

Postharvest Handling of Horticultural Products: Keeping Principles in Perspective

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For all fresh produce, variety selection, climatic conditions and growing practices will greatly affect the quality at harvest. Successful marketing of fresh fruits and vegetables depends on maintaining the quality harvested. Fresh products are alive and respire (e.g. enzymatically converting sugars and acids in the presence of oxygen to carbon dioxide and heat). Careful postharvest handling aims to reduce the rate of respiration and the rate of other processes that cause deterioration and quality loss (water loss, many biochemical changes, softening, etc). Careful, clean, and efficient handling is more important than the sophistication of the postharvest equipment used.

Basic Postharvest Principles

Harvest at the optimum maturity for best eating quality. Immature products have higher postharvest water loss and shrivel during marketing. Harvesting fruits such as apples, tomatoes and melons too soon results in nonuniform ripening and poor flavor. Harvesting products overmature may cause toughness (asparagus, beans), rapid yellowing (cucumbers), undesirable starchiness (sweet corn) or other undesirable flavors (bitterness in lettuce), or short shelf-life (apples, peppers). Harvesting fruit vegetables too ripe (tomatoes) makes physical injury more likely and reduces shelf-life.

Harvest during the coolest part of the day. The product is coolest at sunrise, and harvesting when it is cool minimizes deterioration and water loss. It is easier and cheaper to keep a product cool than to cool a product that has heated up. To minimize the spread of disease, harvest should begin once the foliage has dried. Use clean harvest containers, cutting equipment and gloves. Keep harvested products out of the sun (use an empty container, shade cloth, or other protection) to avoid direct sun injury and unnecessary heating of the product.

Harvest and handle gently. Injured areas on products lead to increased postharvest decay and water loss. Cuts, punctures, abrasions, crushing and bruising all cause significant quality losses. In some cases, products may appear undamaged, but may be bruised internally (melons). Reduce physical damage by reducing the number of steps in which the product is directly handled. The ideal situation is to harvest and directly pack the product into the container in which the product will be marketed (strawberries is the classic example). For most crops this is not feasible, but at least the number of handling steps should be minimized.

Preparation for market often involves cleaning, trimming, washing and grading. This should be done in a protected or shaded area, whether it is a permanent, temporary or mobile structure. Water should be clean (potable) and if reused, a sanitizer should be added to prevent pathogen buildup and contamination. The less brushing, washing and physical handling needed, the better. Cleaning may remove the surface waxes; waxing may then be needed to replace the product's own natural protection. Adequate lighting is important for sorting and grading. Sizing may be done manually, but simple equipment using diverging bar rollers or belt sizers may be useful; automated color and size sorting equipment is increasingly being used. Again, the less handling the better; avoid unnecessary drops, finger damage, abrasions, etc. Pad and cushion hard surfaces. Keep all parts (conveyors, tables) of the packing line smooth-surfaced and clean (wash frequently to remove sand, dirt). For food safety considerations, cleanliness of the product, packingline and employees are all important. Ensure that clean toilet facilities with water and soap for hand washing are always available.

Pack carefully: do not overpack or underpack. Packing too tightly causes compression bruises; packing too loosely causes vibration and abrasion injuries. Keep containers clean. If packing in reusable plastic containers (RPCs), wash the container to remove decay-causing organisms, and sand and dirt that can injure the product. Sanitize using 1 teaspoon of household bleach (5% solution of sodium hypochlorite) per one gallon of water. If using fiberboard cartons, remember that most of the stacking strength is at the corners of carton boxes; therefore stack and align cartons properly. Containers need vents (about 5% of the surface area) for air flow and cooling. Use thin perforated plastic liners in carton boxes to reduce shrivel on products highly susceptible to water loss (delicate leafy greens, summer squash). Paper pads on the bottom and top of plastic-lined boxes will absorb excess moisture and reduce decay. Although sealed plastic bags also reduce water loss, they are risky since if the product is not kept continually cold, depletion of oxygen and development of off-odors can occur. If plastic bags or liners are used, it is best to cool the product before packaging.

