Postharvest Handling Systems: Flower, Leafy, and Stem Vegetables

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The leafy, stem, and floral vegetables are represented by the following commodities:

- Leafy vegetables: lettuce, cabbage, Chinese cabbage, Brussels sprouts, rhubarb, celery, spinach, chard, kale, endive, escarole, green onion, witloof chicory (Belgian endive), radicchio, sprouts, and other leafy greens.
- Stem vegetables: asparagus, kohlrabi, fennel, and cactus stems (nopalitos).
- Floral vegetables: artichoke, broccoli, and cauliflower
- Mushrooms

These commodities are generally characterized as very perishable, with high respiration and water loss rates. Cabbages are a notable exception and may be stored for long periods. The respiration rates of leafy vegetables can vary greatly, as illustrated by data on specialty salad greens and full size lettuce heads (fig. 34.1). The visual appearance (i.e., freshness and characteristic green color) is closely related to the nutritional value of the leafy vegetables, as is shown by data on broccoli stored at 3 temperatures (fig. 34.2). The rapid changes in chlorophyll are closely associated with the visual symptom of yellowing of the beads (florets); shelf life is limited to 2 days at 20°C (68°F), 10 days at 10°C (50°F) and more than 30 days at 0°C (32°F). The vitamin C (ascorbic acid) and carotenoid (about 80% is pro-vitamin A or beta-carotene) concentrations closely follow the changes in chlorophyll concentration. Therefore, in the case of broccoli, a fresh green appearance is also a good indicator of nutritive value.

Postharvest quality and shelf life of the leafy vegetables can be greatly impacted by production practices and variety selection. For example, broccoli varieties can vary by more than 50% in their potential shelf life (table 34.1). High levels of nitrogen fertilization generally reduce shelf life and can affect composition (table 34.2). Another consideration is that postharvest bacterial decay may be higher with excessive applications of nitrogen fertilizer to broccoli and other leafy green vegetables.

The maximum shelf life or the best retention of quality for most of the commodities in this chapter is achieved with storage temperatures near 0°C (32°F) and high RH. For example, the shelf life of broccoli is substantially reduced if it is stored above the optimal temperature (fig. 34.3). Although broccoli is commonly liquid-iced to keep it near 0°C, note that with a long-shelf-life variety stored at 5°C (41°F) and high RH, yellowing does not occur until 21 days.

HARVESTING

The determination of horticultural maturity varies with commodity, but in general size is the principal criterion. For nonheading lettuces, the number of leaves can be used as a harvest index. For iceberg lettuce and cabbages, the solidity of the head determines harvest maturity. Maturity classes for iceberg lettuce are shown in table 34.3 and figure 34.4.

Virtually all leafy vegetables are cut by hand, but harvesting aids may be used with some (Brussels sprouts, celery, and parsley) (figs. 34.5, 34.6). Mechanical harvesting systems have been developed for iceberg lettuce, celery, cabbage, Brussels sprouts, and cauliflower, but

Figure 34.1

Variation in respiration rates of immature and mature leafy vegetables.

