Direct marketing of fresh fruits and vegetables provides the grower with the satisfaction of consumer contact and, hopefully, increased income. Success depends on providing quality products in a clean, customer-friendly environment. This publication covers techniques that prolong the marketable life of farm-fresh produce.

**POSTHARVEST PHYSIOLOGY**

After harvest, physiological changes continue in fresh fruits and vegetables that affect quality and marketability. While these processes cannot be stopped, they can be slowed significantly. Careful postharvest handling can maintain product freshness, prolong shelf life and improve profits. Respiration and transpiration are the processes most responsible for postharvest deterioration.

**Horticultural products classified according to their relative respiration rates**

<table>
<thead>
<tr>
<th>Very Low</th>
<th>Dried fruits and vegetables, nuts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Apple, beets, celery, citrus, cranberry, garlic, grape, melon, kiwifruit, onion, potato (mature)</td>
</tr>
<tr>
<td>Moderate</td>
<td>Apricot, banana, blueberry, cabbage, carrot (no tops), cherry, cucumber, fig, gooseberry, lettuce (head), peach, pear, pepper, plum, potato (immature), radish (no tops), summer squash, tomato</td>
</tr>
<tr>
<td>High</td>
<td>Cane berries, carrot (with tops), cauliflower, leeks, lettuce (leaf), radish (with tops), strawberry</td>
</tr>
<tr>
<td>Very or Extremely High</td>
<td>Artichoke, asparagus, bean sprouts, broccoli, Brussels sprouts, corn, cut flowers, endive, green onions, kale, okra, mushroom, parsley, peas, snap bean, spinach</td>
</tr>
</tbody>
</table>

**Respiration**

A product’s postharvest life expectancy is directly related to its respiration rate. This is the process by which food reserves in produce make energy that keeps it alive. Sugars and starches combine with oxygen from the air to form carbon dioxide, water and heat. This results in produce deterioration, including changes in texture and in flavor, and loss of nutritional value and weight. Shelf life is maximized by reducing the respiration rate as much as possible. Respiration rates vary for different products and are affected by temperature. They are reduced 2 - 4 times for every 18°F temperature decrease. Generally, the higher the respiration rate of a product, the greater the need for postharvest cooling.

**Transpiration or Water Loss**

Fresh produce continuously loses water to the surrounding air through transpiration. This results in produce wilting, shriveling and softening, as well as loss of weight, crispness, juiciness, nutritional quality and flavor.

The surface-area-to-volume ratio affects water loss. For example, the rate of water loss from lettuce, which has a large surface-area-to-volume ratio, is about 1,700 times greater than that of an apple which has a small area. Some produce has features that offer natural resistance to water loss, such as the onion’s dry skin or a pumpkin’s thick rind. Water loss increases with temperature and air speed, but decreases as relative humidity increases.
**Percent daily weight loss for produce stored at ideal temperature and various relative humidities**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Storage Temp.</th>
<th>95% RH</th>
<th>90% RH</th>
<th>85% RH</th>
<th>80% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>32° F</td>
<td>0.011</td>
<td>0.022</td>
<td>0.033</td>
<td>0.044</td>
</tr>
<tr>
<td>Cabbage</td>
<td>32° F</td>
<td>0.058</td>
<td>0.116</td>
<td>0.175</td>
<td>0.233</td>
</tr>
<tr>
<td>Carrots</td>
<td>32° F</td>
<td>0.315</td>
<td>0.630</td>
<td>0.945</td>
<td>1.26</td>
</tr>
<tr>
<td>Celery</td>
<td>32° F</td>
<td>0.46</td>
<td>0.92</td>
<td>1.38</td>
<td>1.84</td>
</tr>
<tr>
<td>Grapes</td>
<td>32° F</td>
<td>0.032</td>
<td>0.064</td>
<td>0.096</td>
<td>0.128</td>
</tr>
<tr>
<td>Lettuce (ave.)</td>
<td>32° F</td>
<td>1.93</td>
<td>3.86</td>
<td>5.79</td>
<td>7.73</td>
</tr>
<tr>
<td>Peaches</td>
<td>32° F</td>
<td>0.15</td>
<td>0.30</td>
<td>0.45</td>
<td>0.60</td>
</tr>
<tr>
<td>Pears</td>
<td>32° F</td>
<td>0.018</td>
<td>0.036</td>
<td>0.054</td>
<td>0.072</td>
</tr>
<tr>
<td>Potatoes (uncured)</td>
<td>45° F</td>
<td>0.070</td>
<td>0.141</td>
<td>0.211</td>
<td>0.282</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>45° F</td>
<td>0.060</td>
<td>0.119</td>
<td>0.180</td>
<td>0.240</td>
</tr>
</tbody>
</table>

**PRODUCE HANDLING**

**Food Safety**

Food safety is an aspect of produce handling that spans the entire production process. Consumer awareness has increased with news stories regarding pesticide safety, Alar, *E. coli* and food poisonings.

