Postharvest Cooling and Handling of Apples

Freshness Facts

**Preferred cooling method:**
Forced air, hydrocooling
(room cooling acceptable)

**Optimum temperature:**
30°F to 40°F, depending on variety

**Freezing temperature:**
........... 29°F

**Optimum humidity:**
.......... 90 to 95%

**Storage life:**
........... 1 to 12 months

Producing a good crop of high-quality apples requires time, skill, and money. To gain full benefit from the crop, it is important to sustain the quality of the apples until they are delivered to the consumer. Proper postharvest cooling and careful attention to handling can prolong the time during which they remain fresh and marketable. Of course, even the best postharvest techniques can only maintain quality, not improve it.

This publication has been prepared to acquaint apple growers, shippers, and processors with energy-efficient handling and cooling methods.

Harvesting and Handling

Harvesting at the correct time is essential to the production of quality apples. To ensure maximum storage life, apples should be harvested when mature but not yet fully ripe or overripe. If harvested before they have matured, apples will have poor eating quality, will be more susceptible to storage disorders such as scald, cork spot, and bitter pit, and may not ripen properly. Ripe fruit should be avoided because it will continue to ripen in storage, rapidly becoming too soft and mealy for sale. Firmness and the level of soluble solids in the apple are good indicators of maturity to use in determining picking time.

Apples are very susceptible to bruising and other forms of mechanical damage and therefore should not be handled any more than necessary. Workers harvesting apples should be cautioned not to drop them or handle them roughly.
The effects of bruising and scuffing cannot be reversed. **Damage from rough handling will accelerate deterioration, reducing the value of the product.**

Apples are normally transported and stored in bulk boxes filled in the orchard. Each of these boxes holds about 600 pounds of fruit. Full boxes should not be allowed to sit for extended periods in direct sunlight nor for more than a few hours before cooling is started. They also should not be overfilled. When overfilled boxes are stacked, many apples throughout the box are bruised.

Bulk boxes represent a substantial investment for most growers and processors. They should be kept clean and in good repair and should be stored indoors when not in use. Most bulk boxes made from hardwood have enough open space between the individual boards in the bottom and sides to ensure adequate air circulation and water drainage. For some of the newer boxes built from plywood, it may be necessary to drill holes to improve air circulation. Five to 8 percent of the lateral surfaces and 3 to 5 percent of the bottom should be open. Better circulation is provided by many small, well- distributed holes than a few large ones.

### Chemical Treatments

Harvested apples are often treated with chemicals to inhibit storage disorders. Dip or spray treatments are commonly used to prevent scald and a group of disorders such as bitter pit that are associated with low calcium levels in the fruit. A good aqueous solution is made of 3 percent calcium chloride plus a scald inhibitor mixed with a surfactant and fungicides. See your county Agricultural Extension Service agent or consult publication AG-37, *Agricultural Chemicals for North Carolina Apples.*

A 0.1 percent concentration of surfactant is usually sufficient to provide complete wetting of the fruit, but more surfactant can be added if droplets begin to form on the apples. If the solution is applied to fruit in bulk boxes or bushel boxes, the calcium chloride may severely corrode the metal fasteners after a few seasons. Rinsing the empty containers with water will help alleviate this problem.

### Cooling and Storage

An apple continues to live and respire even after it is picked. Although respiration cannot be halted completely, the objective of postharvest cooling is to slow the process and thus increase storage life.

Even if apples are to be stored for only a short period, it is still very important that the field heat be removed from them as soon as possible. Rapid cooling will not injure the apples. They may be either hydrocooled or forced-air cooled without removing them from the bulk boxes. If they are hydrocooled, they can also be drenched with a scald inhibitor and fungicide in the same operation.

The higher the holding temperature, the greater the softening and respiration rate and the sooner the quality becomes unacceptable. Apples respire and degrade twice as fast at 40 F as at 32 F. At 60 F they will respire and degrade more than six times faster. The optimum storage temperature for apples depends on the variety, but all are within the range from 30 to 40 F. Most apple varieties grown in North Carolina are best stored at or near 32 F. Apples are moderately susceptible to freeze damage. Temperatures more than 1 or 2 degrees below freezing should be avoided.

All varieties require a relative humidity from 90 to 95 percent, which may require adding water vapor to the air in the storage room with one or more humidifiers. Maintaining the humidity within this range will reduce weight loss, but humidity near the saturation point (100 percent) will encourage the growth of bacteria and fungi. Some varieties of apples, such as Golden Delicious, can be held in plastic liners to keep the humidity at high levels.

