Organic Farming Practices: Postharvest Handling

Optimal quality organic produce that combines the desired textural properties, sensory shelf-life, and nutritional content results from the careful implementation of recommended production inputs and practices, careful handling at harvest, and appropriate postharvest handling and storage. This section will focus on an overview of general postharvest handling considerations unique to the marketing of registered or certified organic produce. An introduction to current permitted and restricted postharvest treatments will be presented.

Planning for Postharvest Quality

Achieving an economically rewarding enterprise via the marketing of organic produce must begin well before harvest. Seed selection can be a critical decision factor in determining the postharvest performance of any commodity. Individual cultivars have variable inherent potential for firmness retention, uniformity, disease and pest resistance, and sensory shelf–life, to list a few key traits. Cultivars chosen for novelty or heirloom traits may be suitable for small-scale production and local marketing but would be disastrous if shipment to more distant markets was attempted. In addition to genetic traits, environmental factors such as soil type, temperature, wind during fruit set, frost, and rainy weather at harvest can have an adverse effect on storage life, suitability for shipping, and quality. Cultural practices may have dramatic impacts on postharvest quality. For example, poor seedbed preparation for carrots may result in sunburned shoulders and green core with many of the specialty carrots favored by consumers at farmers markets. For background on suitable production practices see Sections XXXX in this series.

Planning for postharvest food safety should be included in any crop management plan. Good Agricultural Practices (GAP) need to be developed and formalized for each crop and specific production field to minimize the risk of chemical (ex. heavy metals carryover), physical (ex. sand and soil, wood, plastic or metal shards), and biological (ex. *Salmonella*, *Listeria*, mycotoxins) hazards and contaminants. Prior land use, adjacent land use, water source and method of application, fertilizer choice (such as the use of manure), compost management, equipment maintenance, field sanitation, movement of workers between different operations, personal hygiene, domestic animal and wildlife activities, and other factors have the potential to adversely impact food safety.

It is worth noting that many elements of a GAP plan are likely to be incorporated into the existing organic crop management program and activities. Programs in place to ensure produce quality may be directly applicable to food safety with minor modifications. Applying food safety programs, in turn, have been shown to directly benefit postharvest quality.

Once prerequisite production programs are in place, a systematic evaluation and implementation plan of Good Agricultural Practices during harvest operations and any subsequent postharvest handling, minimal or fresh-cut processing, and distribution to consumers must be developed. Considerations for these activities are covered below.

Harvest Handling

The inherent quality of produce cannot be improved after harvest, only maintained for the expected window of time characteristic of the commodity. Part of successful postharvest handling is knowing what this window of opportunity is under your specific conditions of production, season, method of handling, and distance to market. Among the benefits of organic production, it is often more common to harvest and market near or at peak ripeness than in many conventional systems. However, organic production often includes more specialty varieties that have reduced or even inherently poor shelf life and shipping traits. As a general approach, the following practices can help to maintain quality:

1. Harvest during the coolest time of the day to maintain low product respiration.
2. Avoid unnecessary wounding, bruising, crushing, or damage from humans, equipment, or harvest containers.
3. Shade harvested product in the field to keep it cool. Covering harvest bins or totes with a reflective pad greatly reduces heat gain from the sun and reduces water loss and premature senescence.
4. If possible, move product into a cold storage facility or postharvest cooling treatment as soon as possible. For some commodities, such as berries, tender greens and leafy herbs, one hour in the sun is too long.
5. Don't compromise high quality product by intermingling damaged, decayed, or decay-prone product in a bulk or packed unit.
6. Only use cleaned and, as necessary, sanitized packing or transport containers.

These operating principles are important in all operations but carry special importance for many organic producers due to limited postharvest cooling opportunities.