Cool the product as soon as possible after harvest. Temperature is the most important factor determining deterioration rate. Decreasing the temperature reduces the product's metabolism (respiration and ethylene production), water loss, and the growth of decay-causing fungi and bacteria. Mechanical refrigeration is the basis for most cooling methods. Room cooling (placing products in a refrigerated room) is a relatively low cost, but also slow method. The cold air needs to circulate around the product to remove heat, so leave space between boxes and between pallets. Forced-air cooling pulls the cold air through the containers and greatly increases the rate of cooling. A cold room can be modified with portable and fixed forced-air handlers to increase cooling rates. Hydrocooling (by submersion or spraying cold water) products that tolerate wetting provides fast cooling and avoids water loss. It takes more time to hydrocool packed product and wood or waxed containers are needed. Sanitation of the hydrocooling water (usually by chlorination) is critical to prevent contamination. Some products tolerate contact with ice; crushed or flaked ice can be applied directly or as a slurry in water. Evaporative cooling can be used in hot dry environments by pulling outside air through wet pads to provide high humidity, cooler air. Placing clean moistened sacks inside or over containers of packed product is a simple form of evaporative cooling.

Freshness is a very important quality attribute. Freshness can be maintained by expedited marketing, but can also be achieved by storing for short periods (days) under the proper conditions. The longer the period from harvest to consumption, the greater the emphasis on good temperature management. If products are stored for long periods (weeks), they need to be kept as close as possible to their ideal storage temperature to minimize quality loss. Once the product has been cooled, use low rates of air circulation to reduce water loss during storage. Many vegetable (broccoli, lettuce, carrots, celery, etc.) require low storage temperatures (see table). Many other vegetables (basil, cucumbers, eggplants, tomatoes, peppers, melons) are chilling sensitive and need to be stored at intermediate temperatures (see table). Most vegetables (except onions and garlic) require high humidity during storage. Ethylene is a natural gas produced by all products. However, leafy and root vegetables produce very little ethylene and are damaged by ethylene (russet spotting, bitterness in carrots, loss of leaves in cabbage, yellowing of leafy greens). Many fruits, including fruit vegetables such as tomatoes and melons produce high amounts of ethylene during ripening. Avoid storing ethylene-incompatible fruits and vegetables together.

Use adequate transport vehicles. Secure the load to reduce vibration injury; drive slowly; cover the product to prevent exposure to the sun and excessive water loss. For transporting product to market, use an insulated truck if a refrigerated vehicle is not available. Refrigerated trucks have sufficient refrigeration capacity but often lack air flow capacity for cooling; they can only maintain product temperatures, so products should be pre-cooled before transport. Stack containers on pallets away from the truck walls and leave channels so the cold air can flow around the containers. Avoid temperature fluctuations during loading and unloading since moisture condensation will increase decay (closed docks are therefore best). During display for market,

protect the product from high temperatures, high air velocities, and low relative humidity. Where appropriate, use shade, mist with clean water. Display products in their containers to reduce handling injury.

Ten Important Guidelines for Postharvest Handling in General:

1. **MATURITY.** Harvest the product at the correct stage of maturity.
2. **REDUCE INJURIES.** Reduce the physical handling to a minimum; every time the product is handled, it is damaged.
3. **PROTECT PRODUCT.** Protect the harvested product from the sun; bring it rapidly from the field/exposed area to the packing station and keep out of the direct sun. Transport carefully.
4. **CLEANLINESS & SANITATION.** Keep the packing line as simple as possible and keep it clean. If water is used, use clean water or a sanitizer if the water is reused. Maintain strict worker hygiene.
5. **PACK CAREFULLY.** Sort, classify and pack the product carefully to achieve uniformity and to prevent damage (compression, scrapes, etc.) which causes decay and inferior quality; use an adequate box or container. Packaging can also be informative.
6. **PALLETIZE.** Insure that the boxes are well placed on the pallet and that the pallet is strapped.
7. **COOL.** Cool the product as soon as possible after harvest; generally for every hour of delay from harvest to initiate cooling, one day of shelf-life is lost. Lowering product temperature is the most important way to reduce deterioration.
8. **KNOW PRODUCT.** Know the requirements of the market (size, ripeness, etc) and the product handling requirements (temp., RH, shelf-life, etc.) of the product.
9. **COORDINATION.** Always try to coordinate the postharvest handling so that it is efficient and rapid. Postharvest handling maintains the quality of a product, it can not improve it.
10. **TRAINING.** Train and compensate well the workers involved in critical postharvest handling steps; make sure that workers have the necessary tools to facilitate their work.

