capacity to cool warm lettuce during transit. Field heat retained in the densely packed cartons can be removed by forced air where vacuum-cooling facilities are not available, but it is much less effective. Hydrocooling is effective for nonheading lettuce types but should not be used with head lettuce since the water retained in the head fosters decay.

Optimum Storage Conditions

Lettuce should be quickly cooled and maintained as close to 0 °C (32 °F) as possible with 98 to 100%RH. Head types are better adapted to prolong storage than are the other types, but none keep longer than 4 weeks, and about half that time at 5 °C (41 °F). Film liners or individual polyethylene head wraps are desirable for attaining high RH; however they should be perforated or be permeable to maintain a noninjurious atmosphere and to avoid 100% RH on removal from storage. Lettuce is easily damaged by freezing, so all parts of the storage room must be kept above the highest freezing point of lettuce, -0.2 °C (31.6 °F).

Chilling Sensitivity

Not chilling sensitive, but freezing at -0.2 °C (31.6 °F) must be avoided.

Ethylene Production and Sensitivity

Ethylene production is very low, but exposure to ethylene can result in damage such as russet spotting and leaf yellowing.

Physiological Disorders

Some of the more common disorders of head lettuce include tipburn, russet spotting, brown stain, and pink rib (Ryall and Lipton 1979, Saltveit 1997b). Hard heads are more susceptible to these disorders than firm lettuce. Tipburn is of field origin, but occasionally increases in severity after harvest. Leaves with tipburn have brown, often necrotic leaf margins. Russet spotting, which is caused by exposure to ethylene and its induction of the synthesis, accumulation, and oxidation of phenolic compounds at temperatures around 5 °C (41 °F), occasionally causes serious losses. Russet spots appear as dark brown, oval lesions on the midribs, and on the green leaf tissue in severe cases. It is easily controlled by making sure the storage atmosphere is free of ethylene and that the temperature is below 2 °C (36 °F). Lettuce should not be stored with ethylene-producing commodities such as apples, cantaloupes, pears, and peaches.

Postharvest Pathology

Bacterial soft rot, the most serious disease of lettuce, often starts on bruised leaves and results in a slimy breakdown of the tissue (Saltveit 1997b). A similar breakdown of tissue follows fungal infection by Sclerotinia and gray mold rot caused by Botrytis cinerea. Trimming and storage at 0°C (32 °F) greatly reduce the severity of these disorders.

Onion

Quality Characteristics and Criteria

High quality onions havemature bulbs with good firmness and compactness of fleshy scales. Size, shape, and the color of the dry skin should be typical for the variety. They should be free of mechanical or insect damage, decay, sunscald injury, greening of fleshy scales, sprouting, bruising, doubles, bottlenecks (onions which have abnormally thick necks with only fairly well developed bulbs) and any other defects.

Horticultural Maturity Indices

Harvest maturity depends on the purpose for which the onions are grown. Onions intended for storage should be harvested when 50 to 80% of the tops have fallen over and bulbs are mature with a thin neck. Yields are higher if they are harvested after the tops are completely dry, but then bulbs tend to have a shorter storage life. To hasten maturity, tops can be rolled with a light roller when 10% of them have fallen. About 7 days before lifting, bulbs can be undercut by a blade; such onions should not be used for long -term storage. Onions for bunching can be harvested from the time they are pencil-sized until they have proper bulb size.

Precooling Conditions

In order to maintain high quality, bunched green onions should be precooled to <4 °C (39 °F) within 4 to 6h of harvest. Hydrocooling, forced - air cooling, and vacuum-cooling are used with crushed ice over the product to maintain temperature and moisture. Dry onion bulbs for long-term storage should be precooled to 0 °C (32 °F) immediately after drying, or within 1 mo using cool outside air. The precooling method affects storability. Rapid precooling inhibits rooting and sprouting during storage. Natural cooling (slow) has a positive effect on storability when onions have a long rest period and weather conditions are good for curing. Gradual cooling at 1 °C (1.8 °F) per day in storage is less effective at inhibiting sprouting and rooting than rapid cooling.

