

POSTHARVEST HANDLING OF FRUITS AND VEGETABLES

HORTICULTURE TECHNICAL NOTE

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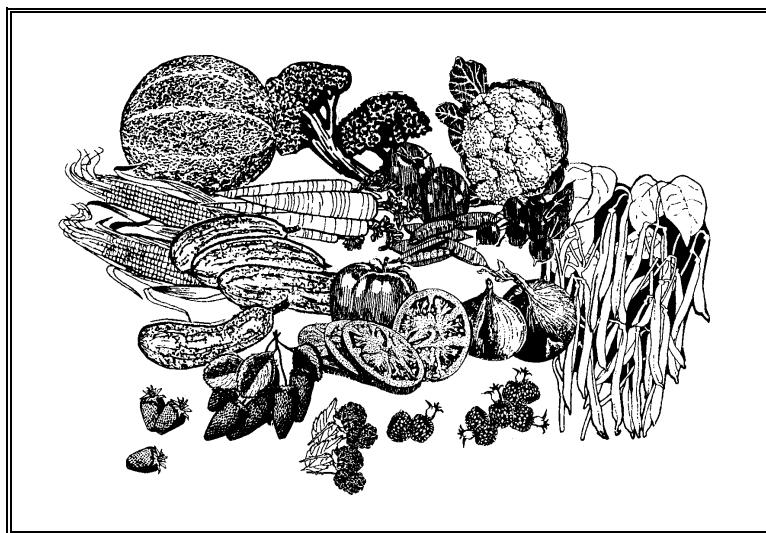
Abstract: *Appropriate production practices, careful harvesting, and proper packaging, storage, and transport all contribute to good produce quality. This publication covers postharvest practices suitable for small-scale operations, and points out the importance of production and harvesting techniques for improving quality and storability. Various methods for cooling fresh produce are discussed, and resources are listed for further information, equipment, and supplies.*

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Introduction

You have spent months working in the fields, and now have a bountiful harvest of beautiful fruits and vegetables. You want to ensure that your customers will also enjoy this healthy harvest. How can you best maintain the quality

and safety of your produce as it travels from the field to the table? How can produce be stored so that it does not need to be sold immediately? High-quality, disease-free produce with a good shelf life is a result of sound production practices, proper handling during harvest, and appropriate postharvest handling and storage.



and have a longer shelf life than others. In addition, environmental factors such as soil type,

temperature, frost, and rainy weather at harvest can have an adverse effect on storage life and quality.

For example, carrots grown on muck soils do not hold up as well in storage as carrots grown on lighter, upland soils. Lettuce harvested during a period of rain does not ship well and product losses are increased (1).

Management practices can also affect postharvest quality. Produce that has been stressed by too much or too little water, high rates of nitrogen, or mechanical injury (scrapes, bruises, abrasions) is particularly susceptible to postharvest diseases. Mold and decay on winter squash, caused by the fungus *Rhizoctonia*, result from the fruits lying on the ground, and can be

alleviated by using mulch. Broccoli heads are susceptible to postharvest rot caused by the bacteria *Erwinia* if nitrogen is applied as foliar feed — a grower should feed the soil, not the leaves. Beets and radishes are susceptible to soil-borne diseases when the soil

Production Practices

Production practices have a tremendous effect on the quality of fruits and vegetables at harvest and on postharvest quality and shelf life. To start with, it is well known that some cultivars ship better

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temperature reaches 80° F; symptoms are black spots on these root crops (2).

Food safety also begins in the field, and should be of special concern, since a number of outbreaks of foodborne illnesses have been traced to contamination of produce in the field. Common-sense prevention measures include a number of *don'ts* (3):

- Don't apply raw dairy or chicken manure or slurries to a field where a vegetable crop such as leafy lettuce is growing.
- Don't apply manure to an area immediately adjacent to a field nearing harvest maturity.
- Don't forget to clean equipment that has been used to apply manure to one field before moving it to another field in production.
- Don't irrigate with water from a farm pond used by livestock.
- Don't harvest fruit from the orchard floor for human consumption as whole fruit or nonpasteurized juices, especially if manure has been spread or animals allowed to graze.
- Don't accumulate harvested product in areas where birds roost.

A grower *should* constantly evaluate water used for irrigation, and compost all animal manures before applying them to fields. There are many good sources of information on growing conditions and production practices that promote postharvest quality. Consult textbooks, Extension publications, and trade journals, and become involved with grower organizations to find out more.

Harvest Handling

Quality cannot be improved after harvest, only maintained; therefore it is important to harvest fruits, vegetables, and flowers at the proper stage and size and at peak quality. Immature or overmature produce may not last as long in storage as that picked at proper maturity (4). Cooperative Extension Service publications are an excellent source of information on harvest maturity indicators for vegetables and fruits.

Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept shaded in the field. Handle produce gently. Crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organisms as well.

Postharvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. The rate of moisture loss may be increased by as much as 400% by a single bad bruise on an apple, and skinned potatoes may lose three to four times as much weight as non-skinned potatoes. Damage can be prevented by training harvest labor to handle the crop gently; harvesting at proper maturity; harvesting dry whenever possible; handling each fruit or vegetable no more than necessary (field pack if possible); installing padding inside bulk bins; and avoiding over or under-packing of containers (4).

Postharvest and Storage Considerations

Packaging

Packaging should be designed to prevent physical damage to produce, and be easy to handle. The *American Vegetable Grower* magazine's annual product guide is a good source of information about suppliers (see **Resources**).