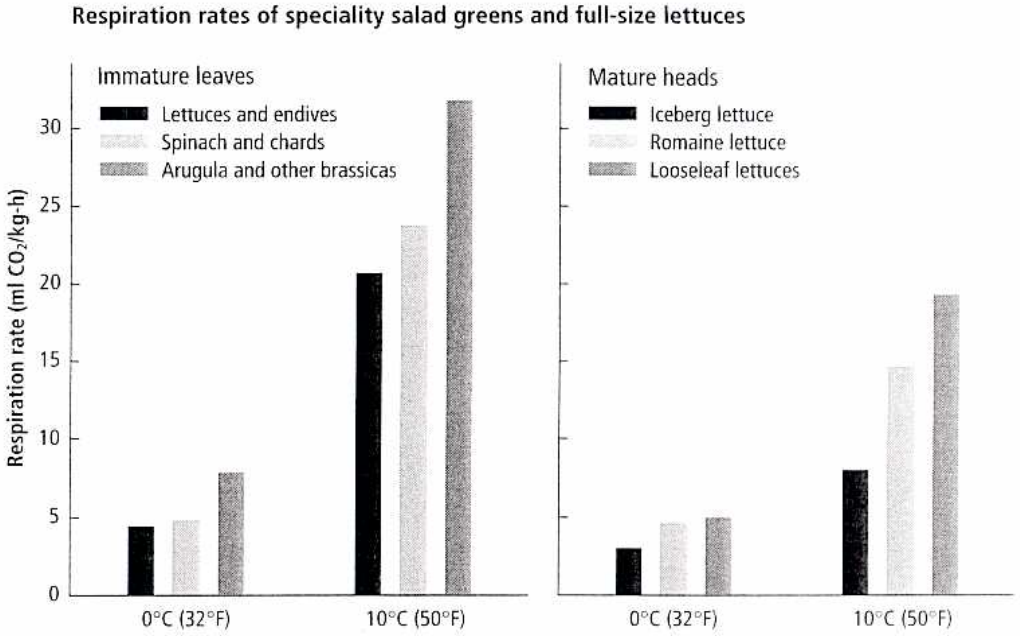
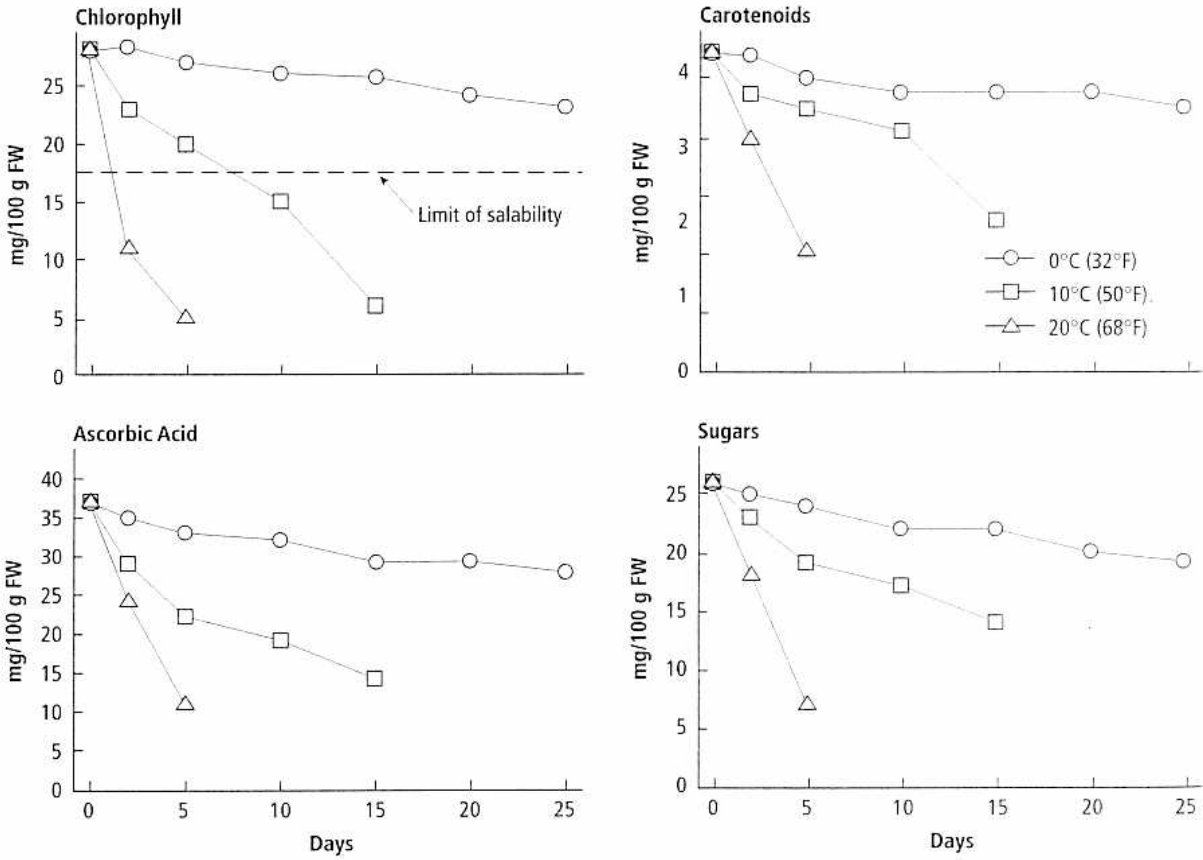


Figure 34.2

Composition of broccoli in relation to storage temperature.



they are not used in California. However, mechanical harvesting is used for spinach and for the small leafy greens for salad mixes.

Stem vegetables are also hand-harvested. A limited amount of asparagus has been experimentally machine-harvested, but damage to the roots with subsequent yield reductions has restricted its use. Asparagus is generally hand-cut when spears are 23 cm (9 in) above the soil surface (figs. 34.7, 34.8). The maturity of floral vegetables is determined by head size and development. All floral vegetables are hand-harvested, but harvest aids (conveyors) are sometimes used for broccoli.

FIELD PACKING

Field packing is used with most of the leafy vegetables (figs. 34.9, 34.10, 34.11). The products are selected for maturity and quality, and then cut, trimmed, wrapped or sleeved, packed in cartons or crates, transported to cooling facilities, cooled, put into temporary cold storage prior to loading or loaded directly, and transported to market. Field packing generally provides greater marketable yields because of reduced mechanical damage. Wrapped and unwrapped lettuce, celery, cauliflower, broccoli, and spinach are mostly field-packed, though the latter three are still taken to packinghouses by a few shippers.

Small celery stalks may be trimmed and packed as hearts in the field or field-packed in bulk containers after harvesting and transported to packinghouses for trimming, sorting, prepackaging, and packing as celery hearts. Wrapped lettuce and cauliflower are hand-selected, cut, and trimmed and then placed on mobile field units, where they are wrapped and packed into cartons (figs. 34.12, 34.13). They are then palletized and transported to the cooling facilities for cooling and subsequent handling.

Rough handling in field packing is a major cause of lettuce and cauliflower marketing losses. For cauliflower it is critical to harvest, trim, and overwrap the head without touching or damaging the very tender curds. Much of the postharvest discoloration and decay on cauliflower can be traced to rough handling at harvest.