Optimum Storage Conditions

Bunched green onions can be stored 3 to 4 weeks at 0 °C (32 °F) with 95 to 98%RH. Under these conditions, bunched onions stored in polyethylene-lined containers and top-iced maintain excellent quality for 1 mo. Storage life decreases to 1 week if the temperature is 5 °C (41 °F), and rapid yellowing and decay of leaves occurs at higher temperatures. Pungent dry onions can be stored for 6 to 9 mo at 0 °C (32 °F) with 65 to 75%RH. High RH induces root growth, while high temperature induces sprouting. A combination of high temperature and high RH increases rotting and decreases quality. Storage below the freezing point of -1 to -2 °C (28 to 30 °F) is recommended in Europe.

Mild type or sweet onions can be kept for 1 to 3 mo; they are stored in common storage with cool, circulating ambient air or in refrigerated cold rooms. Onions grown from seed store better than those grown from sets or transplants. After harvest, onion bulbs enter a state of rest for 4 to 6 weeks, depending on cultivar and weather conditions during growth. Maleic hydrazide, a sprouting inhibitor, is often used to prevent root growth and sprouting during long-term storage. It is applied 2 weeks before harvest, when bulbs are mature and 50% of tops are down, but onion plants must still have five to eight green leaves in order to absorb and translocate the sprout inhibitor to bulbs. Onions intended for storage should be dried well and cured in the field, under sheds, or in storage. After 2 weeks of field drying, onions can be transferred to storage rooms for final drying and curing. Forced -air ventilation at 25 to 27 °C (77 to 81 °F) using outside or heated air is commonly used to dry onions. Onions can be stored and dried on the floor in bulk 3 to 4 m deep or in 500 to 1,000 kg (1,100 to 2,200 lb) boxes. Drying is complete when the onion neck is tight, outer scales are dry and make a rustling noise when touched, and the skin color is uniform. Weight loss of 3 to 5% can occur during drying. Losses from neck rot are reduced by rapid drying immediately after harvest. After drying and curing, the temperature should be lowered gradually to the normal seasonal temperature, or bulbs can be precooled in cold storage at 0 °C (32 °F).

In either case, condensation should be avoided as it encourages rot and changes the color of the dry skin.
In most European countries and in the Northern United States, onions are stored in common storage, using cool, ambient air to maintain optimum temperature and RH. In this condition, onions are usually stored only until the end of March or beginning of April, since further storage can cause losses to sprouting and rotting. Refrigerated storage is used for onions that are to be marketed in late April to early July. For cold storage, onions are usually packed in crates or containers. Air circulation must be sufficient to maintain a constant temperature and remove moisture from inside storage containers. Onions packed in sacks can only be stored for a limited period, about 1 mo, since air movement through sacks is insufficient to maintain proper storage conditions. When stored below -1 to -2 °C (28 to 30°F), onions should be thawed at 5 °C (41 °F) for 1 to 2 weeks before they are removed from storage. Rapid thawing damages onion bulbs. Mild and sweet onions can be stored for only 1 to 4 mo, even in optimal cold storage. CA may extend the storage period. Onions tolerate storage at 30 to 35 °C (86 to 95 °F) for short periods before marketing or processing, but their quality and external color is less attractive than that of cold-stored onions.

Physiological Disorders

Onion bulbs are affected by several physiological disorders. Freezing injury causes soft, water-soaked, fleshy scales and rapid decay after transfer from cold storage to higher temperature, which results in microbial growth. Translucent scales resemble freezing injury and are prevented by prompt cold storage following curing. Translucent scales occur with loss of or changes in carbohydrate content. Storage of onions at >7% CO_2 can also lead to development of translucent scales. Late harvesting and a long drying period at high temperatures produce the highest incidence of translucent scales. Watery scales is a thick leathery skin with watery, glassy, fleshy scales below. The watery scales may later be affected by fungal or bacterial growth. Late harvesting and prolonged field drying produce the highest occurrence of leathery skin. Scale greening, a green coloration of outer scales, is caused by exposure to light after curing.
Ammonia injury is indicated by brown-black blotches resulting from leakage of ammonia during storage

Postharvest Pathology

A number of microorganisms attack onions postharvest. Botrytis neck rot is indicated by watery decay, which begins at the neck and then attacks the entire bulb. A gray fungal mold then cover s the neck of the bulb and later the whole bulb surface. Neck rot can be slowed after harvest, but it cannot be stopped, even during storage under optimum conditions. Proper drying in the field and during storage can decrease this postharvest fungal decay disease. Black mold rot presents a black discoloration and shriveling at the neck and on outer scales caused by Aspergillus niger. Infection usually occurs in the field, but the disease spreads from bulb to bulb postharvest.