Temperature

Temperature is the single most important factor in maintaining quality after harvest. Refrigerated storage retards the following elements of deterioration in perishable crops:

- aging due to ripening, softening, and textural and color changes;
- undesirable metabolic changes and respiratory heat production;
- moisture loss and the wilting that results;
- spoilage due to invasion by bacteria, fungi, and yeasts;
- undesirable growth, such as sprouting of potatoes (5).

One of the most important functions of refrigeration is to control the crop's respiration rate. Respiration generates heat as sugars, fats, and proteins in the cells of the crop are oxidized. The loss of these stored food reserves through respiration means decreased food value, loss of flavor, loss of salable weight, and more rapid deterioration. The respiration rate of a product strongly determines its transit and postharvest life. The higher the storage temperature, the higher the respiration rate will be (4).

For refrigeration to be effective in postponing deterioration, it is important that the temperature in cold storage rooms be kept as constant as possible. Appendix I charts the optimum temperature ranges for various crops. Exposure to alternating cold and warm temperatures may result in moisture accumulation on the surface of produce (sweating), which may hasten decay. Storage rooms should be well insulated and adequately refrigerated, and should allow for air circulation to prevent temperature variation. Be sure that thermometers, thermostats, and manual temperature controls are of high quality, and check them periodically for accuracy (5).

On-farm cooling facilities are a valuable asset for any produce operation. A grower who can cool and store produce has greater market flexibility because the need to market immediately after harvest is eliminated. The challenge, especially for small-scale producers, is the set-up cost. Innovative farmers and researchers have created a number of designs for low-cost structures. Some of these ideas are detailed in Appendix II and in the enclosures attached to this document. Additional designs are available in publications listed in the **Resources** section.

Pre-cooling

Pre-cooling is the first step in good temperature management. The *field heat* of a freshly harvested crop – heat the product holds from the sun and ambient temperature – is usually high, and should be removed as quickly as possible before shipping, processing, or storage. Refrigerated trucks are not designed to cool fresh commodities but only maintain the temperature of pre-cooled

produce. Likewise, most refrigerated storage rooms have neither the refrigeration capacity nor the air movement needed for rapid cooling. Therefore, pre-cooling is generally a separate operation requiring special equipment and/or rooms (4, 5).

Rapid pre-cooling to the product's lowest safe temperature is most critical for crops with inherently high respiration rates. These include artichokes, brussels sprouts, cut flowers, green onions, snap beans, asparagus, broccoli, mushrooms, peas, and sweet corn. Crops with low respiration rates include nuts, apples, grapes, garlic, onions, potatoes (mature), and sweet potatoes (4).

Appropriate pre-cooling methods as well as appropriate storage temperature and humidity for a number of fruits and vegetables are shown in Appendix I. The following methods are the most commonly used:

- **Room cooling:** Produce is placed in an insulated room equipped with refrigeration units. This method can be used with most commodities, but is slow compared with other options. A room used only to *store* previously cooled produce requires a relatively small refrigeration unit. However, if it is used to *cool* produce, a larger unit is needed. Containers should be stacked so that cold air can move around them, and constructed so that it can move through them. Used refrigerated truck bodies make excellent small cooling rooms (4).
- **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 air flow, this method is usually 75–90% faster than room cooling. Fans should be equipped with a thermostat that automatically shuts them off as soon as the desired product temperature is reached.

To avoid over-cooling and dehydration of produce, do not operate forced-air fans after the produce has been cooled to its optimum temperature (4).

- **Hydro-cooling:** Dumping produce into cold water, or running cold water over produce, is an efficient way to remove heat, and can serve as a means of cleaning at the same time. In addition, hydro-cooling reduces water loss and wilting. Use of a disinfectant in the water is recommended to reduce the spread of diseases. Hydro-cooling is not appropriate for berries, potatoes to be stored, sweet potatoes, bulb onions, garlic, or other commodities that cannot tolerate wetting.

Water removes heat about five times faster than air, but is less energy-efficient. Well water is a good option, as it usually comes out of the ground with temperatures in the 50–60° F range. Mechanical refrigeration is the most efficient method for cooling water. A thermal storage immersion hydro-cooler system can be fabricated economically to suit various volume requirements. Used stainless-steel bulk farm milk coolers may be an option. If hydro-cooling water is recirculated, it should be chlorinated to minimize disease problems (4).

A study compared sweet corn quality after hydro-cooling with ice water, well water cooling, and refrigerated air cooling, and subsequent refrigerated storage. Hydro-cooling with ice water lowered the temperature of the ears most quickly. Well

water cooling followed by refrigerated storage appeared to offer no advantage over refrigerated storage immediately after harvest (6).

- **Top or liquid icing:** Icing is particularly effective on dense products and palletized packages that are difficult to cool with forced air. In top icing, crushed ice is added to the container over the top of the produce by hand or machine. For liquid icing, a slurry of water and ice is injected into produce packages through vents or handholds without removing the packages from pallets and opening their tops. Icing methods work well with high-respiration commodities such as sweet corn and broccoli. One pound of ice will cool about three pounds of produce from 85° F to 40° F (7, 8).
- **Vacuum cooling:** Produce is enclosed in a chamber in which a vacuum is created. As the vacuum pressure increases, water within the plant evaporates and removes heat from the tissues. This system works best for leafy crops, such as lettuce, which have a high surface-to-volume ratio. To reduce water loss, water is sometimes sprayed on the produce prior to placing it in the chamber. This process is called *hydrovac* cooling. The primary drawback to this method is the cost of the vacuum chamber system (9).