Keeping the commodity clean is a problem in field-packing operations, particularly when fields are muddy. Product should be placed not on the ground after cutting but on a clean belt or packing area. Sprays of chlorinated water are sometimes used to clean the heads of cauliflower and other leafy vegetables packed in the field. Careful trimming of outer leaves and periodic cleaning of the harvest knives should minimize dirt in the packing area.

Table 34.1. Shelf life range of commercial broccoli varieties harvested from a fall trial in the Salinas Valley (heads stored in air with >95% RH)

Variety	Days shelf-life at 7.5°C (45°F)
Packman	17–19
Liberty	12–17
Patriot	12–17
Green Valiant	13–15
Pinnacle	11–13
Brigadier	9–12
Majestic	9–14

Table 34.2. Differences in shelf life and composition (dry weight basis) of broccoli florets (cv. Legacy) due to varying nitrogen fertilization (Cantwell and LeStrange, unpublished data)

Total nitrogen applied (lb)*	Head size (cm)	Shelf life: Days at 5°C (41°F)	Dry weight (%)	Sugar (mg/g DW)	Chlorophyll (mg/g DW)	Carotenoids (mg/g DW)	Ascorbic acid (mg/g DW)
60	8.1	35	15.6	186	1.1	0.4	10.5
120	10.2	32	15.2	161	1.3	0.4	8.2
180	10.8	29	14.4	146	1.8	0.6	9.0
240	10.9	30	14.0	151	1.5	0.5	9.9
300	11.3	26	13.8	136	1.9	0.6	7.5
LSD.05	1.2	3	0.2	19	0.2	0.1	0.9

Note: * Nitrogen applied in 1 preplant and 2 sidedress applications.

Figure 34.3

Shelf life of broccoli in relation to storage temperature.

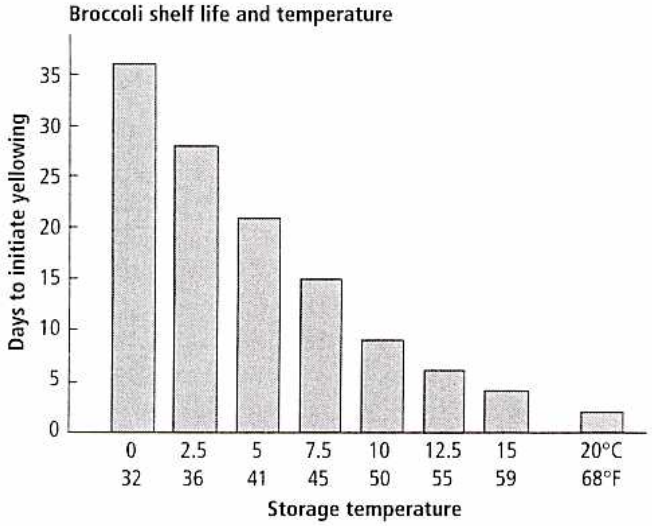


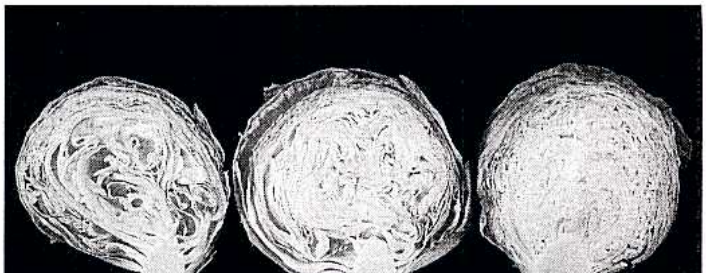
Table 34.3. Solidity (maturity) classes of iceberg (crisphead) lettuce

Solidity class	Postharvest characteristics
1 = Soft, no head formation	Immature; leaves very tender and susceptible to physical damage; has a higher respiration rate than more mature lettuce; sweet flavor, unacceptable for market
2 = Fairly firm, slight head formation	Higher respiration rate than mature lettuce; flavor is sweet, no bitterness
3 = Firm, good head formation; optimal density	Maximum storage life; flavor good and characteristic with little bitterness
4 = Hard, maximum density but no split ribs	More susceptible to russet spotting, pink rib, and other physiological disorders than mature lettuce; less storage life than mature lettuce; less sweet than mature lettuce and has bitter notes
5 = Extra hard; split midribs common; extreme internal pressure	Has minimum storage and shelf life remaining; most difficult to vacuum-cool; poor flavor and bitter taste

Source: Adapted from Kader et al. 1973.

Figure 34.4

Three stages of maturity of iceberg lettuce. These correspond to classes 2, 3, and 4 in table 34.3.