The surface of bulb s must be dry during and after harvest to avoid infection. Storage at 0 °C (32 °F) with moderate RH prevents the spread of this disease. Blue mold rot also produces watery soft rot of neck and outer scales, followed by formation of blue to blue-green mold of the fungus Penicillium spp. Harvest of mature bulbs, proper curing, and storage at 0°C (32 °F) with 60 to 70%RH minimizes blue mold problems. Bacterial soft rot, caused by Erwinia carotovora, develops water-soaked individual scales, or the entire onion, with foul smelling, viscous, liquid-covered rotted areas.

The disease progresses rapidly under warm, humid conditions. Harvesting at full maturity, proper drying, minimizing bruising, and maintaining optimum storage conditions prevent bacterial soft rot.

Pepper

Quality Characteristics and Criteria

Good -quality sweet bell peppers are uniform in shape and are the size and color typical of the variety. The flesh (pericarp) should be firm and relatively thick with a bright skin color and sweet flavor; it should be free from defects such as cracks, decay, and sunburn. Peppers should not be shriveled and dull-looking or pitted. The same quality criteria apply to fresh chili peppers. Dry lines or striations across the skin are not an indication of poor quality —they indicate a hotter pepper.

Horticultural Maturity Indices

Criteria for the maturity of green peppers include fruit size, firmness, and color. For colored peppers the additional criteria of having a minimum of 50% coloration is important. Chili peppers are harvested by hand. They are generally picked when ripe and then dried and allowed to equilibrate in moisture content in covered piles. The major dried peppers are hot red peppers for cayenne and occasionally pimientos for paprika. The pods may be sliced before drying to shorten drying time and improve color and flavor. Seeds may be removed by screening and water sprays.

Precooling Conditions

After harvest, fresh market peppers should be rapidly cooled to no lower than 7 °C (45 °F) at high RH to reduce water loss and shrivel. Precooling can be done using forced-air cooling, hydrocooling, or vacuum-cooling. Properly vented cartons are required to facilitate forced-air cooling. If hydrocooling is used, care should be taken to prevent development of decay. High RH is necessary to avoid desiccation. Waxing has been used to reduce desiccation, but it tends to increase bacterial soft rot. Shelf-life varies among different pod types. Deterioration is often due to moisture loss, with some pod types more prone to desiccation than others.

Optimum Storage Conditions

Fresh peppers can be kept for 2 to 3 weeks at 7 °C (45 °F) with 90 to 95%RH. Storage life can be extended another week by packaging in moisture-retentive films at 7 to 10 °C (45 to 50 °F). Peppers are subject to chilling injury when stored below 7 °C (45 °F) and to accelerated ripening and bacterial soft rot when stored above 13 °C (55 °F). Storage at 5 °C (41 °F) reduces water loss and ripening, but after 2 weeks chilling injury will appear. Some pepper cultivars can be sensitive to chilling if stored at 7 °C (45 °F), so a good storage temperature range is 7 °C (45 °F) to 13 °C (55 °F).

Chilling Sensitivity

Peppers are sensitive to chilling injury when stored below 7 °C (45 °F). Symptoms include surface pitting, water-soaked areas, decay (especially Alternaria), and discoloration of the seed cavity. Symptoms can appear after a few days at 0 °C (32 °F) or a few weeks at 5 °C (41°F). Sensitivity varies with cultivar; ripe or colored peppers are less chilling sensitive than green peppers.

Physiological Disorders

Blossom end rot is characterized by a slightly discolored or dark sunken lesion at the blossom end of the fruit. It is caused by calcium deficiency during growth. Pepper speck appears as spotlike lesions that penetrate the fruit wall. The cause is unknown; some varieties are more susceptible. Chilling injury is described above.

Postharvest Pathology

The most common decay microorganisms are Botrytis, Alternaria, and soft rots of fungal and bacterial origin. Botrytis (grey mold) is a common organism on peppers. Field sanitation and prevention of wounds on the fruit reduce its incidence. Botrytis grows well at the recommended pepper storage temperatures. High CO_2 levels (>10%) can control Botrytis but damages peppers. Hot water dips at 53 to 55 °C (126 to 130 °F) for 4 min can effectively control botrytis rot without causing fruit injury. The presence of alternaria black rot, especially on the stem end, is a symptom of chilling injury. The best control is to store peppers at 7 °C (45 °F). Bacterial soft rot is caused by several bacteria that attack damaged tissue. Soft rots can occur on washed or hydrocooled peppers when water sanitation is inadequate. Peppers are also affected by many of the disease, virus, insect, and nematode pests that affect tomato.