The surface of freshly harvested produce is commonly contaminated with naturally occurring bacteria, yeast and fungi. Dust, insects, soil, rainfall and sometimes humans are the sources of these normally harmless contaminants. Some are plant pathogens, which can cause rot in fresh produce. Others, such as salmonella or certain *E. coli*, are human pathogens, which can cause illnesses, if allowed to grow to large populations.

All produce should be washed before consumption. It may be desirable to remove soil from root crops to create an attractive display. Leave washing of unsoiled produce to the consumer. Washing produce in bulk may spread decay-causing organisms and reduce shelf life. Pickers and produce handlers should practice good personal hygiene to prevent the transfer of any human diseases to consumers. Special care should be taken with cut produce, such as melons, that are intended for fresh consumption. *E. coli* has been known to be spread this way.

**Harvest and Transport**

Handle produce carefully to avoid bruises and skinning. Sort out and dispose of produce damaged by insects, disease or over-maturity. Produce injury results from improper picking and from dumping the picking container into larger containers. Even short drops can cause produce damage. Storage containers should be vented to allow air circulation. Harvesting and field trimming should be closely supervised. Highly perishable produce should be harvested during the morning, when the produce temperature is lowest.

Produce may be hurt during transport from the field. Overfilling transport containers can crush or bruise produce at the bottom or cause damage on top when containers are stacked. Bruises can also result from produce rubbing against rough surfaces. Make the ride from the field as smooth as possible by grading roads and going slowly.

**Field Heat Removal**

Most produce is damaged by heat and sunlight. Shade fruits and vegetables when harvesting and when transporting them from the field. A light-colored tarp protects produce from direct sunlight. Leave at least a four-inch space between the tarp and the produce to allow air circulation and to prevent solar and respiration heat build-up. Field heat removal, or precooling, refers to cooling the produce before marketing or storage, which
slows both respiration and decay organism growth. Immediate field heat removal may be necessary, even for short-term storage, of highly perishable produce.

Precooling can be done by hydrocooling, by icing or by forcing cold air through the produce. Hydrocooling rapidly removes field heat by flooding produce with or immersing it in cold water. Produce which may be successfully hydrocooled are indicated in specific handling recommendations section. Refrigeration or large quantities of ice are required to keep the water at 33-36°F. Cooling is much slower when the water is not sufficiently cold or fast-moving. Also, treatment times must be long enough to reduce produce temperature to within 2-5°F of the water temperature. Damp produce must be kept cool. Warm, wet produce creates an environment that encourages the growth of decay organisms.

Hydrocooling, icing, misting, and covering with wet paper or cloth are all good methods to remove field heat or to prevent temperature rise in produce not hurt by water. Certain products such as berries are damaged by water. These will need to be shaded and rushed to refrigerated storage directly after harvest. Forced air systems can help lower temperatures more rapidly.

**PRODUCE DISPLAYS**

Encourage impulse sales by a creative display of top-quality, fresh produce. Visualize the display through the customer’s eyes as you design it. Emphasize colors by arranging fruits and vegetables to obtain maximum color contrast. Produce sensitivities must also be kept in mind; you may wish to group products by icing, refrigeration or misting needs.

**Shelter**

Although sunlight makes produce look great, it can be damaging, especially in combination with wind. Just a few minutes of sunlight can wilt leafy crops; increase the rate of sugar-to-starch conversion in peas and sweet corn; and wrinkle and dull root crops. Pumpkins and winter squash are exceptions that tolerate sunshine. Similarly, keeping produce dry can be a challenge on rainy days. Provide shade and rain protection with a roof extension, awning or other equipment; be sure the overhang is adequate for windy rainstorms.

Water loss is a problem for many fruits and vegetables, as most are 75-95% water. A breeze will increase the rate of transpiration by preventing a blanket of high-humidity air from forming around the produce. Baby vegetables and those with leaves, tops and broken skins suffer most from water loss.

**Iced Displays**

Ice can be an attractive “natural” substitute for refrigerated display cases. Iced displays are flexible and portable. Properly managed, they provide an optimum temperature and humidity environment for fresh produce. You may use flaked or crushed ice. (Partly melting ice removes sharp edges that would bruise tender produce.) Be absolutely sure ice-maker is connected to a source of drinking-quality water. About 4-5 pounds of ice are needed daily per square foot of display.

Clean ice displays at least weekly to avoid development of slime molds and offensive odors. Empty the unit, scrub it with warm water containing a sanitizer and rinse with hot water; then allow it to cool before restocking.