PACKINGHOUSE OPERATIO

Brussels sprouts, witloof chicory, and mu rooms are typically taken to a packingho as can be many of the other vegetables c sidered here. The vegetables are selected, cut, placed in bulk containers, and then transported to packinghouses for all subs quent handling operations. Compared wi field-packing, packinghouse handling requires more energy and generally resul more physical damage to the product, re ing marketable yields. For example, whit *Agaricus* mushrooms are very easily bruis by careless dumping from the harvest co tainers onto the packing line, and the rou handling results in damaged areas that brown rapidly. In addition, waste manage ment of discarded green material is also a consideration for packinghouse operatior

Packinghouse operations needed to pr pare these products for market include

- trimming and cleaning with chlorinat water (desirable concentrations vary fr 50 to 200 ppm active [total available] chlorine) (mushrooms are not washed
- sorting and grading to eliminate defec products
- sizing, in some cases (sizing is usually subjective and done by hand)
- wrapping or tying individual units (ca flower, broccoli), or in some cases, prepackaging (Brussels sprouts, brocc and cauliflower heads, punnets of mus rooms, bagged celery and romaine hea
- packing in carton shipping containers (often wax-impregnated) or wood crat

COOLING

Delays between harvest and cooling shou be avoided, especially during warm weath since water loss rates will be high. Small leafy items, such as the specialty salad greens and young spinach, are particularl prone to rapid dehydration. Cooling dela will reduce total shelf life and quality of a these vegetables. In asparagus, for examp delays before cooling are the main cause toughening of the spears (fig. 34.14).

Different cooling methods may be appl to the same commodity. The most comm cooling methods in commercial use are

Figure 34.5

Harvesting and trimming celery.

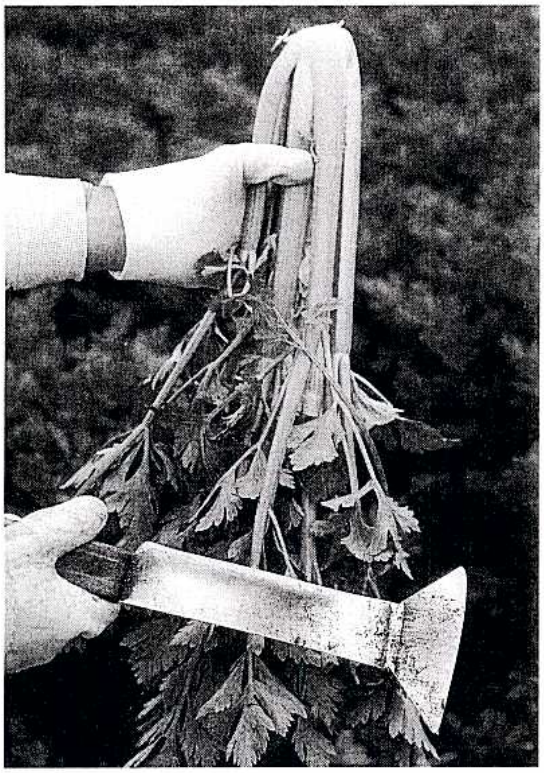


Figure 34.6

Sizing and field-packing celery on a small field cart.

- Vacuum cooling for crisphead lettuce, leaf lettuce, spinach, cauliflower, Chinese cabbage, bok choy, cabbage and other leafy vegetables, and mushrooms.
- Hydro-Vac cooling (vacuum cooling with injection of water prior to vacuum cycle) for celery and many other leafy vegetables.
- Hydrocooling for artichoke, asparagus, leaf lettuce, celery, spinach, some green onions, leek, and many other leafy vegetables.
- Package-icing and liquid-icing for broccoli, spinach, parsley, green onions, and Brussels sprouts.

Figure 34.7

Harvesting asparagus spears.

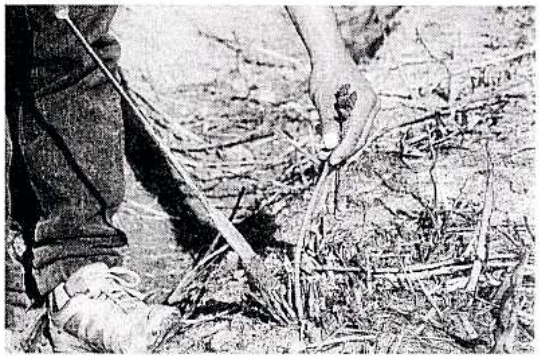


Figure 34.8

Plastic crates for asparagus harvest.

- Room cooling, primarily for artichoke and cabbage, and for the other leafy vegetables in some operations (not generally recommended for this group of vegetables because it is too slow).
- Forced-air cooling (sometimes with initial spraying of water), primarily for cauliflower and to a limited extent for other leafy and stem vegetables, including sprouts. Forced-air cooling is increasingly used for leafy vegetables and mushrooms. In the case of mushrooms, humidified forced-air is used to reduce the drying effect of the rapid air movement.

Figure 34.9

Postharvest handling of leafy vegetables, such as lettuce, celery, and green onions.