Squash

Quality Characteristics and Criteria

Tenderness and firmness are the major quality characteristics. The surface of summer squash should be shiny; dullness is a sign of senescence. Fruit should be firm and free of physical injury. Dark green types should be entirely green; yellowish areas are a sign of senescence. Water loss results in a dull surface and loss of firmness.

Precooling Conditions

Room-cooling, forced-air cooling, and hydrocooling are acceptable methods for removing field heat from summer squash (Lill and Read 1982). Prompt precooling after harvest reduces the rate of water loss and is essential for maximum postharvest life.

Optimum Storage Conditions

Summer squash are highly perishable and not suited for storage longer than 2 weeks. For maximum shelf-life, Summer squash should be held at 5 to 10 °C (41 to 50 °F) with 95%RH.

Chilling Sensitivity

Summer squash are chilling sensitive and should not be exposed to temperatures below 5 °C (41°F). However, variation in chilling tolerance among summer squash types is great. Chilled summer squash show surface pitting and decay rapidly at nonchilling temperatures, though damage may be absent during refrigeration. Chilled fruit have increased rates of water loss upon transfer to nonchilling temperatures.

Physiological Disorders

Summer squash are very susceptible to water loss. Shriveling may become evident with as little as 3% weight loss. Precooling and storage at high RH minimize weight loss. Squash can be waxed, but only a thin coating should be applied. Waxing provides some surface lubrication that reduces chafing in transit. Summer squash skin is very tender; skin breaks and bruises can be a serious source of water loss and microbial infection.

Postharvest Pathology

Decay caused by fungal and bacterial pathogens can cause significant postharvest losses in summer squash. The incidence of decay increases in fruit that have physical injury or chilling stress. Common postharvest diseases include alternaria rot, bacterial soft rot, cottony leak, fusarium rot, phythopthora rot, and rhizopus rot. Alternaria rot can be especially pronounced following chilling injury.

Sweet Corn

Quality Characteristics and Criteria

High-quality sweet corn has uniform size and color (yellow, white, or bicolor); sweet, plump, tender, well-developed kernels; and fresh, tight, green husks. It is free from insect injury, mechanical damage, and decay.

Sweetness is the most important factor in consumer satisfaction. All sweet corn varieties lose sweetness and aroma during storage, but the taste of su1 and su1/se varieties becomes starchy while sh2 varieties eventually taste watery and bland.

Horticultural Maturity Indices

Sweet corn harvest maturity is determined by a combination of ear fill, silk drying, kernel development, kernel sweetness, and kernel tenderness. The appearance of the juice, or endosperm, is a good indicator of maturity for su1 and se varieties, in which a milky (not watery or doughy) consistency represents proper maturity, but not for sh2 varieties, which always have a watery endosperm.

Precooling Conditions

Sweet corn is often >30 °C (86 °F) when harvested, and rapid removal of field heat is critical to retard deterioration. Maximum quality is retained by precooling corn to 0 °C (32 °F) within 1h of harvest and holding it at 0 °C (32 °F) during marketing. In practice, cooling to this extent is rarely achieved. However, cooling is the first step in a good temperature-management program. Sweet corn has a high respiration rate, which results in a high rate of heat generation. Supersweet varieties have respiration rates equal to that of traditional sweet corn varieties and lose sugar as rapidly so cooling is still critical with these newer varieties. Sweet corn should not be handled in bulk unless copiously iced because it tends to heat throughout the pile. Vacuum-cooling can adequately precool sweet corn, but the corn must be first wetted (and top -iced after cooling) to minimize water loss from husks and kernels. Crated sweet corn can be vacuum-cooled from about 30 °C (86 °F) to 5 °C (41 °F) in 30 min. Hydrocooling by spraying, showering, or immersion in water at 0 to 3 °C (32 to 38°F) is effective, though it takes longer than vacuum-cooling if the sweet corn is packed. Bulk sweet corn takes about 60 min to cool from 30 to 5 °C (86 to 41 °F) in a well -managed hydrocooler, while crated sweet corn takes about 80 min—and few if any operators leave it in that long. Periodic monitoring of sweet corn temperature is needed to ensure proper cooling to at least 10 °C (50 °F).

After hydrocooling, top icing is desirable during transport or holding to continue cooling, remove the heat of respiration, and keep the husks fresh. When precooling facilities are not available, sweet corn can be cooled with package ice and top ice.