For Specialty Crops, Make Educated Guesses

When dealing with new crops and determining how they should be handled postharvest, one can make a few educated guesses based on the following questions:

1. Is the crop of tropical or temperate origin? This will likely indicate whether or not it is chilling sensitive.
2. Is the crop a leaf, root or fruit? This can help indicate how susceptible it is to water loss.
3. If the crop is a fruit, are there noticeable “ripening” changes after harvest? The degree of change after harvest is generally related to its rate of deterioration.
4. Are you harvesting the crop when it is rapidly growing or when it has completed its growth phase? Rapidly growing crops generally have very high respiration rates and high deterioration rates.
5. If the crop is a leafy product, are there rapid color changes? This may indicate how sensitive the deterioration process is and how sensitive it may be to exposure to the contaminant ethylene.
6. If the crop is a fruit, are there rapid textural and compositional (starch to sugar conversion) changes? This may indicate a “climateric” type fruit which would produce a lot of ethylene.
7. What are the postharvest characteristics of a related product (another species of the same genus, another genus of the same family, etc.)? Refer to the table for information on various products.
8. What is the estimated storage temperature? Try to place the product into one of the following categories:
A. low temperature (32-41°F); B. moderate (41-50°F); C. moderately high (50-60°F)
9. What is the estimated shelf-life? Try to categorize into one of following categories:
A. short shelf-life: 1-6 days
B. moderate: 7-21 days
C. long: 3-12 weeks or longer
10. Is the product very tender and delicate? Does it bruise easily? This will help to determine what an appropriate packaging system might be.

Examples of Postharvest Requirements for Selected Vegetables and Melons

Product	Harvest Quality	Storage		Shelf-Life Days	Ethylene Sensitivity	Observations
		°F	% RH			
Artichoke, globe	size, tender bracts	32	95	14	Low	sprinkle lightly
Asparagus	bracts at tip closed	36	95	14	Low	stand in water
Basil	fresh, tender leaves	55	95	7	Moderate	stand in water
Beans, Lima	seeds developed, plump	40	95	7	Moderate	sprinkle lightly
Beans, pole & snap	crisp pods, seeds immature	40	95	7	Moderate	sprinkle lightly
Beets, bunched	firm, deep red roots	32	95	14	Low	sprinkle, cut tops
Broccoli	firm head, buds not open	32	95	14-21	High	sprinkle; ice
Brussel sprouts	firm sprouts	32	95	21-28	High	sprinkle; ice
Cabbage	crisp, firm, compact head	32	95	30-180	High	sprinkle lightly
Cantaloupe Melons	stem separates; rind color	36	95	14	Moderate	ice
Carrots, topped	tender, crisp, sweet roots	32	95	28-180	High	sprinkle; cut tops
Cauliflower	compact, white curds	32	95	14-21	High	sprinkle
Celery	crisp, tender petioles	32	95	14-21	Moderate	sprinkle; ice
Corn, sweet	plump tender kernels	32	95	7	Low	ice
Cucumbers	crisp, green, firm	50	95	10	High	sprinkle lightly
Eggplant	seeds immature; shiny, firm	50	95	10	Moderate	
Endive, escarole	fresh, crisp, tender leaves	32	95	14-21	Moderate	sprinkle lightly
Greens, leafy & herbs	fresh, crisp, tender leaves	32	95	10-14	Moderate	sprinkle lightly
Honeydew melons	waxy, creamy colored; heavy	45	90	21	High	
Lettuce	compact head; crisp, tender	32	95	21	High	sprinkle lightly
Onions, dry	firm bulbs, tight necks	32	65	30-180	Low	
Onions, green	crisp stalks, firm white bulbs	32	95	10	Moderate	sprinkle; ice
Parsley	crisp, dark green leaves	32	95	21	High	sprinkle; ice
Peas	tender, green, sweet pods	32	95	7-10	Moderate	sprinkle
Peppers, green	firm with shiny appearance	45	95	14	Low	
Peppers, chili	firm with shiny appearance	45	95	14	Low	
Potatoes, early crop	well-shaped tubers, defect-free	50	90	14	Low	if wash, dry well
Potatoes, late crop	well-shaped tubers, defect-free	45	90	60-180	Moderate	if wash, dry well
Pumpkins	hard rind, good color, heavy	55	65	30-160	Moderate	
Radishes with tops	firm, crisp, dark green leaves	32	95	14-21	Moderate	sprinkle; ice
Rutabagas	roots firm with smooth surface	32	95	60-120	Low	cut tops; sprinkle
Spinach	dark green, fresh, crisp leaves	32	95	10	High	sprinkle lightly
Squash, summer	firm, shiny fruits, right size	45	95	10	Moderate	
Squash, winter	hard rind, corked stem, heavy	55	65	60-120	Moderate	allow cut to heal
Tomatoes, green	firm, jelly present, light green	55	90	21	High	
Tomatoes, ripening	firm, uniform coloration	50	90	14	High	avoid <50F
Turnips	firm, heavy roots	32	95	60-120	Low	cut tops; sprinkle
Watermelons	crisp, good flesh color, heavy	55	90	14	High	