These products can be iced:

Artichokes
Asparagus
Beets
Broccoli
Cantaloupes
Carrots
Cauliflower
Endive
Green onions
Leafy greens
Radishes
Spinach
Sweet corn
Watermelon



These items are damaged by direct contact with ice:

Strawberries
Blueberries
Raspberries
Tomatoes
Squash
Green beans
Cucumbers
Garlic
Okra
Bulb onions
Romaine lettuce
Herbs



Chilling injury

Many vegetables and fruits store best at temperatures just above freezing, while others are injured by low temperatures and will store best at 45 to 55 degrees F. Both time and temperature are involved in chilling injury. Damage may occur in a short time if temperatures are considerably below the danger threshold, but some crops can withstand temperatures a few degrees into the danger zone for a longer time. The effects of chilling injury are cumulative in some crops. Low temperatures in transit, or even in the field shortly before harvest, add to the total effects of chilling that might occur in storage (7).

Crops such as basil, cucumbers, eggplants, pumpkins, summer squash, okra, and sweet potatoes are highly sensitive to chilling injury. Moderately sensitive crops are snap beans, muskmelons, peppers, winter squash, tomatoes,

and watermelons (8). These crops may look sound when removed from low temperature storage, but after a few days of warmer temperatures, chilling symptoms become evident: pitting or other skin blemishes, internal discoloration, or failure to ripen. Tomatoes, squash, and peppers that have been over-chilled may be particularly susceptible to decay such as *Alternaria* rot (7).

Preventing moisture loss

While temperature is the primary concern in the storage of fruits and vegetables, relative humidity

is also important. The relative humidity of the storage unit directly influences water loss in produce. Water loss can severely degrade quality—for instance, wilted greens may require excessive trimming, and grapes may shatter loose from clusters if their stems dry out. Water loss means salable weight loss and reduced profit (4).

Most fruit and vegetable crops retain better quality at high relative humidity (80 to 95%), but at this humidity, disease growth is encouraged. The cool temperatures in storage rooms help to reduce disease growth, but sanitation and other preventative methods are also required. Maintaining high relative humidity in storage is complicated by the fact that refrigeration removes moisture. Humidification devices such as spinning disc aspirators may be used. Even buckets of water will increase humidity as the fans blow air across the water's surface and increase evaporation (10). Keeping the floor wet is helpful, though messy and potentially hazardous to two-legged creatures; frequent cleansing with a weak chlorine solution will be needed to prevent harboring of disease organisms in water and produce scraps on the floor. Crops that can tolerate direct contact with water may be sprinkled to promote high relative humidity (4).

When it comes to maintaining appropriate humidity levels, "the biggest thing for small growers is going to be monitoring equipment," says Kansas State University Extension Specialist Karen Gast. Humidity is measured by an instrument called a hygrometer. Several companies offer small, low-priced hygrometers

suitable for small-scale producers (10). See **Resources** for more information.

Sanitation

Sanitation is of great concern to produce handlers, not only to protect produce against postharvest diseases, but also to protect consumers from foodborne illnesses. *E. coli* 0157:H7, *Salmonella*, *Chryptosporidium*, *Hepatitis*, and *Cyclospora* are among the disease-causing organisms that have been transferred via fresh fruits and vegetables (3, 11). Use of a disinfectant in wash water can help to prevent both postharvest diseases and foodborne illnesses.

Chlorine in the form of a sodium hypochlorite solution (for example, Clorox™) or as a dry, powdered calcium hypochlorite can be used in hydro-cooling or wash water as a disinfectant. Some pathogens such as *Chryptosporidium*,

however, are very resistant to chlorine, and even sensitive ones such as *Salmonella* and *E. coli* may be located in inaccessible sites on the plant surface. For the majority of vegetables, chlorine in wash water should be

maintained in the range of 75–150 ppm (parts per million.) The antimicrobial form, hypochlorous acid, is most available in water with a neutral pH (6.5 to 7.5).

The effectiveness of chlorine concentrations are reduced by temperature, light, and interaction with soil and organic debris. The wash water should be tested periodically with a monitoring kit, indicator strips, or a swimming pool-type indicator kit. Concentrations above 200 ppm can injure some vegetables (such as leafy greens and celery) or leave undesirable off-flavors.

Organic growers must use chlorine with caution, as it is classified as a restricted material. The California Certified Organic Farmers regulations permit a maximum of 4 ppm residual chlorine, measured downstream of the product wash (3). Growers certified by other agencies should check with their certifying agent.

Ozonation is another technology that can be used to sanitize produce. A naturally occurring molecule, ozone is a powerful disinfectant. Ozone has long been used to sanitize drinking water, swimming pools, and industrial wastewater. Fruit and vegetable growers have begun using it in dump tanks as well, where it can be thousands of times more effective than chlorine. Ozone not only kills whatever foodborne pathogens might be present, it also destroys microbes responsible for spoilage. A basic system consists of an ozone generator, a monitor to gauge and adjust the levels of ozone

Amounts of hypochlorite to add to clear, clean water for disinfestation.			
	target ppm	ounces/5 gallons	cup/50 gallons
Sodium hypochlorite	50	.55	.5
(5.25%)	75	.8	.75
	100	1.1	1.0
	125	1.4	1.25
	150	1.7	1.5
Sodium hypochlorite	50	.12	.1
(12.7%)	75	.17	.15
	100	.23	.2
	125	.29	.25
	150	.35	.3

being produced, and a device to dissolve the ozone gas into the water. Systems cost anywhere from \$10,000 to \$100,000, and should be installed by an ozone sanitation company experienced in produce industry applications (12).