Optimum Storage Conditions
Traditional sweet corn varieties are seldom stored for more than a few days because of the resulting serious deterioration and loss of tenderness and sweetness. The loss of sugar is about 4 times as rapid at 10 °C (50 °F) Than at 0 °C (32 °F). At 30 °C (86 °F), 60% of the sugar in su1 sweet corn can be converted to starch in a single day, while only 6% is converted at 0 °C (32 °F). While sh2 varieties lose sugar at the same rate as su1varieties, their higher initial sugar levels keep it sweet -tasting longer.
Chilling Sensitivity
Sweet corn is not chilling sensitive. It should be stored as cold as possible without freezing.

Postharvest Pathology
Decay is not usually a serious problem, but when present it typically occurs on the husk and silks.

Tomato
Quality Characteristics and Criteria
High quality fruit have a firm, turgid appearance; uniform and shiny color; and no signs of mechanical injury, shriveling, or decay. Principal causes for postharvest losses are decay, external damage incurred during harvest and handling, and harvest at an improper maturity stage.

Horticultural Maturity Indices
Depending on the market and production area, tomatoes are harvested at stages of maturity ranging from physiological maturity (mature-green stage) through full-ripe. Immature tomatoes are available for certain regional dishes. It is difficult to accurately determine the completion of physiological maturity.

Ripeness
External Color
Stage

(1) Green – Fruit surface is completely green; the shade of green may vary from light to dark.
(2) Breaker – There is a definite break in color from green to tannish-yellow, pink, or red on not more than 10% of the surface.
(3) Turning – 10 to 30% of the surface is not green; in the aggregate, shows a definite change from green to tannish-yellow, pink, red, or a combination thereof.
(4) Pink – 30 to 60% of the surface is not green; in the aggregate, shows pink or red color.
(5) Light red – 60 to 90% of the surface is not green; in the aggregate, shows pinkish-red or red.
(6) Red – More than 90% of the surface is not green; in the aggregate, shows red color.

Precooling Conditions

Following commercial packing, tomatoes are routinely palletized and cooled to 20 °C (68 °F) for ripening or to 12 °C (54°F) for storage. While room -cooling is common, forced -air cooling is more uniform and produces better quality fruit. Packed, palletized tomatoes with pulp temperature of 28 °C (83°F) actually increased 2 °C (4°F) immediately after being stored at 20°C (68 °F), and only cooled to 23 °C (73 °F) after 24 h using room-cooling However, with forced -air cooling, tomatoes cooled to 20 °C (68 °F) in 2.5 h and ripened more uniformly throughout the pallet than those room-cooled.

Optimum Storage Conditions

Optimal storage temperatures depend on the maturity stage of the tomatoes. Ideal conditions for ripening are 19 to 21 °C (66 to 70 °F) with 90 to 95%RH. Storage at temperatures >27 °C (81°F) reduces intensity of red color, while storage at <13 °C (55 °F) retards ripening and can lead to development of chilling injury, particularly in tomatoes at the mature -green stage. Red tomatoes can be stored at 7 °C (45°F) for a couple of days, though tomatoes stored at 10 °C (50°F) were rated lower in flavor and aroma than those held at 13 °C (55 °F).

Chilling Sensitivity
Tomato fruit are chilling sensitive, and the recommended storage temperature varies with the maturity stage. Mature -green fruit will ripen normally at 13 to 21 °C (55 to 70 °F). On the other hand, ripe tomato fruits can be stored at 10 °C (50°F) without visible symptoms of chilling injury, though flavor and aroma are negatively affected (Maul et al. 2000). Visual symptoms of chilling injury include pitting, nonuniform ripening, and storage decays
Ethylene Production and Sensitivity
Tomato fruit produce moderate amounts of ethylene. Tomatoes are sensitive to ethylene exposure:

Physiological Disorders
Blotchy ripening is characterized by randomized development of green or green-yellowish areas on the surface of red tomato fruit. Apparently the development of this disorder is related to the availability of potassium and inorganic nitrogen in the soil. Areas showing blotchy ripening have less organic acids, SSC, and starch.
Sunburn is associated with excessive exposure to sunlight and the resultant elevated tissue temperature during fruit development, disrupting lycopene synthesis and resulting in the appearance of yellow areas that remain during ripening.

