Postharvest Management of Commercial Horticultural Crops

STORAGE OPERATIONS
FRUITS & VEGETABLES

By
Karen L. B. Gast
Rolando A. Flores

Any fruit and vegetable packing facility must operate reliably. Equipment maintenance, monitoring and management are integral parts of all the activities. More specifically, the aspects that need special attention when managing a cold storage system are condensation and humidity control, temperature control, sanitation, maintenance, container design and positioning, and storage compatibility of commodities.

Condensation and Humidity Control

The relative humidity in refrigerated storage must be within the optimum range for the commodity. For most fruits and vegetables, the optimum relative humidity is 90–95 percent. When relative humidity inside the refrigerated storage is less than 90 percent, the facility should use a humidifier. The relative humidity of the storage can be monitored with a recording hygrometer or at intervals with a sling psychrometer.

The air-to-coil temperature differential of the refrigeration unit must be no greater than 5°F. The temperature differential equals the difference between the temperature of the refrigerant entering the coil and the temperature of the air in the refrigerated facility. Air-to-coil temperature differentials greater than 5°F condense water vapor in the air, reducing relative humidity in the facility and producing ice accumulations on the evaporator coils. When the humidity is lowered, air tends to absorb water from the stored produce, causing it to wilt. Table 1 shows the sensitivity of several commodities to water loss.

If the air-to-coil differential cannot be adjusted, the installation of a humidifier in the refrigerated storage is necessary. The addition of moisture to the facility by dumping water on the floor is a common practice to add moisture to the air. However, wetting the floor is not a good plant sanitation procedure because it also wets hidden and hard-to-reach places where disease organisms can grow.

The removal of ice accumulations on the coils is necessary to keep the refrigeration unit operating properly. Ice accumulations make the equipment operate for longer periods of time to maintain the temperature in the refrigerated storage, consuming more electricity and reducing the lifetime of the refrigeration unit. Some of the ways to eliminate ice accumulations on the coils are electrical defrost, warm water sprays, reverse refrigerant flow, and equipment shutdown for 6–8 hours. The selection of one of these depends on the equipment and facility size.

Temperature Control

A thermostat is important in the refrigerated facility. The thermostat controls the operation of the refrigeration unit so a preset temperature can be maintained in the storage. The thermostat's thermometer should not be used to monitor the storage temperature. A separate recording thermometer should be installed for this purpose. This type thermometer will be helpful in determining whether storage facilities are maintaining ideal conditions. A thermometer that fixes the maximum and mini-

COOPERATIVE EXTENSION SERVICE
KANSAS STATE UNIVERSITY
MANHATTAN, KANSAS

Table 1. Commodity sensitivity to water loss.

Low	
Apples	Onions, dry
Cucumbers	Potatoes
Eggplant	Pumpkins
Garlic	Squash, Winter
Kiwi	
Melons	
Casabas, Crenshaws,	
Honeydews, Persians	
Average	
Asparagus	Pears
Avocados	Peas
Bananas	English
Beans, Snap	Snow
Brussel Sprouts	Peppers
Cabbage	Rhubarb
Carrots	Summer Squash
Cauliflower	Sweet Potatoes
Celery	Tomatoes
Chiroy	Topped
Corn, Sweet	Beets
Cranberries	Carrots
Endive	Celeriac
Escarole	Rutabagas
Leeks	Parsnips
Lettuce	Radishes
Nectarines	Turnips
Okra	Watermelon
High	
Apricots	Cantaloupe
Blackberries	Cherries
Broccolli	Chinese Vegetables
Bunched Greens	Grapes
Beets	Kohlrabi
Turnip	Mushrooms
Green Onions	Peaches
Mustard	Plums
Parsley	Raspberries
Radish	Strawberries
Spinach	
Chard	

mum temperatures could be an alternative for the recording thermometer.

These thermometers, however, indicate the air temperature in the facility and not the produce temperature. The most important temperature to control is the produce temperature. For this reason, it is necessary to check the pulp temperature of the produce. A comparison of the produce pulp temperature, the amount of time the produce has been in storage, and the thermostat setting can indicate to the operator if the thermostat needs resetting or the equipment needs adjusting.

