

Pear scald is associated with pears that have been stored too long and have lost their capacity to ripen. It is not related to apple scald and has not been controlled by any supplemental treatments. The problem develops progressively earlier as the temperature is raised progressively above 30 F. Yellowing of the fruit is the principal storage symptom. Bartlett and Bosc are the two most susceptible varieties. Anjou and Comice may not develop scald but do lose their capacity to ripen. Periodic inspection is desirable to be sure that green varieties of pears be removed from storage before yellowing progresses to the danger point. Yellow pears may show no scald in storage, but upon removal to a ripening temperature, scald may develop. If pear scald does show in storage, the pears have been kept too long and are probably worthless. The Anjou variety has a scald similar in appearance and response to apple scald. Oiled wraps are used as a means of control.

Gray mold rot caused by *Botrytis cinerea* will grow at cold storage temperatures and can be a serious rot to long stored winter varieties such as Anjou and Winter Nelis. If no control measures are used, nesting may occur by the spread of the disease from one fruit to another by contact. The most effective control is by the use of copper-treated fruit wraps to prevent the spread of the disease from one fruit to another.

GRAPES

Grapes are widely grown in the United States, but of the 3 million tons produced annually, over 90 percent are grown in California. This state produces grapes of the *Vitis vinifera* species almost exclusively (about 2½ million tons annually) which accounts for over 98 percent of the production of this European type. Of this amount, 500 to 600 thousand tons are utilized as table fruit.

These statistics become particularly significant from a pre-cooling and storage standpoint since many varieties of the *Vitis* species can withstand the rigors of handling, transport and storage required of table grapes for wide distribution over a long marketing period. Almost all of this fruit is precooled and much of it stored for varying periods before consumption. On the other hand, for fresh use, the fruit of the species *Vitis labrusca* (American or Eastern type), is largely limited to local market distribution.

Grapes live relatively slowly, and should be mature before harvest because they do all of their ripening on the vine. Mature here means that stage of physiological development when the fruit appears pleasing to the eye and can be eaten with satisfaction. However, grapes should not be over-ripe as this predisposes the fruit to two serious post harvest disorders: (1) weakening of the stem attachment in some varieties, such as Thompson seedless, which causes the berries to separate from the pedicel attachment, and (2) progressively greater susceptibility to the invasion of decay organisms. Danger of decay is also enhanced if the fruit has been exposed to rain or excessively damp weather before harvest—conditions favorable for the inception of field infections by *Botrytis cinerea* Pers that result in a higher decay potential in the fruit.

Storage Environment

Recommended storage temperatures for *Vitis vinifera* (European or California type) grapes are 30 to 31 F. The relative humidity should be from 87 to 92 percent. Although temperatures as low as 28 F have not been injurious to well-matured fruit of some varieties, other varieties of low sugar content have been reported damaged by exposure to 29 F. Storage plants in California that specialize in storing grapes should provide uniform air circulation in the rooms. Some

have precooling rooms where the grapes are cooled to 36 to 40 F in 6-24 hr before they are placed in storage. In some plants all of the cooling is done in the storage rooms, but only a few have sufficient air movement to cool the fruit as quickly as desired. Experience has indicated that approximately 4000 to 6000 cfm per carload of fruit is required in rooms used for precooling. After the fruit has been precooled the air velocity should be reduced to a rate which will maintain uniform temperatures throughout the room (no more than 10 to 20 fpm in the channels between the lugs). Ventilation is required only to exhaust sulfur dioxide and air following fumigation.

The normal change that takes place in grapes in storage involves chiefly loss of water. The first noticeable effect is drying and browning of stems and pedicels. This effect becomes evident with a loss of only 1 to 2 percent of the weight of the fruit. When the loss reaches 3 to 5 percent, the fruit loses its turgidity and softens.