Blossom-end rot involves a calcium deficiency caused by either poor uptake or poor translocation into the fruit. Symptoms begin in the green fruit as a small discoloration at the blossom end that increases in size and becomes dry and dark brown. Occurrence increases dramatically when calcium levels in the soil system drop below 0.08 %. Eventually, secondary decay organisms colonize weakened tissues.

Graywall is noticeable as necrotic vascular tissue in the pericarp fruit wall. It begins developing at the green stage and has been associated with marginal growing conditions such as cool weather, low light levels, poor nutrition, saturated soils, tobacco mosaic virus, and bacteria; however, the cause is still undetermined. Graywall can be a serious disorder in both field and greenhouse production systems.

Irregular ripening is characterized by the appearance of nonuniform ripening and white internal tissue. It has been associated with feeding of sweetpotato whitefly on tomato fruit.

Internal bruising is recognized by the appearance of yellow to green locular gel in ripe tomatoes. It is caused by an impairment of normal ripening of the locular gel following a physical impact at the green or breaker stage of ripeness. Fruit with internal bruising show significant reductions in vitamin C content, TA, consistency, and total carotenoids. Besides altering quality attributes, internal bruising also affects flavor. Breaker-stage tomatoes are more sensitive to internal bruising than those handled at the green stage.

Postharvest Pathology

Tomatoes are susceptible to numerous fruit decays from the field through postharvest handling. Postharvest decay often develops in wounds and bruised tissue and during fruit softening. Sound tomatoes can be inoculated by plant pathogens via cross-contamination from diseased fruits dirty harvest containers, and poorly sanitized water handling systems and packing line components. Populations of decay pathogens can be adequately controlled through a regular sanitation program in the field and during handling, packing, and ripening-storage operations.

Causes of bacterial decay include soft rot (Bacillus spp., Erwinia carotovorassp., Pseudomonas spp., and anthomonas campestris), and lactic acid decay (bacterial sour rot) (Lactobacillus spp.and Leuconostoc mesenteroides).

Fungal decay sources include alternaria rot (black rot) (Alternaria alternata), fusarium rot (Fusarium spp.), gray mold rot (Botrytis cinerea), mucor rot (Mucor mucedo), phoma rot (Phoma ssp.), phomopsis rot (Diaporthe spp.), phytophthora rot (buckeye rot) (Phytophthora spp.), pleospora rot (Pleospora herbarum, Stemphylium botryosum imp. stage), rhizopus rot (Rhizopus stolonifer, R. oryzae), ring rot (Myrothecium roridum), sclerotium rot (Sclerotium rolfsii), sour rot (Geotrichum candidum), target spot (Corynespora cassiicola), and watery soft rot (Sclerotinia minor, S. sclerotiorum). Tomato spotted wilt virus induces a mottled coloration at the red stage.

Turnip and Rutabaga

Quality Characteristics and Criteria
High-quality turnips are firm and are free of growth cracks, woodiness, rot, injury, and pithiness.

Horticultural Maturity Indices
Root diameter and freedom from woodiness are maturity indices for turnips. If sold as topped turnips, roots should be at least 4.4 cm (1.75 in) in diameter.

Precooling Conditions
Turnips can be cooled in the wash water, but a temperature differential of 10 °C (50 °F) or more should be avoided to prevent cracking.

Optimum Storage Conditions
Turnips can be held 4 to 5 mo at 0 °C (32 °F) with 90 to 95%RH.

Controlled Atmosphere (CA) Considerations
Unknown.

Retail Outlet Display Conditions
Turnips should be stored and displayed under high RH and refrigerated to slow shrivel. They can be misted.

Chilling Sensitivity
Turnips are not sensitive to chilling and should be stored as cold as possible without freezing.

Ethylene Production and Sensitivity
Turnips produce no detectable ethylene and are insensitive to ethylene.

Physiological Disorders
Turnips can develop growth cracks from overmaturity or boron deficiency, brown heart from boron deficiency, and pithiness from water stress. Root shriveling and loss of firmness can occur from storage at >2 °C (36 °F) or at low RH.

Postharvest Pathology
Dry rot or phoma rot (Leptospharia maculans), watery soft rot (Sclerotina minor or S. scerotiorum), alternaria rot (Alternaria brassicae), rhizoctonia rot (Thanatephorus cucumeris), gray mold (Botrytis cinerea), and bacterial soft rot (Erwinia crotovora ssp.carotovora) can occur in harvested roots, generally resulting from field infection.