Hydrogen peroxide can also be used as a disinfectant. Concentrations of 0.5% or less are effective for inhibiting development of postharvest decay caused by a number of fungi. Hydrogen peroxide has a low toxicity rating and is generally recognized as having little potential for environmental damage. The ATTRA

publication *Sources for Organic Fertilizers and Amendments* lists several sources of food-grade hydrogen peroxide.

Creative growers can customize their produce-washing system to promote sanitation and increase efficiency and ease of operation. At Drumlin Community Farm in Madison, Wisconsin, the crew “used to wash greens and small crops by the handfuls in wash tubs and air dry them on screen tables. Now they line harvest containers with a mesh produce bag, dunk the whole bagful at once, and dry two bagfuls at a time in an old washing machine set to spin cycle.” At another farm, loose greens are dumped into a 500-gallon bulk milk tank. The water in the tank is agitated with bubbling air from a jacuzzi motor. The washed greens are scooped out of the tank with a mesh bag-lined laundry basket, and the bags of greens are then spun dry in a washing machine. The grower removed the washer’s agitator to make more room for the produce (13).

This type of system has several advantages – it reduces handling (and potential damage) of the crop; it makes the washing process more time and labor efficient; and it enhances postharvest quality by getting the crop cooled down, washed, dried, and in cold storage much more quickly. Perhaps most importantly, washing greens in large batches rather than one-by-one reduces physical stress on the worker’s back and arms.

At a cost of \$2–8 each, woven polyester or nylon bags are durable, lightweight, water-permeable, and fast-drying. Suitable mesh laundry bags may be found at hardware or discount stores (13). The **Resources** section lists two companies that sell mesh bags by mail order. Spin-drying can be done with a washing machine, honey extractor, or commercial salad spinner. A restaurant or industrial-scale salad spinner is an efficient machine for both washing and drying greens (available from restaurant supply stores; prices range from \$650 to \$1500).

Some further tips for postharvest handling of lettuce and other leafy greens: package in breathable or perforated plastic bags; refrigerate

at 33° F; carry to market in a portable cooler, either refrigerated or with ice, and keep in the cooler until ready to display. If displaying unwrapped heads at a farmers’ market, mist occasionally with cold water.

Ethylene

Ethylene, a natural hormone produced by some fruits as they ripen, promotes additional ripening of produce exposed to it. The old adage that one bad apple spoils the whole bushel is true. Damaged or diseased apples produce high levels of ethylene and stimulate the other apples to ripen too quickly. As the fruits ripen, they become more susceptible to diseases.

Ethylene “producers” should not be stored with fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life, and specific symptoms of injury. Some examples of ethylene effects include:

- russet spotting of lettuce along the midrib of the leaves;
- loss of green color in snap beans;
- increased toughness in turnips and asparagus spears;
- bitterness in carrots and parsnips;
- yellowing and abscission of leaves in broccoli, cabbage, Chinese cabbage, and cauliflower;
- accelerated softening of cucumbers, acorn and summer squash;
- softening and development of off-flavor in watermelons;
- browning and discoloration in eggplant pulp and seed;
- discoloration and off-flavor in sweet potatoes;
- sprouting of potatoes;
- increased ripening and softening of mature green tomatoes (8); and
- shattering of raspberries and blackberries (2).

Ethylene producers include apples, apricots, avocados, ripening bananas, cantaloupes, honeydew melons, ripe kiwifruit, nectarines, papayas, passionfruit, peaches, pears, persimmons, plantains, plums, prunes, quinces, and tomatoes (14). Produce that is sensitive to ethylene is indicated in Appendix I.

Mixed loads

When different commodities are stored or transported together, it is important to combine only those products that are compatible with respect to their requirements for temperature, relative humidity, atmosphere (oxygen and carbon dioxide), protection from odors, and protection from ethylene (4).

In regard to cross-transfer of odors, combinations that should be avoided in storage rooms include: apples or pears with celery, cabbage, carrots, potatoes, or onions; celery with onions or carrots; and citrus with any of the strongly scented vegetables. Odors from apples and citrus are readily absorbed by meat, eggs, and dairy products. Pears and apples acquire an unpleasant, earthy taste and odor when stored with potatoes. It is recommended that onions, nuts, citrus, and potatoes each be stored separately (4).

Storage crops

What about the crops that will not be transported and marketed fresh after harvest? Growers can extend their selling season into the winter months by growing root crops and other vegetables and fruits suited for long-term storage. The challenge is in keeping quality high by creating and maintaining the correct storage environment. As *Growing for Market* editor Lynn Byczynski notes,

Most storage crops require low temperatures and high humidity, two factors that don't come together easily. Several others require low humidity and low temperatures. And then there are a few that fall in between...Root crops such as beets, carrots, turnips, rutabagas, and leeks store best at 32° F and 90% humidity. Potatoes prefer temperatures of 40–60° F and 90% humidity. Onions and garlic like it cool – 32° – but require less humidity – about 65–75%. Winter squash prefer temperatures of 50–60° F, but dry. That's four different types of storage for vegetables that will hold a month or more: cold and humid; cold and dry; cool and humid; cool and dry (10).