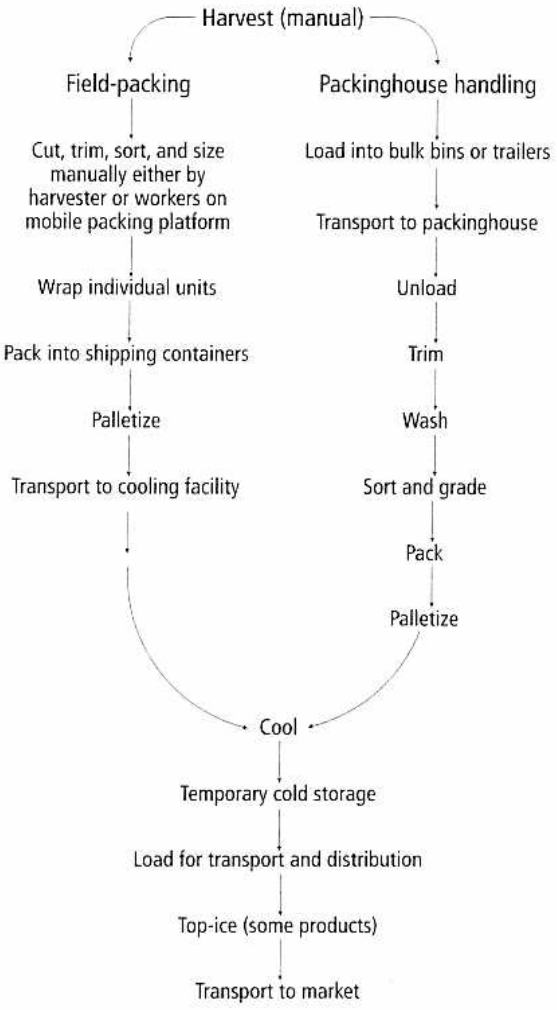
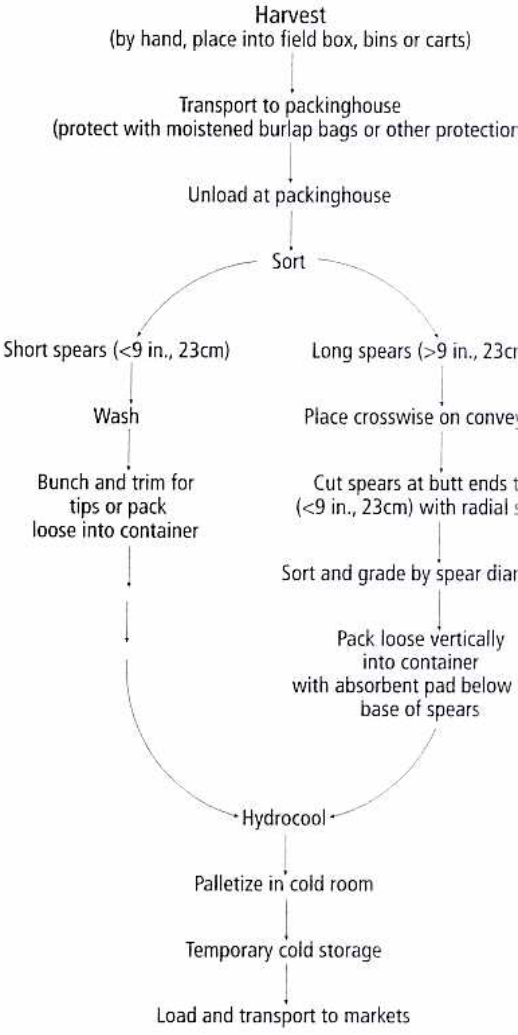


Figure 34.10

Postharvest handling of asparagus.



RECOMMENDED STORAGE CONDITIONS

Most of these vegetables are grown throughout the year in different production areas. For this reason, long-term storage is usually not required. These products are frequently loaded into refrigerated trailers and marine containers immediately after cooling. In general, these products respond best to storage temperatures of 0° to 1°C (32° to 34°F).

Freezing must be avoided; it can occur at temperatures slightly below 0°C (32°F), since sugar content is generally low in most of these vegetables. Slight freeze damage of lettuce may occur in the field and results in the cuticle separating from the leaf. This may lead to increased discoloration and decay during storage. Freeze damage during storage typically appears as dark translucent spots, which result in water-soaked areas ar loss of crisp texture once the leaf tissue thaws. Symptoms of freezing injury on othe leafy vegetables are similar.

For temporary storage, temperatures of 0 to 2°C (32° to 36°F) and a 90 to 95% RH ar recommended. For marketing within 1 to 2 weeks, however, storage temperatures consis tently below 5°C (41°F) are generally adequate to maintain good quality. Figure 34.15 shows the result of storing gai-lan, a close re ative of broccoli. The most perishable part, the flower bud, deteriorated much more at 5°C (41°F) than it did at 0°C (32°F) during the 3-week storage. A few commodities in this group of vegetables are chilling-sensitive The optimal storage temperature of asparagu is 2.5°C (36°F). A few other commodities ar very chilling-sensitive, such as tropical leafy

Figure 34.11

Postharvest handling of floral vegetables (artichoke, broccoli, and cauliflower).