Postharvest Storage

Temperature is the single most important tool to maintain postharvest quality. Other than field cured or durable products, removing field heat as rapidly as possible is highly desirable. Harvesting cuts off a vegetable from its source of water. However, it is still alive and will lose water, and therefore turgor, due to respiration. Field heat can accelerate the rate of respiration and therefore the rate of quality loss. Proper cooling protects quality and extends both the sensory (taste) and nutritional shelf life of produce. The capacity to cool and store produce creates greater market flexibility. There is a tendency by growers to underestimate the refrigeration capacity needed for peak cooling demand. It is often critical to reach the desired short-term storage or shipping pulp temperature rapidly to maintain the highest visual quality, flavor, texture, and nutritional content of fresh produce. The most common cooling methods are:

1. Room cooling: An insulated room or mobile container equipped with refrigeration units. Room cooling is slow compared with other options. Depending on the commodity, packing unit, and stacking arrangement the product may cool too slowly to prevent water loss, premature ripening, or decay.
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3. Forced-air cooling: Fans are used in conjunction with a cooling room to pull cool air through packages of produce. Although the cooling rate depends on the air temperature and the rate of airflow, this method is usually 75–90% faster than room cooling. Design considerations for very small-scale to sophisticated large-scale units are available in DANR #21567.
4. Hydrocooling: Showering produce with chilled water is an efficient way to remove heat, and can serve as a means of cleaning at the same time. Use of a disinfectant in the water is essential and the some of the currently permitted products are discussed in the following section. Hydrocooling is not appropriate for all produce. Waterproof containers or resistant waxed-corrugated cartons are required. Currently waxed corrugated cartons have limited recycling or secondary use outlets and reusable, collapsible plastic containers are gaining popularity. A list of vegetables that are suitable for hydrocooling is available in DANR 3311 and 21567
5. Top or liquid icing: Icing is an effective method to cool tolerant commodities and is equally adaptable to small or large-scale operations. Ice-tolerant vegetables are listed in DANR 3311 and 21567. Ensuring that the ice is free of chemical, physical, and biological hazards is essential.
6. Vacuum cooling: Under vacuum, water within the plant evaporates and removes heat from the tissues. This system works well for leafy crops, such as lettuce, spinach, and celery, which have a high surface-to-volume ratio. Water may be sprayed on the produce prior to placing it vacuum. As with hydrocooling, proper water disinfection is essential (See Sanitation and Water Disinfection). The cost of the vacuum chamber system restricts its use to larger operations.

The considerations and selection of appropriate cooling methods and appropriate storage temperature and humidity conditions for a large diversity of vegetables are available in DANR publications 3311 and 21567. In large cooling operations handling both conventional and organic commodities, it is common to hydrocool (also water-spray vacuum cooling) organic produce at the beginning of daily operation, after a full cleaning and complete water exchange. This practice is intended to prevent carry-over or cross-contamination of organic produce with synthetic pesticide or other prohibited residues. This will generally require at least overnight short-term storage.

Other postharvest issues involving combined steps of unloading commodities from harvest bins, washing, and precooling must also be evaluated for adherence to organic standards. Some operators use flotation as a method of reducing damage at the point of grading and packing. Entire bins are submerged in a tank of water treated with a chemical flotation aide that allows the picked product to be gently removed and separated from the container. Lignin sulfonates are allowed in certified organic handling as a flotation aid for water-based unloading of field bins or other density separation applications.

Sanitation and Water Disinfection

Preventive food safety programs, proper sanitation of equipment and food contact surfaces, and water disinfection should be integrated into every facet of postharvest handling. Food safety and decay/spoilage control are concerns for produce handlers at all scales of production. *E. coli* 0157:H7, *Salmonella*, *Shigella*, *Listeria*, *Cryptosporidium*, Hepatitis, and *Cyclospora* are among the disease-causing organisms that have been associated with fresh fruits and vegetables. There are several cases of food-borne illness traced to poor or unsanitary postharvest practices, especially non-potable cooling water and ice.