The two structural options for storage of these crops are coolers and root cellars. Byczynski provides an example of a farm using both: "The Seelys have a bank barn, which has the bottom floor built into a hillside...They have built both coolers and a dry storage room into the lower floor to provide different combinations of temperature and humidity for the vegetables they store." Coolers used for root crop storage will require water added to the air and regular monitoring of the humidity level (see discussion under *Preventing moisture loss* above.) Some growers have used concrete basements of houses, closed off from heat and with ventilation to let in cold winter air, as root cellars. Another idea is to bury a big piece of culvert under a hillside (10).

Whatever the method, only "perfect" produce is suitable for long-term storage, so careful inspection is critical. Any damaged produce is going to spoil and induce spoilage in the rest of the crop. Byczynski advises growers to "either rub off soil and leave the crops somewhat dirty, or wash them and let them dry thoroughly before putting them in storage. With onions, garlic, winter squash, pumpkins and sweet potatoes, it's important that they be cured thoroughly before storage" (10).

Conclusion

Postharvest handling is the final stage in the process of producing high quality fresh produce. Being able to maintain a level of freshness from the field to the dinner table presents many challenges. A grower who can meet these challenges, will be able to expand his or her marketing opportunities and be better able to compete in the marketplace. This document is intended to serve as an introduction to the topic and a resource pointer; the grower is advised to seek out more complete information from Extension and other sources.

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Resources:

Further Information

Commercial Cooling of Fruits, Vegetables, and Flowers.

By James Thompson, et al. 1998. 65 p.

University of California, ANR

Publications # 21567

Detailed descriptions of proper temperature management for perishables and commercial cooling methods. Complete discussion of design for hydro-cooler and forced-air cooler systems, the two most commonly used cooling methods. 25 graphs and illustrations, 11 color plates, and 15 tables. Available for \$10 plus \$3.50 s/h. Make check payable to UC Regents and specify pub. #21567.

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UC-Davis Produce Facts website

<http://postharvest.ucdavis.edu/Produce/ProduceFacts/index.html>

Separate postharvest fact sheets for a great variety of fruit, vegetable, and ornamental crops. Each fact sheet includes information about maturity and quality indices, optimum temperature and relative humidity, rates of respiration and ethylene production rates, responses to ethylene and controlled atmospheres, physiological and pathological disorders: causes and control, and other relevant information. Periodic updates of these fact sheets will be published as new information becomes available. The goal is to eventually post fact sheets for all major perishable crops.

Perishables Handling
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Perishables Handling, a quarterly publication from the UC-Davis Postharvest Outreach Program, reports research in progress, recent publications, and brief reviews of various aspects of postharvest technology of horticultural crops. A one-year subscription costs \$25. Back issues are available for \$8 each. Tables of contents of back issues may be reviewed on-line at:
<http://postharvest.ucdavis.edu/Pubs/POSTPhn.html>

Produce Handling for Direct Marketing
Natural Resource, Agriculture, and Engineering Service (NRAES)
1992. 26 p. NRAES-51.

For growers selling seasonal produce at farmers' markets and roadside stands. Describes postharvest physiology, food safety, produce handling from harvest to storage, refrigeration, produce displays, and specific handling recommendations for over 40 fruits and vegetables. Includes eleven tables and eight figures.

Refrigeration and Controlled Atmosphere Storage for Horticultural Crops
1990. 44 p. NRAES-22

General construction procedures for storage facilities: structural considerations, site selection, thermal insulation, vapor barriers, and attic ventilation. Explanations of various refrigeration systems, with descriptions of equipment and operating procedures. Controlled atmosphere storage construction, testing, and operation, especially in relation to apple storage.

Both of these NRAES publications are available, for \$8 each plus a total of \$3.75 s/h, from:

NRAES
Cooperative Extension
152 Riley-Robb Hall
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(607) 255-7654
<http://www.nraes.org>

Postharvest Handling & Cooling of Fresh Fruits, Vegetables, and Flowers for Small Farms
By L.G. Wilson, M.D. Boyette, and E.A. Estes.
1995. 17 p.

North Carolina Cooperative Extension Service.
Leaflets 800-804.

Five-part series: Quality Maintenance; Cooling; Handling; Mixed Loads; References. Available on-line at:
<http://www.ces.ncsu.edu/depts/hort/hil/post-index.html>

North Carolina State University also offers the following fact sheets on postharvest cooling and handling, at:
www5.bae.ncsu.edu/programs/extension/publicat/postharv/index.html

Apples AG-413-1
Strawberries AG-413-2
Peppers AG-413-3
Sweet Corn AG-413-4
Cabbage and Leafy Greens AG-413-5
Onions AG-413-6
Blueberries AG-413-7
Greenbeans and Field Peas AG-413-8
Tomatoes AG-413-9
Proper Postharvest Cooling and Handling Methods AG-414-1
Design of Room Cooling Facilities AG-414-2
Forced-Air Cooling AG-414-3
Hydrocooling AG-414-4
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Chlorination and Postharvest Disease Control AG-414-6
Cool and Ship: Low Cost Portable Forced Air Cool Unit AG-414-7
Packaging Requirements for Fresh Fruits and Vegetables AG-414-8

For information on ordering print copies of these publications, contact:

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(919) 515-2861

Kansas State University offers the following publications on postharvest management of commercial horticultural crops. All are available on-line at:
<http://www.oznet.ksu.edu/library>