Chilled apples that are suddenly transferred into warm air are likely to "sweat" - that is, water vapor in the air will condense on them. Sweating also occurs when the doors of a cold storage room are opened, allowing warm, moist air to enter. Sweating itself does not harm the fruit, but it causes wetting, which encourages the growth of fungi and bacteria. Chilled apples should not be allowed to warm and then be rechilled. To prevent sweating, allow chilled apples
to warm gradually inside the storage area, if possible, before bringing them out into the open air.

Since apples are stored longer than many other types of produce, it is essential that both the storage rooms and containers be clean and sanitary. Storage rooms should be thoroughly cleaned before they are filled. If molds are found to be growing in the storage room, the interior surfaces may be disinfected with a 0.25 percent solution of sodium hypochlorite (1 gallons of household chlorine bleach in 20 gallons of water) applied with a high-pressure washer. Surfaces should be allowed to air dry for several days.

Refrigeration coils, fans, and ducts should also be inspected and cleaned regularly. Refrigeration coils are especially likely to become clogged with dust and dirt that will substantially decrease their thermal efficiency. Thermostats and wet-bulb thermometers should be recalibrated from time to time with an accurate mercury thermometer. Humidistats can be checked for accuracy with a sling psychrometer. If possible, avoid positioning the sensing elements of controllers on exterior walls or on the ceiling. Instead, locate them in the open near the apples.

Remember that thermometers measure the temperature of the air and not the fruit. Fruit temperature will almost always be higher than air temperature and can be accurately measured only with several pulp thermometers inserted into the fruit in various locations throughout the room.

It is also a good idea to check all interior and exterior surfaces periodically for air leaks and damaged insulation. Door gaskets should be checked for a good seal by inserting a sheet of paper between the door and the frame, closing the door, and then attempting to pull the paper out. If it slips out easily, the gasket should be replaced or adjusted.

**Cooling Methods**

To reduce the cooling load and make the cooling process as energy efficient as possible, apple temperatures should be as low as possible before cooling begins. As much fruit as possible should be harvested during the cool hours of the day to reduce the cooling load. Allowing the apples to sit outside overnight in bulk boxes or trucks will generally not lower their temperature much and may actually cause the apple pulp temperature to increase.

Several methods are satisfactory for cooling apples. The graph on the next page shows relative cooling times for the three most common methods, described in the following sections. Whichever method is used, care should be taken to ensure that the apples cool quickly and thoroughly with the least use of labor and energy.

**Rate of temperature change for three cooling methods.**

**ROOM COOLING.** For many years apples have been cooled by storing them in refrigerated rooms. One of the least expensive methods for cooling apples, room cooling is accomplished by simply stacking bulk boxes inside a refrigerated room where the heat is allowed to dissipate slowly. This method requires a minimum of handling and labor. After cooling is completed, the facility can be used for short-term storage as well. Because cooling occurs over a period of several days or even longer, the electrical energy demand from the refrigeration system is relatively low. As
a result, a smaller, less expensive cooling system can be used, and the cost of electricity is lower than for more rapid cooling methods.

A disadvantage of this method is that it may take too long to cool the apples. Tests have shown that when apples in tightly stacked bin boxes are placed in a cold storage room, it may take from several days to more than two weeks for the apples to reach the same temperature as the air. In some cases the rate of heat transfer from apples in the middle of the box is insufficient to overcome the temperature rise produced by natural respiration. Without forced air movement, heat is lost only from the produce near the outside of the package. As a result, cooling is uneven and the cooling time may be too long to prevent serious deterioration and loss of quality.

If room cooling is used, be sure to allow adequate space for proper air circulation between rows of stacked bulk boxes. Do not stack rows of bulk boxes less than 6 inches apart nor less than 8 inches from an outside wall or ceiling. Properly directing the flow of air from the refrigeration coils can significantly increase the rate of cooling. For more information, refer to Agricultural Extension Service publication AG-414-2, *Design of Room Cooling Facilities: Structural and Energy Requirements*.

**FORCED-AIR COOLING.** It is becoming more common to use forced-air cooling to cool apples quickly. Forced-air cooling is accomplished by exposing the bulk boxes in a storage room to a higher air pressure on one side than the other. The unequal air pressure forces the cool air past the produce, greatly increasing the cooling rate. It is essential, therefore, that the apple containers have sufficient open space to allow for air movement. Depending on the fan capacity and the produce being cooled, forced-air cooling is from 4 to 10 times faster than room cooling.

Fan selection is critical. Not all fans can produce enough pressure to move air through the produce. Forced-air cooling fan systems can be designed to meet various cooling load requirements. They should be able to operate efficiently under relatively high static loads and to deliver about 2 to 3 cubic feet of air per minute for each pound of fruit. One sufficiently large fan can be used to cool as many as 50 standard bulk boxes of apples.

