APPLE STORAGE

Pre- and Post Harvest

STOREX
CONTROLLED ATMOSPHERE

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References

Keith Thompson: Fruit and Vegetables Harvesting

Mike Boyette
Philip Morris Professor
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L. G. Wilson
Ed Estes

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Top Countries Production of Apples (1980-2020)

China is the top country by apples production in the world. As of 2020, apples production in China was 40.5 million tones that accounts for 63.63% of the world's apples production. The top 5 countries (others are the United States of America, Turkey, India, and Russia) account for 83.48% of it.

Growing conditions

Apples grow best in full sun. But specifically in more a hot climate or hot summer there could be a danger of so called sun burning. Whe apple trees are planted in shadow the fruit quality and production could be limited Apples grow best in well-drained loamy soil, although they will grow in more sandy soil or in soil with some clay. Important is a well-balanced nutrition of the soil for production, taste and post-harvest quality, normally apples grow best in a neutral soil pH of 6.0 to 7.0.

Depended to the growing area and climate water supply is important during the growing period in countries/areas where night frost is a common situation. Hail protection with so called hail nets are common in same areas.

For optimal post-harvest quality are regular calcium and fungicide sprays necessary to avoid physiological and fungal diseases.

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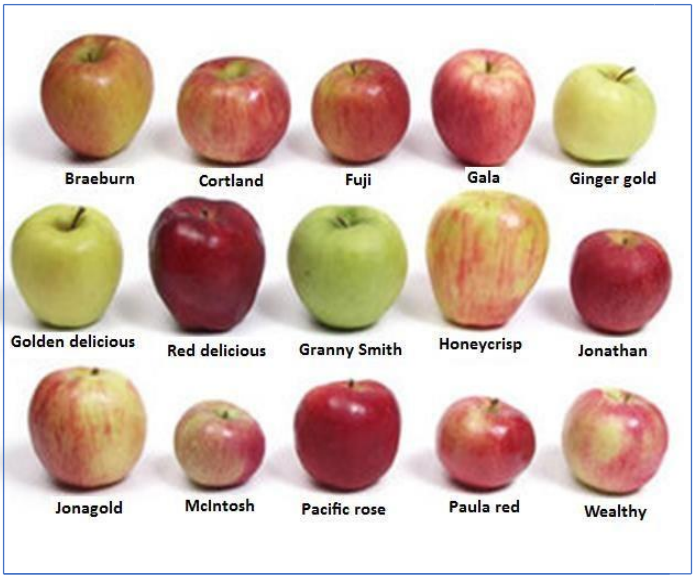
Climate

The apple is a hardy, deciduous woody perennial tree that grows in all temperate zones. Apples grow best where there is cold in winter, moderate summer temperatures, and medium to high humidity. There are apples for fresh eating, juice production, some for cooking, and some for preserving and juice prodcution.

An example of dominant varieties is indicated below. But some other important varieties are Pink Lady, Kanzi and Elstar. Climate, soil type, availability of water and market strategy are very decisive for the ultimate choice of varieties Apple trees are grafted on specific rootstocks which gave the ability of a fast and high production of the apple tree. Worldwide the type EM IX9 is most commonly used.



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Harvest time

Apple season is around the month of September/ October for the Northern hemisphere For the Southern hemisphere the harvest time is March/ April depending to the different varieties

While peak harvest generally occurs in September/October in the northern hemisphere for most of the apples and coming into the stores, there are some cultivars which are ready as early as late July and others that aren't ripe until October or even November. Normally early ripened varieties have a shorter storability.
The harvest time is very important for the storage quality of apples. Apples intended for a long storage period should be harvested earlier. But not too early for a good taste after storage.

Harvest method

The best way to pick an apple is **to cup it in the palm of your hand**, lift it up then give it a gentle twist until it comes away. Each apple should detach complete with its stalk. **There are no machines capable of harvesting an apple**. For the different bi-color apples in many cases it is necessary to pick the apples at different times based on the blush color.

Post-harvest Handling

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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. There are several methods to determine the optimal harvest date like firmness, soluble solids- and starch content or in combination the so called Streif index. But generally there is for each variety a specific time between the full bllom stage and the first moment of picking and could be finetuned by the mentioned measurements.
But also important is the size of the fruits for a good production/ha and the quality for the market.
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.

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, especially also storage rot and will reduce the value of the product.

Apples are normally transported and stored in bulk boxes (bins) filled in the orchard. Most bulky 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. Wooden bins are common used in the Netherlands but there is a serious tendency for the use of synthetic bins. In many other countries synthetic boxes are widely used (Italy)

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.

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Post-harvest diseases

As already mentioned we distinguish 2 types of post-harvest diseases namely fungal diseases and physiological diseases

Fungal diseases

Gray Mold

Gray mold (*Botrytis cinerea*) is a common post-harvest disease on apples worldwide. This fungus has the ability to spread from decayed fruit to surrounding healthy fruit through fruit-to-fruit contact during storage.

Gray mold (**Botrytis cinerea**) originating from infection at stem or stem bowl; gray spore masses may be visible at the diseased area under high humidity.

Gray mold commonly originating from infection of wounds on the fruit; decayed area brown, spongy to firm; decayed tissue may become soft at a very advanced stage.

Blue mold

Blue mold (primarily *Penicillium expansum*) is a very common post-harvest fungal disease on apples worldwide. This disease is of economic concern to both the fresh-fruit industry and the

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fruit-processing industry because some strains produce the mycotoxin patulin, which can rise to unacceptable levels affecting the quality of apple juice.

Blue mold originating from infection of wound on fruit; decayed area brown, soft and watery, with a sharp margin; blue-green spore masses visible.