Containers and Packaging – Fruits and Vegetables MF979
Fruits and Vegetables – Precooling Produce MF1002
Harvest Maturity Indicators for Fruits and Vegetables MF1175

Storage Conditions – Fruits and Vegetables
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Storage Operations MF1033
Storage Options MF1030

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Manhattan, KS 66506-3402
(785) 532-5830
e-mail: orderpub@oz.oznet.ksu.edu

The University of Wisconsin has produced a very helpful set of "Work Efficiency Tip Sheets" for fresh-market vegetable growers. These materials were developed by the Healthy Farmers, Healthy Profits Project, with the goal of sharing labor-efficiency practices that maintain farmers' health and safety while increasing profits. Topics in the series include:

A Specialized Harvest Cart for Greens A3704-1

Stooping or kneeling and crawling to harvest salad greens requires a lot of time and energy. An alternative is to build a simple cart that allows you to sit and roll while you harvest. The cart also holds your harvest container, so it rolls along with you. Parts for the cart will cost about \$150.

Mesh Produce Bags: Easy Batch Processing A3704-2

Elements and benefits of the batch method for washing greens, as discussed above under the heading "Sanitation."

Standard Containers A3704-3

Standard containers for carrying and moving produce are made of molded plastic, have sturdy handles, and are stackable. They're easier to use and more efficient than bushel baskets, buckets or wooden crates.

Narrow Pallet System A3704-4

If you currently carry boxes of produce by hand, switching to a narrow pallet system may save you time and money. With a hand pallet truck you can move up to 16 half-bushel boxes at a time. This system can cut your time spent moving boxes by more than 60% and will dramatically reduce the stress put on your body.

These tipsheets may be ordered from the following address, or accessed on-line at:

<http://www.bse.wisc.edu/hfhp/>

Cooperative Extension Publishing
Rm. 170, 630 W. Mifflin St.
Madison, WI 53703
(608) 262-3346
<http://www.uwex.edu/ces/pubs/>

Sydney Postharvest Lab

<http://www.postharvest.com.au>

This Australian website offers postharvest handling and storage information, with extensive links to other postharvest sites.

Growing for Market

Editor: Lynn Byczynski

P.O. Box 3747

Lawrence, KS 66046

(800) 307-8949

This monthly newsletter is a great resource for small-scale growers. Lots of good, practical information from other producers, with frequent coverage of postharvest topics. Subscriptions cost \$30. for one year, or \$55. for two years.

Manufacturers & Suppliers

NOTE: This list is intended to be neither comprehensive nor exclusive. Endorsement of any particular product or company is not implied.

American Vegetable Grower

Meister Publishing Company

37733 Euclid Ave.

Willoughby, OH 44094

(440) 942-2000

The annual "Source Book" issue (July) is a comprehensive listing of manufacturers and suppliers of every type of product for farmers, including postharvest equipment and supplies. 12 issues/\$15.95. Single issue/\$2.75.

Cady Industries

P.O. Box 2087

Memphis, TN 38101

(800) 622-3695

Sells a 32" x 27" McKnit nylon bag with 1/8" mesh for \$6 each, with a minimum order of 10.

The Nylon Net Co.

845 North Main St.

Memphis, TN 38107

(800) 238-7529

Sells a 1/4" nylon mesh "diver's bag" with drawstring, 24" x 34", for \$8.28 each.

Delta Track
P.O. Box 398
Pleasanton, CA 94566
(800) 962-6776

Sells "Hygro Thermometers": about the size of a deck of cards, battery operated, digital display of temperature and humidity, records daily min./max. of each.

Spectrum Technologies
23839 W. Andrews Rd.
Plainfield, IL 60544
(800) 248-8873

Sells humidity monitors.

Barr, Inc.
1423 Planeview Dr.
Oshkosh, WI 54904
(920) 231-1711
e-mail: info@barrinc.com
<http://www.barrinc.com>

Distributor of used coolers, freezers, and refrigeration systems.

Cool Care Consulting, Inc.
4020 Thor Dr.
Boynton Beach, FL 33426
(561) 364-5711
e-mail: ron.roberts@coolcareinc.com
<http://www.coolcareinc.com>

Sells postharvest pre-cooling and refrigeration equipment, including forced air, ice, hydro, vacuum, modular, and mobile cooling units.

Bio Safe Systems
80 Commerce St.
Glastonbury, CT 06033
(888) 273-3088
e-mail: Rob@biosafesystems.com
<http://www.biosafesystems.com>

Sells organic-approved, eco-friendly washwater treatments/disinfectants.

The electronic version of **Postharvest Handling of Fruit & Vegetables** is located at:
<http://www.attra.org/attra-pub/postharvest.html>