Several produce package arrangements are acceptable for forced-air cooling. In general, containers are arranged in a shell fashion. *Air is always pulled, never blown*, through no more than one layer of apple boxes. The faster the air moves past the apples, the faster the apples cool, but also the faster they lose water. Therefore, the forced-air cooling system should be operated only until the apple pulp temperature reaches 38o to 40 F. Forced-air cooling requires close monitoring of the relative humidity. If the relative humidity dips below the optimum 90 to 95 percent level for even a short period, substantial water loss and fruit shrinkage will occur.

Forced-air cooling lowers the temperature of the apples much more rapidly than room cooling. A larger refrigeration system may be required to handle the increased load, a fact to be considered when planning a new facility or when switching to forced-air cooling. Determinations need to be made on an individual basis. Even though the electrical energy demand is higher for forced-air cooling, a properly designed system can increase overall cooling efficiency by 15 to 25 percent because it takes less time to cool the fruit. For more information on forced-air cooling, refer to Agricultural Extension Service publication AG-414-3 *Maintaining the Quality of North Carolina Fresh Produce: Forced-Air Cooling*.
HYDROCOOLING. One of the quickest methods for removing field heat from apples is hydrocooling. This process is accomplished by flooding the fruit with large volumes of chilled water, normally in a hydrocooler designed specifically for that purpose. Washers used to apply fungicides and scald inhibitors usually cannot be successfully converted into hydrocoolers. It may be possible, however, to apply fungicides and scald inhibitors during hydrocooling. If a sufficiently large quantity of cold well or stream water is available, it can be used as a relatively low-cost source of hydrocooling water. Stream water should be used only after it has been checked for purity. For hydrocooling to be quick and efficient, the water must:

- Be kept at a temperature as near to 32 F as possible;
- Move past the apples as fast as possible;
- Contact all the apples.

It is not advisable to remove all the heat by hydrocooling alone. To save time and energy, apples are seldom hydrocooled to lower than 45 F. Slower methods such as forced-air or room cooling are usually employed to remove the balance of the heat. The rate at which apples may be hydrocooled depends on their size. In general, as the diameter of the apple doubles, so does the length of time required to cool it. This means that large apples need to be hydrocooled longer than small ones. However, pound for pound, the same amount of cooling capacity is required. An approximate rule of thumb to use in determining the size of the refrigeration systems needed for hydrocooling is to provide 5 tons of refrigeration capacity for each thousand pounds of apples cooled per hour.

For more information on hydrocoolers, see Agricultural Extension Service publication AG-414-4, *Maintaining the Quality of North Carolina Fresh Produce: Hydrocooling.*
Controlled Atmosphere Storage

In recent years, more and more late-season North Carolina apples have been placed in controlled atmosphere (CA) storage. With this storage method it is more important than ever that the fruit be carefully handled and promptly cooled to remove field heat. The faster that the optimum low storage temperature is attained, the sooner controlled atmosphere conditions can be established.

Controlled atmosphere storage prolongs marketable life by lowering the oxygen concentration and increasing the carbon dioxide concentration in the storage atmosphere. CA storage facilities are specially constructed, airtight cold storage rooms with auxiliary equipment to monitor and maintain specific gaseous atmospheres. Oxygen concentrations from 2 to 3 percent and carbon dioxide concentrations from 1 to 5 percent below that achieved by low temperatures alone. These concentrations of oxygen and carbon dioxide also reduce the ability of the ethylene produced by ripening apples to further accelerate fruit ripening.

Although ethylene activity is reduced in CA storage, it has taken many years to recognize that ethylene levels of more than 1,000 parts per million, which commonly accumulate in conventional CA storage facilities, can still have a detrimental effect on storage life. Oxygen, carbon dioxide, and ethylene levels should be monitored daily and controlled within narrow limits. Concentrations of carbon dioxide greater than 10 percent can injure apples, whereas oxygen concentrations of less than 1 percent can cause storage disorders.

Recommendations for controlled atmosphere storage conditions are changing as a result of ongoing research. Optimum conditions depend on several factors, including variety and growing conditions. The current recommendations for many apple varieties is an atmosphere containing 5 percent carbon dioxide and 3 percent oxygen at a temperature of 32 F. However, these recommendations are being reexamined and replaced in some areas by recommended concentrations of 1.5 percent oxygen and less than 0.5 percent carbon dioxide. Specially selected and treated apples can be commercially stored for more than 10 months in these new controlled environments.

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