The refrigerated facility should be equipped with more than one thermometer so they can be compared and recalibrated if necessary. To prevent undercooling or chill injury to the produce, and the resulting economic losses, readings of a sling psychrometer and settings of the thermostat and humidistat must be compared.

Sanitation

Every commodity requires special sanitation procedures. To prevent contamination of produce, the cleanliness and sanitation of the storage room and containers must be assured. The removal of condensation water, dirt, residuals, and trash from the storage room will help maintain produce quality and extend the life of the facility.

If mold is present on the walls, floor or containers, they must be disinfected with a solution of 0.50 percent sodium hypochlorite, prepared by mixing 1 gallon of chlorine bleach with 9 gallons of water. This solution must be applied where needed and the surface vigorously brushed. After cleaning with the bleach solution, it is best to leave the refrigerated storage open to the air to dry. Cleaning walls, floor and containers with this solution is a good pre- and post-season practice for every storage facility. If there are problems with decay, cleaning should be done more often, and handling practices should be changed to ensure a cleaner workplace.

Maintenance

Refrigerated storage for produce calls for regular inspection of refrigeration coils, fans, motors, compressor, ducts, doors, locks and hinges, lights, and any other piece of equipment. When inspecting the refrigeration coils, all dust and dirt must be removed. Adjustments should be made so there are no parts touching in the fans or other moving elements. Belts should have protective covers at all times; if a cover is not good, it must be fixed, but not removed. Any unusual noise must be inspected and repaired. The oil level in the compressor must be checked, changed, and maintained. Air infiltration through door seals

must be prevented and seals adjusted, repaired or replaced. The facility should be as airtight as possible.

Refrigerant pressure must be checked periodically. New regulations in terms of uses and types of refrigerant available require prevention of leakages and venting to the atmosphere (See Extension publication "Questions and Answers about Refrigerant Replacements," MF-975). A scheduled maintenance program is not difficult to set up and would help the facility operator prevent produce losses due to equipment failures.

Storage Facility Loading

Many factors determine how produce should be loaded into storage:

1. How long it will be stored.
2. The maturity or ripeness at harvest.
3. How it is packed.
4. Whether it was precooled.
5. The size and shape of the storage facility.
6. Mechanical or manual loading.

Standard practice is "first in, first out," whether the produce is stored a few hours or a few months. This ensures that each lot will be in storage a minimal time. In order to keep track of the storage time, containers should be clearly labeled on the ends with the date the produce entered storage. It is recommended that inventory cards for produce that goes into cold storage be kept in a safe place. These cards should list type of produce, quantity, harvest date, packing date, precooling method used, storage entry date, and special handling procedures.

For long-term storage, there are exceptions to the "first-in, first-out" rule. In apples, individual cultivars can have a different storage life, depending on the their maturity at harvest. At mid-maturity, apples have the longest storage life, while at early and late maturity, their storage life is shorter. To maximize the storage life of all fruit, careful management is required in loading the facility. Early season apples are sold first and stacked closer to the door or to the strorage entrance.

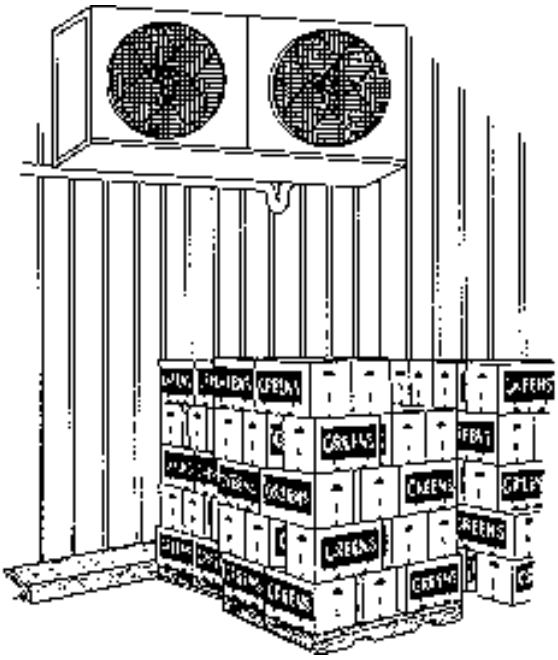
Mid-season apples should be stored in the back of the cooler. Late-season apples should be stacked in the middle and front, replacing the early apples as they are removed from storage. Late apples should be sold next and finally, the mid-season apples.