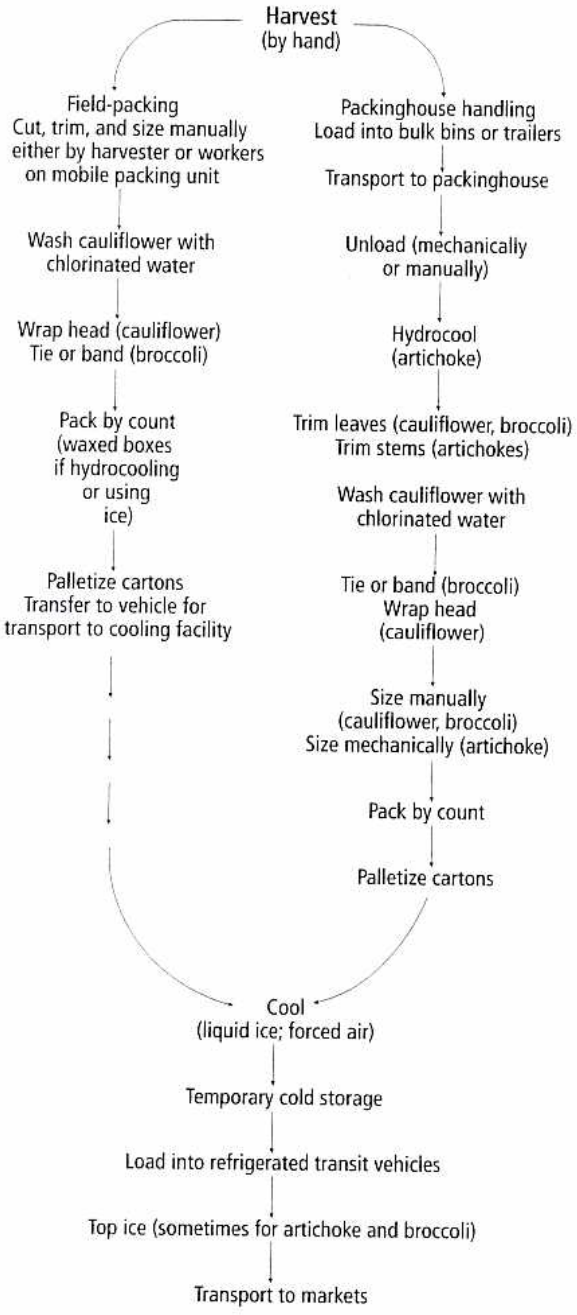


Figure 34.12

Field-packing of crisphead lettuce into cartons with plastic film liners.

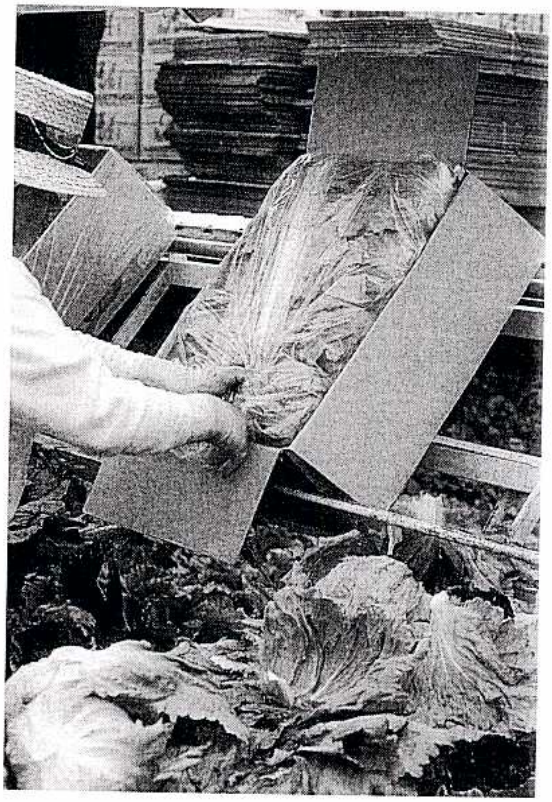
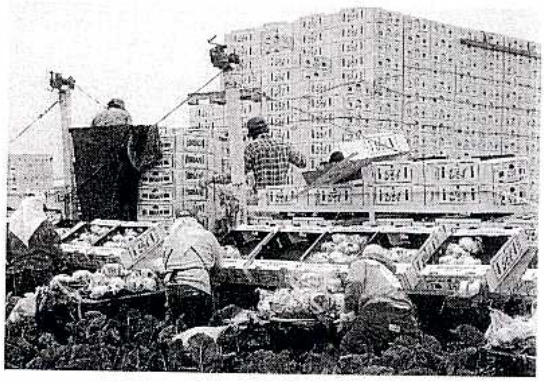


Figure 34.13

Field-packing of cauliflower on a mobile packing unit.



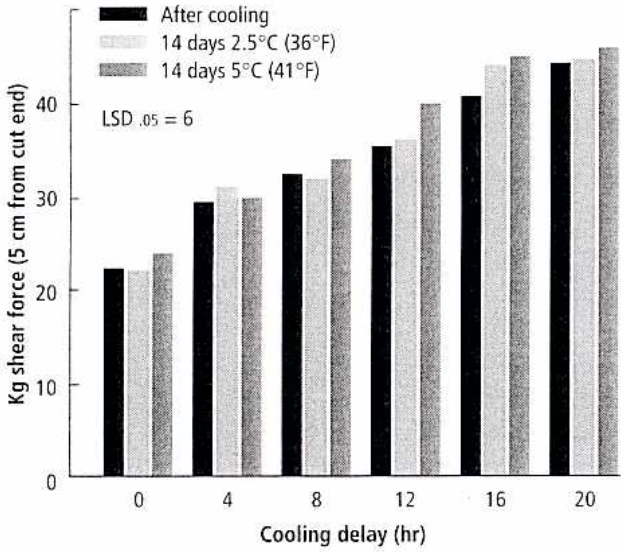
greens (e.g., water spinach) and nopalitos, or cactus stems, and their recommended storage temperatures are 7.5° to 10°C (45° to 50°F). See the appendix for optimal storage conditions for specific products.