Grapes are particularly vulnerable to the drying effect of the air because of their relatively large surface to volume ratio, especially that of the stems. Stem condition is very important as a quality factor and is an excellent indicator of the past treatment of the fruit. Emphasis should be placed on maintaining stems in a green fresh condition both from an appearance standpoint and because stems become brittle when dry and are apt to break. The stem of a grape cluster, unlike that of other fruits, is the handle by which the fruit is carried so if breakage occurs (shatter) the fruit is lost for all practical purposes even though the shattered berries may still be in excellent condition. Therefore careful attention should be paid to those operations which will minimize moisture loss, including prompt and rapid precooling, and reduced air velocity after the field heat is removed, with as low a vapor pressure deficit as possible.

Maintaining a relative humidity of 90 percent in grape storages is often a problem especially at the beginning of the storage season when the rooms are being filled with dry lugs. Each lug will absorb from ¼ to ¾ lb of water over a period of a month, and unless moisture is supplied to the room this water must come from the fruit. An effective method of supplying water to minimize shrinkage is by spray humidification. A fine spray can be obtained which will vaporize readily even at 31 F with proper balance of water and air pressure using the correct type of nozzle.

The color of red and blue varieties gradually turns darker in storage. White varieties, such as Othello and Thompson seedless eventually turn brown, but this is not due to chilling injury.

Fumigation

It is necessary to fumigate grapes with sulfur dioxide after they are packed to prevent or retard the spread of decay. The treatment surface sterilizes the fruit, particularly wounds made as a result of handling.

It has become common practice to accumulate packed fruit in the precooling during the daily packing and fumigate the fruit in the evening. In this way precooling is not delayed and the fumigation can be done after most of the working crew has left. Thus this initial treatment often becomes the responsibility of the refrigeration personnel.

Other commodities should not be treated with the grapes or even held where the fumigant can reach them, as most of them are very easily injured by the gas. Because grapes also can be injured, they should be exposed to only the minimum quantity of sulfur dioxide required, which will depend upon: (1) the decay potential and condition of the fruit, (2) the amount of fruit to be treated, (3) the type of containers and packing materials, (4) the air velocity and uniformity of air

Storage of Apples, Pears, Grapes, and Bananas

distribution, (5) size of the room, and (6) losses from leakage and sorption on walls. Under favorable conditions a basic sulfur dioxide concentration of 0.5 percent by volume for 20 min is adequate. To keep the concentration at this level, the absorptive capacity of the lugs and fruit as well as their volume must be considered. The dosage can then be calculated from the following equation:

$$W_s = \frac{A \times B}{E} + (C \times D) \quad (2)$$

- where
 W_s = quantity of sulfur dioxide required, pounds.
 A = concentration of sulfur dioxide to be used, percent.
 B = free volume of room (total volume minus ¼ cu ft for each 28 lb lug), cubic feet.
 C = number of carloads of 28 lb lugs (1000 lugs per car).
 D = quantity of sulfur dioxide absorbed by each carload, pounds.
 E = volume occupied by 1 lb of sulfur dioxide gas at 32 F (5.5 cu ft).

One pound per car for factor D is adequate when the fruit is sound, air velocities are maintained past both sides of every lug at 50 fpm or more (75 to 100 fpm if the fruit has curtains over it or the clusters are wrapped), and the room is relatively gas-tight with no opportunity for the fumigant to be lost on refrigeration surfaces. Conversely a higher value of 2 lb per car would be used when these factors are less favorable.

It is necessary to refumigate grapes at weekly intervals in storage to prevent field infections by *Botrytis cinerea* from spreading to adjacent sound fruit. The amount of sulfur dioxide needed depends upon the same factors as for the initial treatment. However, a basic concentration of 0.1 percent for 30 min is adequate. Also, an absorptive factor in the range of ¼ to ¾ lb of sulfur dioxide per carload should be used.

The gas must be distributed quickly and evenly to all parts of the room. This can be done by spacing special nozzles 6 ft apart along the ceiling in the room. If the outlet is placed in front of a fan, there should be one for each fan, or the air from the single fan should be distributed evenly across the room through a plenum.