Blue mold originating from infection of wound on a Granny Smith fruit; spore masses formed at the infection site.

Speck Rot

Speck rot (*Phacidiopycnis washingtonensis*) is a postharvest disease of apples. Fruit infection originates in the orchard. The source of the inoculum comes from dead or diseased plant tissue of the 'Manchurian' crabapple pollinizers in affected orchards.

Speck-rot as a Stem-end rot symptoms on a Red Delicious apple after storage.

Speck-rot as a Calyx-end rot symptoms on a Red Delicious apple after storage.

Sphaeropsis Rot

Sphaeropsis rot (*Sphaeropsis pyriputrescens*) is a newly reported post-harvest disease of apples and pears. First discovered in D'Angou pears, but was later determined to cause worse problems in apples.

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Sphaeropsis rot originating from a stem infection on a Golden Delicious apple; decayed area brown, firm.


Sphaeropsis rot originating from a calyx infection on a Red Delicious fruit.


Sphaeropsis rot originating from a calyx infection on a Fuji apple.


Internal decayed flesh is light tan to brown; strong distinct "bandage-like" odor commonly associated with Sphaeropsis rot, particularly when fruit is cut.

Mucor Rot

Mucor rot can cause significant losses of fruit, but is generally not a major problem, when good harvest management and water sanitation practices at packing are implemented.


Mucor rot (Mucor piriformis) on a Golden Delicious fruit showing very soft, juicy, decayed tissue with a sharp margin. Mucor rot decay often has a sweet odor.

Powedery Mildew

Powedery Mildew may be found on apple buds, blossoms ,leaves, twigs and fruit. When fruits are infected, the surface may become russetted or discolored, and sometimes dwarfed. Fruit is most susceptible during the period around petal fall.

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Powdery mildew may result in a net-like scarring called russeting.

Bull's eyes Rot

Bull's eye rot occurs on Pacific Northwest apples, particularly on apples from orchards with perennial canker problems on trees. Bull's eye rot also occurs in Europe and some other fruit-growing regions.

Bull's eye rot on a Golden Delicious fruit; lesion is flat to slightly sunken, brown to dark brown with lighter brown to tan in the center, resembling a Bull's eye.

Fungal diseases more common in North western Europe

Phytophthora, Nectria and Monilia are more common in the orchard

Storage rot:

Neofabraea (Gloeosporium) - lenticel rot

Cadophora (Phialophora) – fisheye rot

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Fibulorhizoctonia –lenticelspot

Physiological diseases

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Post-harvest 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 down 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 to stop the ripening and moisture loss . Rapid cooling will normally not injure the apples but if the cooling temperature is too low it can lead to freezing damage. 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.

Preferred cooling method:	Forced air, hydrocooling (room cooling acceptable)
Optimum temperature:	-1,1 ºC to 4,4 ºC depending on variety
Freezing temperature:	-1,6 ºC depending to variety and soluble solids content
Optimum humidity:	90 to 95%

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Storage life:	1 to 12 months

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 fungi and physiological diseasesSome varieties of apples, such as Golden Delicious, can be held in plastic liners to keep the humidity at high levels.

A right stacking the bins in the cooling room is necessary for a a good air circulation resulting in a good temperature distribution in the cooling room.

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. Not only storage rooms have to be cleaned but also storage bins

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. Calibration of temperature sensors with melting ice is the best method.. 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.

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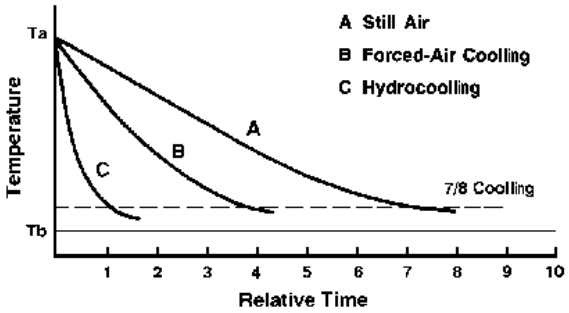
Cooling Methods



- ✓ 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. A disadvantage of this method is that it may take too long to cool the apples.
- ✓ FORCED-AIR COOLING.
  It is becoming more common to use forced-air cooling to pre-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. Fan selection is critical. Not all fans can produce enough pressure to move air through the produce.
- ✓ 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.

For hydrocooling to be quick and efficient, the water must:

- Be kept at a temperature as near to 0 °C as possible;
- Move past the apples as fast as possible;
- Contact all the apples.

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Controlled Atmosphere Storage (CA)

In recent years, more and more late-season 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.

Specifically a lower oxygen concentration in the storage room delayed the repiration of the fruits. In the respiration process are sugars in the used as a substrate and will is converted into carbon dioxide and water. This process releases heat, which is then dissipated through the cooling. The heat production is always proportional to the carbon dioxide production. Also the lower oxygen and higher CO2 content in the store reduced the sensitivity and production on of ethylene. This gaseous hormone is produced by the apple fruit and stimulate the ripening.

CA storage facilities are specially constructed, airtight cold storage rooms with auxiliary equipment to monitor and maintain specific gaseous atmospheres.

Oxygen concentrations from 1 to 3 percent and carbon dioxide concentrations from 1 to 5 percent below that achieved by low temperatures alone.

Optimum conditions depend on several factors, including variety and growing conditions. The current recommendations for many apple varieties is an atmosphere containing 1-5 percent carbon dioxide and 1-2 percent oxygen at a temperature of 1 oC.

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Specially selected and treated apples can be commercially stored for more than 10 months in these new controlled environments.

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