A high RH (>90%) is required for optimal storage of this group of vegetables. For some, such as mushrooms and sprouts, it is especially important to avoid water condensation on the product surface since it will greatly favor bacterial decay. For most of the other vegetables in this group, free moisture on the surface is not problematic, as long as the product is kept cold.

Long-term storage is not recommended, except for cabbage, Chinese cabbage, and celery. In long-term storage, temperatures near ideal are needed to maximize storage life and reduce losses. For long-term storage, air circulation should be minimized to that required for proper temperature control to avoid excessive water loss.

Figure 34.14

Toughening of asparagus spears due to cooling delays. Spears were held at 25°C (77°F) with high RH for indicated durations, then cooled and stored at 2.5° C or 5° C for 14 days.



Exposure to ethylene should be avoided during storage and throughout the handling system. Ethylene induces russet spotting disorder in lettuce (fig. 34.16) and decreases the shelf life of all green, leafy vegetables. Factors to take into consideration are variety susceptibility, ethylene concentration, length of exposure, and storage temperature. There is considerable variation among varieties of iceberg lettuce in their susceptibility to ethylene and the development of russet spotting. Although varieties of Chinese cabbage also vary in the development of black speck, a similar defect, this physiological disorder is not induced by ethylene (fig. 34.17). Ethylene increases yellowing in the dark leafy greens and causes abscission of leaves in cauliflower and cabbage heads. Figure 34.18 shows the effect of ethylene on several quality characteristics of gai-lan. See chapter 16 for more information on undesirable effects of ethylene and how to avoid injury.

Exposure to light causes undesirable greening and bitterness in witloof chicory (Belgian endive). This can be controlled by using solid carton boxes with no vents to avoid light, packaging the product in dark paper, and at retail, using light-proof containers or keeping endive temperature at 5°C (41°F) or lower. At low temperature the desired yellow-white color of the heads is maintained since chlorophyll synthesis is inhibited.

Figure 34.15

Visual appearance of gai-lan after storing 3 weeks at 0°C (32°F) or 5°C (41°F).

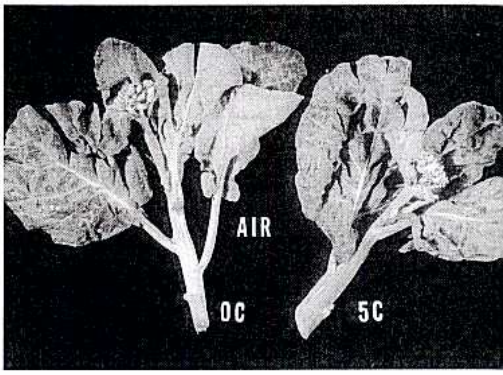
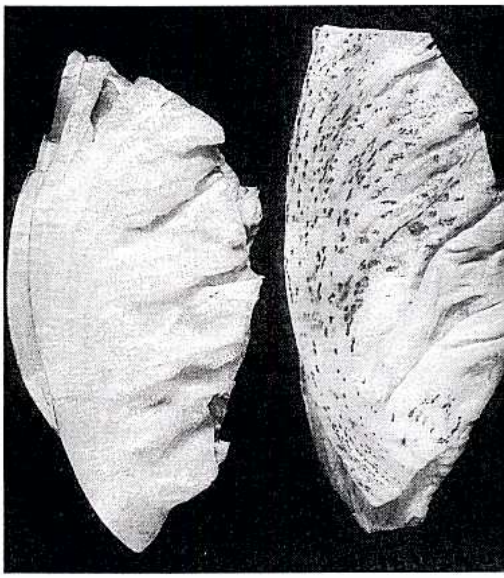


Figure 34.16

Russet spotting on crisphead lettuce: no symptoms are apparent on leaf at left; severe symptoms appear at ri



Modified Atmospheres. Most leafy, sten and floral commodities respond favorably t modified atmospheres, although this technique is used on a limited scale commercia for these intact vegetables (for fresh-cut ve etables, see chapter 36). Atmosphere recon mendations for selected commodities are shown in table 34.4. Low-O_2 atmospheres to 3% O_2) favor longer shelf life in all prod ucts except asparagus and mushrooms. Th recommendations for CO_2 modification ar more variable. Asparagus tips, easily damag during sorting and packing, develop less decay when stored under high-CO_2 atmospheres (fig. 34.19). Spinach and broccoli, although benefited by modified atmospher can easily develop off-odors if O_2 concentr tions drop too low.

Figure 34.17

Black speck development in 16 Chinese cabbage varieties. Heads were stored at 5°C (41°F) for 14 days. The higher the bar, the more severely affected by black speck.