The same requirements of proper container alignment, adequate fan capacity, and uniform air distribution apply here as for the initial treatment. The lugs should be oriented parallel to the air flow and channels ¾ to 1½ in. should be provided on both sides and kept unobstructed completely through the stacked fruit. The fruit should be stacked as near the ceiling as possible or drop curtains provided over the fruit to prevent the air from passing over the fruit and thus bypassing the channels. The working distance between pallets should be kept to an absolute minimum to avoid wide channels, and no holes should be left in the wall of lugs when pallets of fruit are withdrawn.

The hot gas method of delivery may be used if the room requires 10 lb or less of gas. The steel cylinder containing the liquid sulfur dioxide is first connected to the gas inlet and the valve then opened. The cylinder should be then placed in a pot of boiling water to vaporize the fumigant as rapidly as possible. Only about 1 lb per minute can be delivered this way.

For larger quantities the cold gas method is usually more practical. A riser extends to the bottom of the cylinder through which the liquid sulfur dioxide rises and flows through the delivery line. Every precaution must be taken that there is adequate air volume and velocity to vaporize and mix the gas thoroughly with the air before it reaches the fruit. Up to 100 lb of the material can be released in 2 to 3 min.

After 30 min the room should be purged of the gas—laden

air until personnel can remain in the space without excessive discomfort.

In plants that are devoted entirely to the storage of grapes, the gas is sometimes released into the air ducts of the plant, thus utilizing the air cooling system for even distribution and good circulation in the rooms. If a brine spray system of refrigerating the air is employed, a bypass should be installed around the spray chamber so that the gas does not come into contact with the wet metal surfaces, since it readily forms a corrosive acid in combination with water. For the same reason sulfur dioxide should be cleared from the air of the rooms before the damper is turned and the air is circulated through the spray. It is advisable to check the acidity of the brine frequently to guard against corrosion.

Sulfur dioxide has certain properties that demand care in its use as a fumigant in cold storage plants. The concentrations recommended for the fumigation of grapes in storage can cause respiratory spasms and death if the victim cannot escape from the fumes. When working in even weak concentrations of sulfur dioxide, one should wear goggles to protect against injury to the eyes, and a gas mask fitted with canister for acid gases (not the usual canister for ammonia gas) should be used. Concentrations as low as 30 to 40 ppm can be detected by smell. It requires several times these concentrations to cause discomfort.

A second property of sulfur dioxide which cannot be over-emphasized is its injurious effects on other produce. For this reason, care must be taken that only grapes are stored in the room that is to be fumigated, and also that there are no leaks through wall or halls to adjacent rooms containing other produce.

A third property of sulfur dioxide that demands emphasis is its corrosive action on metals, particularly iron and zinc, which are commonly used in the construction and coating of coils, brine spray chambers, etc., in cold storage plants. Use of acid-resistant paints on exposed metals is helpful in reducing this corrosive action.

Periodical inspection of the fruit to see whether the sulfur dioxide gas is reaching the center of the stacks or whether some grapes are being over-treated is recommended. If the pedicels and stems retain a yellow or green color and if broken berries show no mold and appear to be dried or seared, the gas has reached the fruit in question and is having the desired effect. When serious bleaching is observed on unbroken grapes, the concentration has been too high or the exposure too long, and there should be better distribution of the gas, lower concentration, or shorter fumigation periods.

The most common cause of loss in grape storage is gray mold rot (*Botrytis* sp.). Prompt cooling, constant low temperatures of 30 to 31 F and regular fumigation in storage are the chief aids in controlling it. Rains or foggy weather during harvest are the important contributing factors in starting gray mold infections. When inclement weather gives reason to question the storage quality of grapes, the inspection of incoming lots of fruit is a wise precaution against unjustified storage claims. Often incipient infections of gray mold, called *ship skins*, can be found on grapes several days after they have been wet by rain.

Fumigation with sulfur dioxide in storage prevents new infections of the fruit but does not control infections that have already occurred in the vineyard. Frequently these have not developed far enough to be detected at harvest and consequently are the primary cause of decay in storage. A method of measuring field infection has been developed and used to forecast decay during storage. The forecast indicates the lots that are sound and can be safely stored and also those that are likely to decay and should be marketed early. Pre-