

mended storage temperature as soon as possible. Since modification of the atmospheric composition is not possible until the room is filled and sealed, it is desirable that any one room be filled within a few days, if the greatest benefit is to be obtained. Once the room is sealed, the oxygen content of the atmosphere will be reduced by fruit respiration, and the CO_2 content controlled by scrubbing. Usually a lye solution is used during the initial period, but water scrubbing is feasible thereafter. Sometimes flushing with nitrogen gas is used as an initial means of lowering the O_2 content to about 10 percent. Table 3 indicates approximate temperature and atmospheric requirements for controlled atmosphere storage of several varieties. Since these may vary from region to region, more precise requirements should be determined from authorities within a region.

Table 3 Requirements for Controlled Atmosphere Storage of Apples

Variety	% CO_2	% O_2	Temperature—F
McIntosh	2-5	2-3	38
Delicious and Golden Delicious	1.5-3	2.5-3	30-32
Baldwin, Jonathan, Rome Beauty, Stayman Winesap	1-5	2-3	30-32
Yellow Newtown	5-8	2-3	38-40

Apples packed in boxes with polyethylene liners sealed after packing have been used as a means of creating a modified atmosphere. In many instances, it is possible to closely approach the atmospheric composition of a controlled atmosphere room, because of differential permeability of the film to O_2 and CO_2 . Unfortunately, great variability exists in the composition of the atmospheres in different containers, so that no dependence can be placed on improved storage life. Also when the apples are marketed, the film liner must be opened in some way to avoid possible harmful effects of low O_2 or high CO_2 as the temperature rises. Although film liners seem impractical as a means of altering atmospheric O_2 and CO_2 , unsealed film liners have proven very helpful in controlling excessive moisture loss from varieties such as Golden Delicious. Desiccation, although often severe in cold storage warehouses, should not be of sufficient concern to justify film liners for fruit in controlled atmosphere rooms.

Storage Disorders

Storage troubles of apples may be caused either by invasion by microorganisms or by the fruit's own physiological processes. Rots caused primarily by fungi are covered in Chapter 51. Physiological disorders although sometimes resembling rots are related to biochemical processes within the fruit that are not understood. Susceptibility to such disorders is often a variety characteristic, but may be influenced by cultural and climatic factors and storage temperature. Only the most important storage disorders will be discussed here. For further information, see Chapter 51.

Scald is the most serious disorder affecting apples in storage. It first appears as traces of light mottling on the greener surfaces of the fruit. Darkening becomes more severe with elapsed time and will extend to red colored surfaces. Ordinarily, scald affects only the skin, but in severe cases may extend into the flesh. It develops rapidly at warm temperatures so that apples

with light scald in storage may be severely scalded during marketing.

Fruits harvested in the early mature stage are more susceptible than those harvested later. Any delay in cooling the fruit after harvest will aggravate the problem. Susceptibility varies greatly with variety but most varieties can develop the trouble. Arkansas, Stayman Winesap, Grimes Golden, Rome Beauty and Rhode Island Greening are especially susceptible varieties. Variations in the severity of scald from season to season indicate a strong climatic effect on its development. The problem seems to be associated with volatile organic materials produced by the fruit, but removal of accumulations in the surrounding atmosphere does not necessarily give control. The use of ventilation, air purification, oiled wraps, or shredded oil paper have not given the desired control.

Experimental results in recent years have shown diphenylamine to be very effective in controlling apple scald when used as a fruit dip at a concentration of 1000 to 2000 ppm. Representations have been made to the Food and Drug Administration petitioning for approval of the use of this material by the apple industry.

Bitter pit is characterized by small sunken spots on the fruit surface. They are most prevalent near the blossom end and although usually near the surface, they may be found deep in the flesh as well. At first, they show as small water soaked areas that shrink and turn brown as water is lost from them, and end up as brown localized areas of dead tissue. Baldwin, Rhode Island Greening, York Imperial, Yellow Newtown, Delicious and Gravenstein are some of the varieties most susceptible. The problem is most severe when apples are picked on the immature side, and may be worse on light crop years when fruits are of large size.

Prompt storage at a low temperature and high relative humidity and early marketing are means of minimizing losses. The cause of bitter pit is not known but recent studies in Australia and the United States show a possible connection with calcium and magnesium nutrition.

Soft scald is characterized by dark brown blister-like areas of irregular pattern extending over the fruit. In its earliest stages, it may resemble apple scald, but the two seem not related. The affected areas are soft, slightly sunken and well defined. The skin and outer portion of the flesh is involved. Although the exact cause of soft scald is not known, it is known that a combination of circumstances influence its appearance. It is most likely to occur on apples harvested at an advanced stage of maturity and is aggravated by delayed storage and storage at temperatures of 30 to 32 F. If apples are harvested at an early stage of maturity, storage at 30 to 32 F has been successful, but late harvested apples of susceptible varieties may require elevated storage temperatures of 34 to 36 F. Jonathan and Rome Beauty are highly susceptible varieties followed by Cortland, Winter Bananas, Golden Delicious, Northwestern Greening and Wealthy.

Internal browning and brown core are two other disorders that are forms of chilling injury. The former is associated with the Yellow Newtown apple grown in the coastal area of California and is characterized by brownish streaks radiating into the flesh from the core. Susceptibility varies between years and orchards. It can be controlled by storage at 40 F, but because of the short storage life at this temperature, a compromise temperature of about 36 F is ordinarily used except in controlled atmosphere storage. Brown core is found primarily in McIntosh apples in the northeastern states, but may also be found in Rhode Island Greening, Baldwin and others. Its appearance and control are similar to that described for internal browning. The best means of control of both disorders is controlled atmosphere storage at 38 to 40 F.