Sources of Information on Postharvest Handling:

1. Cantwell, M. (compiler). 2003. **Fresh-cut Products: Maintaining Quality and Safety**. UC Davis Postharvest Horticulture Series No. 10. Binder of articles, bulletins, etc. for 3 day annual fresh-cut workshop. (UC Postharvest Research & Information Center, Wickson Hall, Univ. California, Davis, CA 95616).
2. FDA. 1998. **Guide to Minimize Microbial Food Safety Hazards** for Fresh Fruits and Vegetables. (FDA, Center for Food Safety & Applied Nutr., 200 C St. S.W. (HFS-22), Washington, D.C. 20204).
3. Gorny, J.R. (ed.). 2001. **Food Safety Guidelines for the Fresh-cut Produce Industry**. 4th edition. 216pp. International Fresh-cut Produce Association, 1600 Duke St., Suite 440, Alexandria VA 22314-3421.
4. Gross, K.C., C.Y. Wang, and M. Saltveit. 2002. **The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops**. U.S. D.A. Agriculture Handbook 66. <http://www.ba.ars.usda.gov/hb66/>.
5. Kader, A.A. (ed.). 2002. **Postharvest Technology of Horticultural Crops**. Univ. CA Div. Agr. Natl. Res. Publication #3311. 535 pp. UC Postharvest Research & Information Center, Wickson Hall, UC Davis; <http://postharvest.ucdavis.edu>.
6. Kays, S.J. **Postharvest physiology of perishable plant products**. 1991. AVI, Van Nostrand Reinhold, NY, 532 pp.
7. Kitinoja, L. and A.A. Kader. 2002. **Small-scale postharvest handling practices: A manual for Horticultural Crops** (4th ed). UC Postharvest Research & Information Center, UC Davis; <http://postharvest.ucdavis.edu>. 260 pp.
8. Seymour, G.B., J.E. Taylor and G.A. Tucker (eds.) 1993. **Biochemistry of Fruit Ripening**. Chapman & Hall, New York. 454 pp.
9. Suslow, T.V. 1998. **Postharvest Chlorination- Basic Properties**. UC Div. Agr. Natl. Resources Publication 8003. 8 pp. <http://ucgaps.ucdavis.edu/documents/newsletter537.htm>
10. Suslow, T.V. Postharvest handling for organic crops. UC Div. Agr. Natl. Resources Publ. 7254. 8 pp <http://anrcatalog.ucdavis.edu/>; <http://ucgaps.ucdavis.edu/documents/newsletter611.htm>
11. The Packer. **Weekly newspaper for the produce industry**. Subscription includes guides updated yearly on produce availability and merchandizing, trends in produce marketing, packaging and transportation. www.thepacker.com
12. Thompson, J.F., F.G. Mitchell, T.R. Rumsey, R.F. Kasmire and C.H. Crisosto. 1998. **Commercial Cooling of Fruits, Vegetables and Flowers**. UC Div. Agr. Natl. Resources Publication 21567. 61 pp. UC Postharvest Research & Information Center, Wickson Hall, UC Davis; <http://postharvest.ucdavis.edu>.
13. University of California **Postharvest Web page**: <http://postharvest.ucdavis.edu/>
14. University of California **Good Agricultural Practices webpage**: <http://gaps.ucdavis.edu>
15. Wills, R., B. McGlasson, D. Graham and D. Joyce. 1998. **Postharvest. An introduction to the Physiology and Handling of Fruit, Vegetables and Ornamentals**. Univ. New South Wales Press, Ltd., Sydney, 262 pp.