For organic handlers, the nature and prior use of water is a special consideration. Postharvest water cannot, at any time, contain prohibited substances dissolved in water. This responsibility applies to the organic producer, handler, processor or retailer. Even incidental contamination from a prohibited material would render product non-certified. Organic producers, packers, and handlers are required to keep accurate and specific records of postharvest wash or rinse treatments, identified by brand name and source. For a more complete discussion of postharvest water disinfection see DANR 8003.

In brief, proper use of a disinfectant in postharvest wash and cooling water can help prevent both postharvest diseases and food-borne illnesses. Since most municipal water supplies are chlorinated and in recognition of the vital role of water disinfection, organic growers, shippers, and processors may use chlorine within specified limits. All forms of chlorine (ex. liquid sodium hypochlorite, granular calcium hypochlorite, and chlorine dioxide) are restricted materials as defined by existing organic standards. The application must conform with Maximum Residual Disinfectant Limit under the Safe Drinking Water Act, currently 4 mg/L (4 ppm) expressed as Cl2. The California Certified Organic Farmers (CCOF) regulations have permitted this threshold of 4 ppm residual chlorine, measured downstream of the product wash [Due to food safety concerns the CCOF has recent modified this threshold to permit 10 ppm residual chlorine measured downstream of the wash step]. Growers certified by other agencies should check with their certifying agent.

As a general practice, minimizing field soil on product, bins, totes, and pallets by pre-washing will significantly reduce the disinfectant demand of the water and lower the total required volume of antimicrobial agent. Pre-washing also removes plant exudates released from harvest cuts or wounds that can rapidly react with oxidizers, such as hypochlorite and ozone, requiring higher rates to maintain the target 4 to 10 ppm downstream activity.

For both organic and conventional operations, liquid sodium hypochlorite is the most common form used. For optimum antimicrobial activity with a minimal concentration of applied hypochlorite, the water pH must be adjusted to 6.5 to 7.5. At this pH range, the majority of the chlorine is in the form of hypochlorous acid (HOCl) which delivers the highest rate of microbial kill and minimizes the release of irritating and potential hazardous chlorine gas (Cl_2). Chlorine gas will exceed safe levels if the pH is too acid. Products used for pH adjustment must be from a natural source such as citric acid, sodium bicarbonate or vinegar. Calcium hypochlorite, properly dissolved, may provide benefits of reduced sodium injury to sensitive crops (ex. some apples varieties) and limited evidence points towards extended shelf-life due to calcium uptake (ex. tomatoes and bell peppers). Amounts of hypochlorite to add to clear, clean water for disinfestations are the following:

	Upstream Target ppm*	fl. oz/5 gal.	cups/50 gal
Sodium hypochlorite (a.i.5.25%)	25	.28	.25
	50	.55	.50
	75	.80	.75
	100	1.10	1.00
Sodium hypochlorite (a.i.12.7%)	25	.06	.05
	50	.12	.10
	75	.17	.15
	100	.23	.20

* Organic certification standards permit a maximum of 10 ppm residual chlorine downstream of the product wash step. Each crop, water source and quality, water pH, and other factors will influence the total upstream hypochlorite needed to maintain this target level. A general starting point is 50 ppm for produce with low soil content or minimal tissue damage and cell leakage(such as from harvest cuts) following harvest. Some products, such as spring mix, may require higher initial upstream chlorination due to high amounts of organic compounds released from harvest wound sites tying up available hypochlorous acid. This is best determined in practice and on-site with appropriate monitoring equipment or kits, which include titration methods in combination with oxidation-reduction potential (ORP) probes. Higher levels of hypochlorite or other chlorinated products are permissible for equipment surface and crate or tote cleaning provided treatment is followed by a thorough clean water rinse (See Cleaners and Disinfectants).