Use ice displays for leafy greens and other produce that normally requires refrigeration. If ice displays are unavailable, only small quantities of such produce should be put out at one time. The remainder should be held in refrigerated storage or in large, iced coolers.

<table>
<thead>
<tr>
<th>Should be displayed on ice</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus</td>
<td>Celery</td>
</tr>
<tr>
<td>Beets (bunched)</td>
<td>Lettuce/Endive</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Onions (green)</td>
</tr>
<tr>
<td>Brussels sprouts</td>
<td>Parsley</td>
</tr>
<tr>
<td>------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Carrots</td>
<td>Radishes</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Spinach</td>
</tr>
<tr>
<td><strong>Should not be displayed on ice</strong></td>
<td></td>
</tr>
<tr>
<td>Beans, snap</td>
<td>Melon</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>Squash (all kinds)</td>
</tr>
<tr>
<td>Eggplant</td>
<td>Tomatoes</td>
</tr>
</tbody>
</table>

**Tips on Using Iced Displays**

1. Spread 1½ - 2 inches of crushed ice in bottom of display.

2. Arrange produce in rows from front to back. Don’t stack it too deeply (6-8 inches at most); ice cools only what it contacts.

3. Avoid displaying produce in plastic bags or film wrap, which keeps the ice from directly contacting the product. Such packaging also holds in condensed moisture and reflects a glare from its surface, making the product harder to see.

4. Spread a 1/2 inch layer of ice evenly over the top of the produce. Resupply top ice as it is needed to maintain a thin, even layer.

5. To minimize ice needs:
   a. Use fluorescent not incandescent lights.
   b. Keep displays out of direct sun.
   c. Precool produce before displaying.
   d. Insulate the display table with 1" Styrofoam or 5/8" polyurethane board.

**SPECIFIC PRODUCE HANDLING AND DISPLAY RECOMMENDATIONS**

**Asparagus** is a very tender vegetable that bruises easily. It deteriorates rapidly in heat and benefits from immediate postharvest cooling. Maintain a high relative humidity. Store spears with their cut ends in water, keeping the tips dry, and refrigerate to 35°F.

**Green Beans** are picked as immature fruit, while still smooth and narrow. Beans bruise easily, so handle carefully and keep displays small to avoid excessive handling. Leave stems on the beans or the open ends will allow moisture to escape and pathogens to enter. Ideally, green beans are cooled and displayed at about 45°F. Beans picked early in the day may be displayed without cooling, if the harvest will be sold the same day.

**Broccoli** heads are fragile and bruise easily with rough handling. Broccoli needs low temperatures and high relative humidity. They benefit from immediate field heat removal by icing or hydrocooling. Ice the displays and keep broccoli no more than two heads deep. Trim stalks to a uniform length.

**Brussels Sprouts** have the best flavor when harvested in cool weather. They will last longer if iced or refrigerated.

**Cabbage** should be cut close to the ground. Retain at least four wrapper leaves to protect the head, unless they are disease and insect damaged. Cabbage is one of the least perishable vegetables, but its temperature should be reduced quickly after harvest to prevent wilting. Do not display cabbages in the sun or wind or pile them very deeply.

**Cauliflower** is extremely perishable and should be handled carefully to prevent bruising. Trim wrapper leaves to head level. Display cauliflower in single layers to avoid bruising. Heads benefit from rapid cooling and protection from moisture loss.

**Celery** is highly perishable and should be kept cool and misted. Use rubber bands to keep stalks together. Wire ties can damage stalks and should be avoided.

**Chinese Cabbage (Napa) and Pak Choi.** If pak choi is too brittle for handling, let it wilt slightly in the field before packing. All types benefit from immediate cooling and prevention of moisture loss. Keep displays shallow and ice or mist periodically.
**Corn** quality is determined primarily by its sugar content, which decreases rapidly after harvest or if picked after peak maturity. Immediate hydrocooling or icing prolongs quality. Without cooling, keep a small display and restock frequently. Keep extra corn in the shade, iced, or in refrigerated storage. The time between harvest and display should be as brief as possible. Corn loses water through its husk’s flag leaves, so remove them.

**Cucumbers** are picked as immature fruit and have easily bruised skin. Clean them before displaying. Discard over-mature fruits. Cukes suffer most from moisture loss, so they should be stored with high humidity. Covering them with wet cloth or paper helps. Cucumbers are chilling-sensitive and should not be held below 50° F for over two days.

**Eggplant** should be harvested immature and tender. Cut the stems short; the calyx sometimes possesses spines that can bruise the delicate fruit. They are sensitive to chilling injury; store at about 50 F °.

**Edible Flowers**, stems, and small leaves are very delicate. Cool them immediately in the field and keep them refrigerated and in high humidity. Display in clear plastic boxes containing a few ounces each.