Container Design and Positioning

The container design and its positioning in the refrigerated storage facility must allow for air circulation within containers and around produce. Containers should not obstruct air circulation. There should be 6–8 inches between the containers and the walls, and at least 18 inches between containers and the ceiling. Guidelines painted on the floor and walls are helpful in getting containers and pallets spaced correctly.

The cold air must move freely not only around the containers but also around the produce. For that reason, produce containers should have from 5–8 percent of the lateral area open (perforated), and 3–5 percent of the the bottom area open. A properly designed container should be structurally sound and allow air circulation for the produce within. Figure 1 shows a recommended stacking pattern for produce in a refrigerated facility.

Figure 1. Proper container stacking in cold storage.



Boyette, M.D. et al., 1989. Design of Room Cooling Facilities: Structural and Energy Requirements, North Carolina Agricultural Extension Service AG-414-2).

Table 2. Ethylene-sensitive and ethylene-producing commodities.

Ethylene Sensitive	
Apples	Honeydew
Apricots	Juan Canary
Asparagus	Persian
Avocados	Watermelon
Bananas	Mustard Greens
Beans, Snap	Nectarines
Broccoli	Okra
Brussel Sprouts	Parsley
Cabbage	Peaches
Cabbage, Chinese	Peas
Carrots	English
Celery	Snow
Chard	Pears
Chiroy	Peppers
Collards	Persimmon
Cucumber	Plums
Caikon Radish	Potatoes, Late
Eggplant	Spinach
Endive	Summer Squash
Escarole	Sweet Potatoes
Greens, Leafy	Tomatillas
Kiwi	Tomatoes
Leeks	Turnip Greens
Lettuce	Watercress
Melons	
Cantaloupe	
Casaba	
Crenshaw	

Ethylene Producers	
Apples	Juan Canary
Apricots	Persian
Avocados	Santa Claus
Bananas	Mushrooms
Kiwi	Nectarines
Melons	Peaches
Cantaloupe	Pears
Casaba	Persimmon
Crenshaw	Plums
Honeydew	Tomatoes

Storage Compatibility

Precaution is necessary when storing different types of produce together. Warm-season produce needs temperatures of 45°F–55°F and will suffer chilling injury if stored at temperatures best for cool-season produce (32°–36°F). If cool-season produce is stored at higher temperatures, its storage life is shortened (See Extension publication "Storage Conditions," MF-978).

Commodities that are ethylene sensitive should not be mixed with ethylene producing ones. Table 2 presents a partial list of commodities and classifies them according to ethylene sensitive and ethylene producing. For example, apples are ethylene-producing so they should not be kept in the same storage with potatoes.

Odor compatibility is another concern. Many commodities produce odors that are easily absorbed by others. Table 3 lists these. If they are stored together, the grower may end up having "oniony" apples and "appley" cabbage.

Table 3. Odor compatibility between commodities.

Odor Producer	Odor Absorber
Apples, Pears,	Cabbage, Celery, Carrots, Onion, Potatoes
Leeks	Grapes
Onions, dry and green	Grapes, Mushrooms, Corn, Rhubarb, Apples, Pears, Celery
Carrots	Celery
Pepper	Beans, Avocados

Good management of storage facility operations is important to make it efficient and profitable. It is good to keep in mind that **produce quality cannot be improved; it can only be maintained.**

KSU KANSAS STATE UNIVERSITY

COOPERATIVE EXTENSION SERVICE, MANHATTAN, KANSAS

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