Ozone is an attractive option for water disinfection and other postharvest applications. Ozonation is a powerful oxidizing treatment and is effective against chlorine-resistant decay microbes and food-borne pathogens, acting far faster than permissible chlorine concentrations. This may be a distinct advantage for cooling or wash procedures with short contact times. Ozone oxidative reactions create far fewer disinfection by-products (ex. trihalomethanes are a health and environmental concern) as compared to chlorination. The decision to use ozonation rather than chlorination in organic postharvest operations may be made despite higher capital and operating costs in comparison with chlorine or other available methods.

Ozone must be generated on-site at the time of use and has a very low stability, as short as 20 minutes even in clear water. Clear water is essential for optimal performance and adequate filtration of input or recirculating water is needed. Depending on scale and ozone generation output, complete systems costs start at about $10,000. Small-scale units are available for a few thousand dollars and are suitable for limited water-use and small batch applications. For specifications and installation consult an experienced ozone service provider (See Resources Directory).

Food-grade hydrogen peroxide (0.5 to 1%) and peroxyacetic acid are additional options. In general, peroxyacetic acid (PAA) has good efficacy in water dump tanks and water flume sanitation applications. PAA has very good performance, as compared to chlorine and ozone, in removing and controlling microbial biofilms (tightly adhering slime) in dump tanks and flumes. At this time, one disadvantage is a higher cost per unit and availability is restricted to large bulk units.

Cleaners, Sanitizers, and Disinfectants
A partial list of allowed cleaners, disinfectants, sanitizers, and postharvest aides follows:

Acetic acid. Allowed as a cleanser or sanitizer. Vinegar used as an ingredient must be from an organic source.

Alcohol, Ethyl. Allowed as a disinfectant. Alcohol must be from an organic source.

Alcohol, Isopropyl. May be used as a disinfectant under restricted conditions.

Ammonium sanitizers. **Quaternary ammonium** salts are a general example in this category. Quaternary ammonium may be used on non-food contact surfaces. Its use is prohibited on food contact surfaces, except for specific equipment where alternative sanitizers significantly increase equipment corrosion. Detergent cleaning and rinsing procedures must follow quaternary ammonium application. Monitoring must show no detectable residue prior to the start of organic packaging (ex. fresh-cut salads).

Bleach. Calcium hypochlorite, sodium hypochlorite and chlorine dioxide are allowed as a sanitizer for water and food contact surfaces. In California, product (fresh produce) wash water treated with chlorine compounds as a disinfectant cannot exceed 10 ppm residual chlorine measured downstream of product contact.

Detergents. Allowed as equipment cleaners. Also includes surfactants and wetting agents. All products must be evaluated on a case-by-case basis.

Hydrogen peroxide. Allowed as a water and surface disinfectant.

Ozone. Considered GRAS (Generally Regarded As Safe) for produce and equipment disinfection. Exposure limits for worker safety applies.

Peroxyacetic acid. Water and fruit and vegetable surface disinfectant.

Other Postharvest Treatments

Carbon dioxide. Permitted for post-harvest use in modified and controlled atmosphere storage and packaging. For crops that tolerate treatment with elevated CO_2 ($\geq$ 15%), suppression of decay and control of insect pests can be achieved.

Fumigants. Naturally occurring forms are allowed (ex. heat vaporized acetic acid). Must be from a natural source.

Wax. Must not contain any prohibited synthetic substances. Acceptable sources include carnuba or wood-extracted wax. Products that are coated with approved wax must be indicated as such on the shipping container.

Importance of Optimal Storage and Shipping Temperature

Although we stress rapid and adequate cooling as a primary method of postharvest handling, many vegetables are sub-tropical in origin and susceptible to chilling injury. Chilling injury occurs when sensitive crops are exposed to low temperatures that are above the freezing point. Damage is often induced in a very short time of exposure but not apparent for several days or until transfer to warmer display conditions. Some examples of sensitive crops are basil, tomato, eggplant, green beans, okra, and yellow crookneck squash. For some vegetables different parts have distinct sensitivities, such as eggplant where the cap or calyx is more sensitive and turns black before the fruit itself is affected. The effects of chilling injury are cumulative in some crops. Chilling injury may not be apparent until produce is removed from low temperature storage. Depending on the duration and severity of chilling, after several hours to a few days of warmer temperatures, chilling symptoms become evident in the following ways:

- Pitting and localized water loss
- Browning or other skin blemishes
- Internal discoloration
- Increased susceptibility to decay
- Failure to ripen or uneven color development
- Loss of flavor, especially characteristic volatiles
- Development of off-flavors

Temperature management also plays a key role in limiting water loss in storage and transit. As the primary means of lowering respiration rates of fruits and vegetables, temperature has an important relationship to relative humidity and thus directly affects the rate of water loss. Relative humidity of the ambient air conditions in relation to the relative humidity of the crop (essentially 100%) directly influences the rate of water loss from produce at any point in the marketing chain. Water loss may result in wilting, shriveling, softening, browning, stem separation, or other defects.

Transport to and display at roadside stands or farmers market often result in exposure of sensitive produce to extended periods of direct sun, warm (or even high) temperatures and low relative humidity. Water loss can be rapid under these conditions, resulting in limp, flaccid greens and loss of appealing natural sheen or gloss in fruits and vegetables. Providing postharvest cooling prior to and during transport and a shading structure during display can minimize rapid water loss at these market outlets.

Approved fruit and vegetable waxes are effective at reducing water loss and enhancing appearance. Uniform application and coverage of waxes or oils with proper packing line brushes or rolling sponges is important. Plastic wraps or other food-grade polymer films retard water loss. Adequate oxygen exchange is necessary to prevent fermentative respiration and the development of ethanol and off-odors or flavors. Wraps or bags must have small perforations or slits to prevent these conditions especially when temperature management is not available.

Exposure of bagged or tightly wrapped produce to direct sunlight will rapidly raise the internal temperature. Water loss will result and, if followed by cooling, free water condensation will develop that may result in accelerated decay.

Specialized films, that create modified-atmospheres (MA) when sealed as a bag or pouch, are available for many produce items that have well-characterized low oxygen and elevated carbon dioxide tolerances. Not all commodities benefit from MA.

Packing design and packaging can also be designed to minimize water loss. To minimize condensation inside the bag and reduce the risk of microbial growth, the bags may be vented, microperforated, or made of material permeable to water vapor. Barriers to water loss may also function as barriers to cooling and packing systems should be carefully selected for the specific application. Any packaging materials, storage or transport containers or bins that contain synthetic fungicides, preservatives, or fumigants (or any bag or container that had previously been in contact with any prohibited substance) are not allowed for organic postharvest handling. In small-scale handling, reuse of corrugated containers from conventional produce is strongly discouraged by organic certifying organizations. Re-use of difficult to clean containers that held conventional produce may be prohibited by specific organic registration or certifying authorities.

During transportation and storage, relative humidity (more properly vapor pressure deficit) is critical, even at low temperature. For a more complete discussion of optimal relative humidity for fruits and vegetables and the principles for prevention of water loss see DANR 21567.

Ethylene

Management of ethylene may be another postharvest consideration for quality maintenance during storage and transportation. Ethylene is a natural hormone produced by plants and is involved in many natural functions during development including ripening. Ethylene treatments may be applied for degreening or accelerating ripening events in fruits harvest at mature but unripe development stages. For a detailed discussion of the role of ethylene in ripening and postharvest management see DANR 3311.

In organic handling, ethylene gas produced by catalytic generators is prohibited, except for bananas. As the majority of ethylene-responsive organic produce is harvested at a fully ripe stage, this restriction is not currently a significant barrier.