**Garlic** should be cured for about 10 days after digging. It can be displayed in bulk, braided or with the leaves removed. The bulbs require low humidity; never pack in plastic or mist them.

**Herbs** are normally sold by the leaf stalk, arranged in bunches. Harvest herbs at midmorning; receiving some morning sunlight increases the essential oils that give them flavor and aroma. Stand cut stems in water to prevent wilting. Keep them shaded and cool. Most herbs can be misted and refrigerated. Basil is damaged by moisture and rosemary is damaged by icing.

**Leeks and Green Onions** are dug or pulled and sometimes washed. Clean well and trim roots to about an inch long and trim leek leaves to uniform length. Refrigerate or ice them to prevent water loss.

**Lettuce, Endive and Escarole** should be cut at the base near the soil and unattractive leaves removed. These crops are very perishable from the time of harvest. Cool heads immediately and prevent moisture loss by spraying or covering with wet paper or cloth. At the market, refrigerate, ice or mist them. Packaging in plastic bags prevents wilting. Wire ties may crush stems unless done very carefully.

**Melons** should not be stored at cold temperatures, generally, but cut, wrapped portions should be displayed on ice.

**Mustard Greens, Collards and Kale** can be sold by the leaves or as entire young plants. They will benefit from quick postharvest cooling. Ice them in the field and the display; they wilt at room temperature. Insect control is important.

**Onions** should be cured and the dried leaves either cut or braided. Onions are cured by keeping them at 75-80° F until the necks are tight and the outer scales are dry. Keep onions cool and dry for longest storage.

**Peas** deteriorate rapidly in hot weather and should be cooled immediately after harvest. Peas on display should be refrigerated or packed with ice for longer shelf life.

**Peppers** do not need special attention at harvest or display. Avoid temperatures below 45° F to prevent chilling injury.

**Potatoes** have tender skin and bruise and skin easily. Discard damaged tubers. Wash potatoes before displaying, but dry them thoroughly. Keep potatoes in the dark, since
they will turn green and unsafe quickly in bright light.

**Pumpkins and Winter Squash** suffer from chilling injury at temperatures lower than 45° F. For best quality and long storage, cure all (except acorn) for 10 days at 70° F.

**Root Crops** include beets, carrots, parsnips, radishes, rutabagas, celeriac and turnips. Wash roots before displaying. Heavy scrubbing will leave visible brush marks and encourage water loss and wilting. Leaves may be left on, if desired.

**Spinach, Beet Greens and Swiss Chard** can be sold as plants or separate leaves. In the field, shade and cool harvested leaves or they will wilt quickly. At the stand, ice or refrigerate leaves. Mist, if the air is dry, but misting without cooling encourages rot. Banding with wire ties may crush leaves; packaging in plastic bags is preferred.

**Summer Squash** should be harvested young, while the skin is still shiny. Summer squash has tender skin, bruises very easily and is susceptible to chilling injury. Do not ice squash or expose to temperatures below 45° F. Display in the shade.

**Tomatoes** should be picked ripe for best flavor; however, ripe tomatoes must be sold quickly. At harvest, place tomatoes in shallow boxes; deep piling causes pressure bruises. Remove stems to reduce stem punctures. Never ice or refrigerate tomatoes; they are susceptible to chilling and their flavor is ruined. Keep displays shaded.

**Berries of all types** are extremely delicate. They lose flavor and quality after a few days in storage. Cool them immediately after harvest to 32° F and display them in a cool area. Package berries in a salable container and never fill them more than a few inches deep. A plastic covering will prevent moisture loss. Do not cover with plastic, unless the berries have been cooled. Do not mist or ice berries. Most berries should not be washed prior to sale.

**PEST CONTROL**

Flies, bees and other insects can discourage people from purchasing your produce. To minimize pest problems, eliminate potential insect hiding places, regularly trim the vegetation around the market and prevent standing water. Keep soiled produce in tightly closed garbage containers and remove it regularly. Keep the market area free of clutter to eliminate breeding sites.

Flies can be controlled with various traps, sticky paper and electric “bug zappers.” None are ideal solutions and all will be objectionable to some of your customers. If fly control, beyond cleanliness and good hygiene, is needed, try to locate the devices in an area away from produce and people.

Fruit flies (vinegar flies) prefer rotting produce, so cleanliness is imperative for control. An oscillating fan will disperse fruit fly concentrations and thus reduce unsightliness. No insecticides are registered for use around produce. For yellow jackets and stinging insects, remove overly ripe fruit to reduce attraction. Find and destroy nests after sunset with insecticides designed for this purpose. Remember, some people have serious allergies to insect stings.

By Jim Kropf, WSU Area Agent, King and Pierce Counties
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