By Janet Bachmann and Richard Earles
NCAT Agriculture Specialists

August 2000

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APPENDIX I

Storage Conditions for Vegetables and Fruits					
	Temperature F	% Relative humidity	Precooling method	Storage life Days	Ethylene sensitive
Apples	30-40	90-95	R, F, H	90-240	Y
Apricots	32	90-95	R, H	7-14	Y
Asparagus	32-35	95-100	H, I	14-21	Y
Avocados	40-55	85-90		14-28	Y
Bananas	56-58	90-95		7-28	Y
Beans, snap	40-45	95	R, F, H	10-14	Y
Beans, lima	37-41	95		7-10	
Beets, roots	32	98-100	R	90-150	
Blackberries	31-32	90-95	R, F	2-3	
Blueberries	31-32	90-95	R, F	10-18	
Broccoli	32	95-100	I, F, H	10-14	Y
Brussel sprouts	32	95-100	H, V, I	21-35	Y
Cabbage	32	98-100	R, F	90-180	Y
Cantaloupe	36-41	95	H, F	10-14	Y
Carrots, topped	32	98-100	I, R	28-180	Y
Cauliflower	32	90-98	H, V	20-30	
Celery	32	98-100	I	14-28	Y
Cherries, sweet	30-31	90-95	H, F	14-21	
Corn, sweet	32	95-98	H, I, V	4-6	
Cranberries	36-40	90-95		60-120	
Cucumbers	50-55	95	F, H	10-14	Y
Eggplant	46-54	90-95	R, F	10-14	Y
Endive	32	90-95	H, I	14-21	Y
Garlic	32-34	65-75	N	90-210	
Grapefruit	50-60	85-90		28-42	
Grapes	32	85	F	56-180	
Kiwifruit	32	95-100		28-84	Y
Leeks	32	95-100	H, I	60-90	Y
Lemons	50-55	85-90		30-180	
Lettuce	32	85-90	H, I	14-21	Y
Limes	48-50	85-90		21-35	
Mushrooms	32	95		12-17	
Nectarines	31-32	95	F, H	14-18	Y
Okra	45-50	90-95		7-14	Y
Onions, bulb	32	65-70	N	30-180	
Onions, green	32	95-100	H, I	7-10	
Oranges	32-48	85-90		21-56	
Peaches	31-32	90-95	F, H	14-28	Y

	Temperature F	% Relative humidity	Precooling method	Storage life Days	Ethylene sensitive
Pears	32	90-95	F, R, H	60-90	Y
Peas, in pods	32	95-98	F, H, I	7-10	Y
Peppers, bell	45-55	90-95	R, F	12-18	Y
Peppers, hot	45-50	60-70	R, F	14-21	Y
Pineapple	45-55	85-90		14-36	
Plums	32	90-95	F, H	14-28	Y
Potatoes, early	50-60	90	R, F	56-140	
Potatoes, late	40-50	90	R, F	56-140	Y
Pumpkins	50-60	50-75	N	84-160	
Radishes	32	95-100	I	21-28	
Raspberries	32	90-95	R, F	2-3	Y
Rutabagas	32	98-100	R	120-180	
Spinach	32	95-100	H, I	10-14	Y
Squash, summer	41-50	95	R, F	7-14	Y
Squash, winter	50-55	50-70	N	84-150	
Strawberries	32	90-95	R, F	5-10	
Sweet potatoes	55-60	85-90	N	120-210	Y
Tangerines	40	90-95		14-28	
Tomatoes	62-68	90-95	R, F	7-28	Y
Turnips	32	95	R, H, V, I	120-150	
Watermelon	50-60	90	N	14-21	
F = forced-air cooling, H = hydrocooling, I = package icing, R = room cooling, V = vacuum cooling, N = no precooling needed. Sources: USDA Agricultural Marketing Service, Kansas State University Cooperative Extension Service					

APPENDIX II

The Portacooler

A portable precooler designed by USDA researchers can be built with readily available materials at a cost of around \$1,200. The most expensive component is an air conditioner. If a used air conditioner is available, the initial investment will be decreased. The Portacooler can be towed to the field and used to reduce field heat of berries, vegetables, and other high-value crops immediately after picking.

The structure of the Portacooler is a basic wood frame and plywood panel construction (see diagram). The outside dimensions of the cooler are 4 feet high by 4 feet wide by 8 feet long. The frame is made of 2 by 3's spaced 2 feet on center, excluding the doorway and the air conditioner space. The frames are sheathed with 1/2 inch plywood. The precooler is insulated with 2-inch thick plastic foam that fits firmly between the frame studs.

After the frame and sheathing are completed, the electrical components can be installed (see diagram). The standard junction box, power switches, daily cycle timer, and industrial thermostat control box should be mounted on the outside of the front wall near the air conditioner. An adjustable, industrial thermostat control box should be mounted on the outside of the front wall near the air conditioner. An adjustable, industrial thermostat must be connected to the air conditioner to replace the existing thermostat. Mount strip

heaters using copper wire so that they contact the cooling coils of the air conditioner. Mount the blower on the front inside wall, centered above the air conditioner so that the blower discharge is 12 inches below the inside ceiling.

All electrical components should be properly grounded, and wiring should comply with national and local electrical codes. Consult a licensed electrician for more information about how to install any components of the electrical system.

The Portacooler can be powered from either an electrical wall outlet or a gasoline-powered generator. The main electrical connection from the power source is split to the individual switches. From the switches, the power travels to the blower and to the air conditioner. The strip heaters and the thermostat are wired from the timer. The timer creates a defrost cycle by alternating power from the compressor to the strip heaters. (An interval of compressor shutdown time should be approximately 2.5 minutes during every 10 minutes.)