In contrast to its role in ripening, ethylene from plant sources or environmental sources (ex. combustion of propane in lift trucks) can be very damaging to sensitive commodities. In brief, ethylene producers should not be stored with fruits or vegetables that are sensitive to it. External ethylene will stimulate loss of quality, reduced shelf life, increased disease and specific symptoms of ethylene injury, such as,

- Russet spotting of lettuce
- Yellowing or loss of green color (ex. cucumbers, broccoli, kale, spinach)
- Increased toughness in turnips and asparagus spears
- Bitterness in carrots and parsnips
- Yellowing and abscission (dropping) of leaves in Brassicas

- Softening, pitting, and development of off-flavor in peppers, summer squash, and watermelons
- Browning and discoloration in eggplant pulp and seed
- Discoloration and off-flavor in sweet potatoes
- Increased ripening and softening of mature green tomatoes

In addition to providing adequate venting or fresh air exchange, ethylene adsorption or conversion systems are available to prevent damaging levels (as low as 0.1 ppm for some items) in storage and during transportation. Potassium permanganate ($KMnO_4$) air filtration systems or absorbers are allowed for post harvest handling provided that strict separation from product contact is assured. Other air filtration systems for ethylene removal based on glass-rods treated with a titanium dioxide catalyst and ultraviolet light inactivation are available for cold rooms. Ultraviolet light/ozone-based systems of ethylene elimination are also commercially available.

Special Issues

Although irradiation technologies are strongly disfavored by much of the organic industry, X-ray irradiation is allowed for metal detection in packing. Metal detection is a common practice in many minimally-processed and packaged organic vegetables and salad mixes.

The use of incompletely composted animal manure in organic production is prohibited due postharvest food safety concerns. Organic standards specify from 60 to 120 days, depending on certifying agency and crop, prior to planting or harvesting crops for human consumption. The California Certified Organic Farmers organization (CCOF) requires that all animal manure used for soil amendment be composted or treated according to current standards for Class A level pathogen reduction, as specified by the Environmental Protection Agency (EPA). Documenting the compost process conditions for each batch is an essential part of the required record keeping ensuring compliance with preventative food safety programs. In addition, composting reduces the potential for plant growth inhibition often associated with raw manure usage. Properly composted manure can be applied directly to growing vegetable crops with little concern. However, although composting can degrade many, if not most, organic contaminants (i.e. pesticides), it cannot eliminate heavy metals. Composting concentrates heavy metals that are a concern with sewage sludge (biosolids), also a composted product occasionally used in production that can impact postharvest safety. Biosolids are typically prohibited from use by many organic certification organizations including the CCOF.

Shippers must be are aware of special requirements for transporting organic product whether by highway truck carrier, air, or containerized marine and intermodal shipping. Mixed load shipment of organic and conventional product is permitted if “Organic” labeling is prominently and clearly displayed. In addition, there must be no risk of contamination of organic commodities or direct contact with conventional product. Typically, carriers of bulk, raw organic product must maintain complete records of clean-out dates and products. Procedures for transport carrier cleaning, or other treatments, must includes steps to prevent contamination from cleaners or fumigants, ripening agents, pest control agents, diesel fumes and other vehicle maintenance products.

Resources

Postharvest Handling References:

Commercial Cooling of Fruits, Vegetables, and Flowers. 1998. J.F. Thompson, et. al., University of California DANR Publication 21567

Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. 1986. USDA Agricultural Handbook #66. R. E. Hardenburg, A. E. Watada, C. Y. Wang. 130 pp

Handling, Transportation, & Storage of Fruits and Vegetables. 1983. A. L. Ryall and W. J. Lipton. Avi Publishing, Westport, CONN. 587 pp.

Postharvest Technology of Horticultural Crops. 1992. University of California DANR Publication 3311. A.A. Kader Technical Editor.

Other Resources:

California Certified Organic Farmers
http://www.ccof.org/section1.htm

Organic Materials Review Institute
http://www.omri.org/

Community Alliance with Family Farmers (CAFF) Resource Directory
http://www.caff.org/sustain/resource_groups.html

UC Postharvest Research and Information Center
http://postharvest.ucdavis.edu

UC Small Farms Center
http://www.sfc.ucdavis.edu/