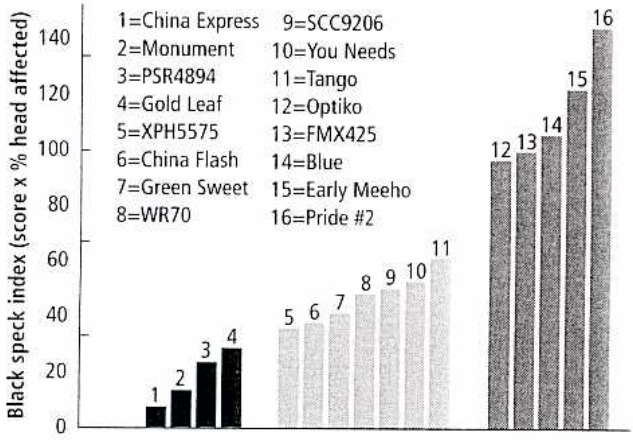


Table 34.4. CA and MA recommendations for leafy, stem, and floral vegetables

	Temperature range			
Product	**°C**	**°F**	**% O_2**	**% CO_2**
Artichoke	0–5	32–41	2–3	2–3
Asparagus	1–5	34–41	21	10–14
Broccoli	0–5	32–41	2	5–10
Cabbage	0–5	32–41	2–3	3–4
Cauliflower	0–5	32–41	2–3	3–4
Celery	0–5	32–41	1–4	3–5
Chinese cabbage	0–5	32–41	1–2	0–5
Green onions	0–5	32–41	2–3	0–5
Leeks	0–5	32–41	1–2	2–5
Lettuce	0–5	32–41	1–3	0
Mushrooms	0–5	32–41	21	10–15
Spinach	0–5	32–41	7–10	5–10
Witloof Chicory	0–5	32–41	3–4	4–5

Source: Adapted from Saltveit 1997.

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Figure 34.18

Effect of a low concentration of ethylene on green color, flower bud deterioration, and pithiness of gai-lan stored at 5°C (41°F).

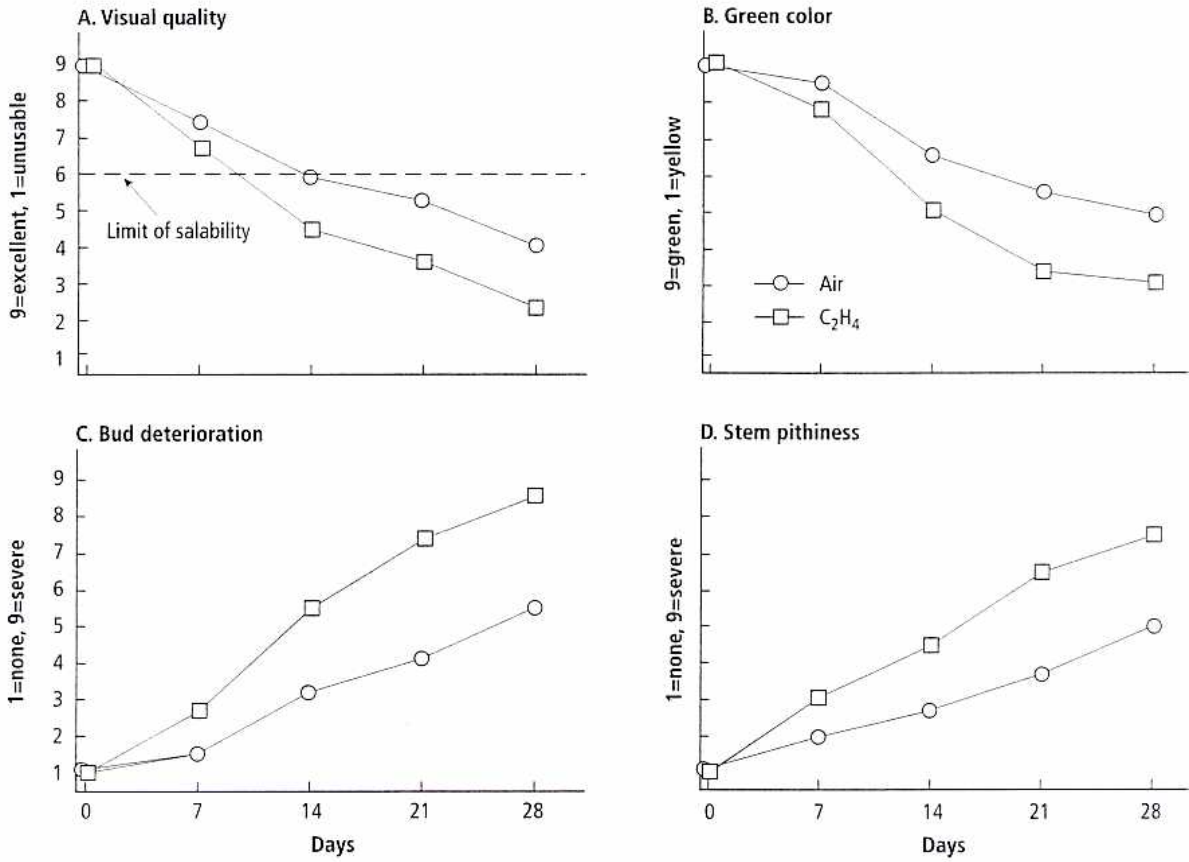

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Figure 34.19

Changes in the quality of the tips and stems of asparagus held in air or high-CO_2 atmospheres.