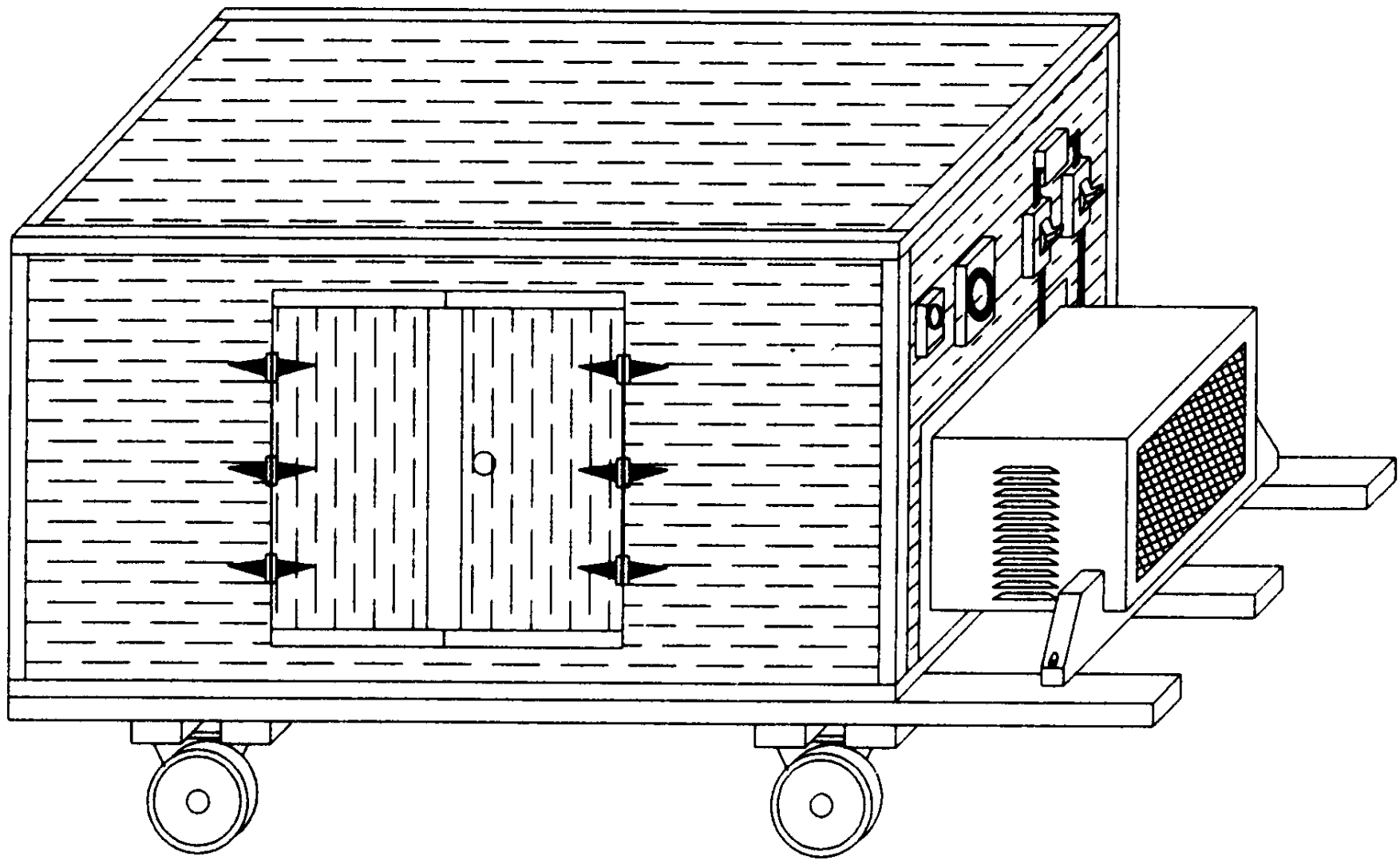
Once the cooler is assembled, and the electrical components hooked up, mount the air flow bulkhead. Mount the bulkhead with blower discharge hoe flush with the edge of the blower discharge, allowing a 6-inch-high return-air gap along the floor.

All wood surfaces should be coated with polyurethane and an all-weather sealer to prolong the useful equipment life.

General Material List

• air conditioner, 12,000 Btu, 115 V.....	1
• centrifugal blower, 1/3 hp, 1210 c.f.m.	1
• 20-amp wall switch, with boxes and covers	2
• 4 by 8 ft, exterior AC, 1/4-in plywood.....	11
• lumber, 2 by 3 in, 8 ft long.....	30
• lumber, 2 by 4 in, 12 ft long.....	3
• lumber, 2 by 6 in, 8 ft long.....	1
• industrial wheels, 5-in diameter.....	2
• industrial wheels, 5-in diameter, swivel.....	2
• dry wall screws, 2 1/2-in long.....	5 lb
• dry wall screws, 1-in long	1 lb
• water sealer	1 gal
• polyurethane coating	1 gal
• weather stripping, 1-in wide roll	1
• insulation, 2 in, 4 by 8 ft sheets.....	5
• 1/4-in plywood, 4-in wide strips	12 ft
• door latch, sliding bolt	1
• thermostat, 115 B, 16 amp, remote bulb	1
• strap hinges, screw fastened, 3-in long.....	4
• lumber, 2 by 10 in, 4 ft long.....	1
• standard junction box	1
• strip heaters, 150 watt, 8 in, 115 B.....	2
• insulated wire	30 ft
• cycle timer, SPDT, 115 B, 20 amp, 1 hour	1

The design, construction, and research of the Portacooler was conducted by Joseph Anthony, Gerald Berney, William Craig, and Daniel P. Schofer. For further information, contact Daniel Schofer, Room 1211 South Bldg., 12 & Independence, Box 96456, Washington, D.C. 20090-6456.



Electrical Diagram