PEARS

Although pear production in the United States is less than 5 percent of that of apples, it is a substantial enterprise, particularly in the Pacific Coast states where more than 85 percent of the pears are produced. Bartlett is the most important variety, exceeding the total of all others by a wide margin. Other Pacific Coast varieties are Hardy, Comice, Anjou, Bosc and Winter Nela. The eastern states are limited in varieties because of the severe problem of fire blight and grow primarily the Kieffer variety. Although most Bartlett and Hardy, and many Winter Nela, pears are canned, cold storage prior to ripening for canning is the usual procedure. A 10-day to 2-week cold storage period of Bartlett pears is commonly used by many canners because it improves the uniformity of ripening. Substantial quantities may also be stored for extended periods approaching maximum storage life of the variety in order to better utilize processing facilities.

Maturity at harvest has a very important bearing upon subsequent storage life, as it does in the apple. However, unlike the apple, pears do not ripen on the tree, nor do most varieties ripen at cold storage temperatures. If harvested too early, they are subject to excessive water loss in storage. If permitted to become over-mature on the tree, their storage life is shortened and they may be highly susceptible to scald and core breakdown. Flesh firmness as measured by a pressure tester is perhaps the best measure of potential storage life of pears from any single orchard. For the Bartlett variety, a firmness of 19 to 17 lb may indicate best storage quality. If average firmness is as low as 15 lb, individual pears may be sufficiently advanced in maturity that storage for any prolonged period is hazardous. Pressure test information for each lot of pears going into storage may be very helpful to the owner of the fruit and the cold storage operator in determining the storage program.

Careful harvesting and handling practices are essential to good storage quality. Bruises and skin breaks are likely sites for infection by microorganisms. Varieties such as Winter Nela and Bosc are highly susceptible to stem punctures caused by stems broken in the harvesting operation. Comice is also easily damaged because of its very tender skin. Many pears are now being harvested into pallet bins holding about 1000 lb of fruit. These bins create no special problems, but care in dumping fruit from a picking container is highly important in keeping mechanical damage to a minimum.

For best storage quality rapid cooling after harvest is essential. Pears ripen rapidly at elevated temperatures but the early stages of ripening are obscured by failure to soften or change color. Therefore, a considerable part of the storage life may be used up without a visible change being observed. Where cold storage rooms do not have adequate refrigeration and ventilation capacity for the rapid cooling of hot fruit, precooling should be considered prior to placing in the storage room. Cooling in special rooms constructed for this purpose or hydrocooling has proven effective. When warm fruit is placed in a room with cold fruit, the loading arrangements should be such that the temperature of the cold fruit is not elevated. The recommended storage temperature for pears is 30 to 31 F. Recommendations as low as 29 F have been made, but the risk of freezing injury is great unless the temperature in all parts of the room can be controlled precisely. Pears are not subject to chilling injury as are some apple varieties, so elevated storage temperatures are not required. The stacking arrangement in the cold storage room recommended for apples also applies for pears.

As pears lose water more readily than do most apple varieties, it is important to maintain good humidity conditions in

Table 4 Storage Life of Pear Varieties at 30-31 F

Variety	Storage Life, Months
Bartlett, Comice, Hardy and Kieffer	2-3
Bosc	3-4
Anjou	4-6
Winter Nela	6-7

the storage room. For long storage, 90 to 95 percent relative humidity is recommended. Perforated film box liners have given excellent results in moisture loss control.

The approximate storage life of pears at 30 to 31 F is shown in Table 4. These values assume an additional time for transportation and marketing. If Bartlett pears for canning are harvested at the best stage of maturity and cooled quickly to 30 to 31 F, their safe storage life may be as long as 4 months, since marketing involves only ripening for processing. However, it should be noted that quality deteriorates during storage, particularly as the maximum storage life is approached.

After removal from storage, best dessert quality is attained if pears are ripened in a controlled temperature range of about 60 to 70 F. This applies to canner fruit as well as that for fresh use. Ripening at 68 to 72 F is more practical for canner fruit than lower temperatures because the shorter time involved reduces overhead costs with no measurable differences in quality.

Controlled atmosphere storage of pears looks promising based upon experimental studies. The storage life of Bartlett pears can be extended to 5-6 months for good storage quality fruit in an atmosphere containing about 5 percent CO_2 and 2.5 percent O_2 at 32 F. Perhaps this could be further extended if the temperature were 30 F. Not quite as effective, but showing good results, were atmospheres of 1 to 2.5 percent O_2 with no CO_2 involved.

Commercial storage of pears in controlled atmosphere has not been considered as necessary as in the apple industry. Since no low temperature disorders have been recognized, there has not been an important need for further extension of the storage life. This has been particularly true of the Bartlett variety where surpluses for fresh use have gone into processing. If controlled atmosphere storage were used on any important scale with Bartlett, the fall and winter varieties would probably face a considerable market adjustment.

Polyethylene film liners, while unneeded to modified atmospheres because of great variability, have proven useful in extending the storage and market life of pears by reducing water loss to an insignificant level.

Storage Disorders

The principle storage disorders in pears are (1) core breakdown, (2) failure to ripen and scald, and (3) fungous rots, particularly gray mold (*Botrytis cinerea*).

Core breakdown is associated with overmaturity at harvest. This problem has become more important since growth regulator sprays have been used to keep pears from dropping during the harvest season. Pressure test information of late harvested fruit is helpful in locating lots susceptible to core breakdown. Records are important also relative to time lapse between harvest and storage, since pressure test information may not be a true measure of relative storage quality where storage is delayed. Pear color, particularly in California Bartlett, is a very poor measure of potential storage life because of great variability between pears from different districts.