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Handling Apples from Tree to Table

By

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INTRODUCTION

The condition of apples offered for sale by grocers and other retail vendors is sometimes disappointing to the purchaser. To the extent that the demand for apples is influenced thereby it affects the market price of the fruit and the returns to the grower. The factors of condition that are most important are the stage of ripeness of the fruit and its freedom from decay, bruising, and other injuries.

Growers who invest a season's work in pruning, fertilizing, spraying, and cultivating their orchards with all the care and expense necessary to produce a clean crop of high-quality fruit cannot help being disturbed by the poor condition of apples offered by retailers, which also constitutes one of the greatest handicaps to success of organizations established by the apple industry to advertise and otherwise promote the sale and use of apples.

Growers oftentimes are inclined to place the blame for the lack of quality in the apples offered in grocery stores and other outlets on the retailers and other intermediate factors in the merchandising chain. They feel that the retailers and other handlers of the fruit are not "apple-minded," that to them apples are just so much perishable merchandise which must be handled and priced according to the risk attached; that, in the absence of knowledge as to how the risks can be minimized, the retail price of the fruit is often pyramided to a point at which sales are retarded and the whole industry suffers correspondingly, and that, consequently, customers are often unable to buy the kind of apples that they would like and turn to competing fruits.

Market men, on the other hand, hold that frequently the fruit when received has already deteriorated so much that its value is greatly reduced and the hazards of further deterioration while in process of sale are greatly increased. Most retailers are no more interested in apples than in any other commodity that will yield the same profit; so, if there are unusual risks in handling apples, this fruit naturally will not receive the consideration that it otherwise would.

It is the purpose of this circular to present in concise, nontechnical form the available information on the way in which apples should be handled from the time of harvest so that they will reach the ultimate consumer in prime condition, and to give the reasons for the various recommendations. This information is of special importance under existing war conditions when provision of adequate supplies of all kinds of foods is being emphasized. It would be of little use to produce greatly enlarged crops if they are to be allowed to deteriorate on the way to market or in storage. Therefore, while carrying out a program for increased production of essential foods, emphasis should be given to the avoidance of waste and the proper conservation of the crops produced. Furthermore, proper handling of apples during harvesting and packing, and the use of proper storage methods before shipment, will lessen the load on transportation facilities already heavily taxed by war traffic, by avoiding the hauling of fruit to market which should be left on the farm or taken to nearby byproduct plants.

THE GROWER'S RESPONSIBILITY

In the business of placing good-quality fruit before the consumer it is the responsibility of the producer to grow a crop of good apples. Many growers are, however, more interested in growing a good crop of apples. The difference between the two objectives may seem slight, but in the general problem of giving the public the kind of apples that will stimulate demand, it is significant. It is axiomatic that the orchard must be properly pruned, sprayed, and cultivated to produce a profitable crop. Every successful orchardist, although alert for new ideas in apple culture, is already familiar with good cultural practices and is producing a certain proportion of good apples. Progressive growers constantly strive to increase the proportion of good apples as well as to increase the size of the crop.

When to Pick Apples

One of the principal causes of the poor condition of apples as they finally reach the consumer is the failure to pick them at the proper stage of maturity. If apples are picked too soon, they are more likely to shrivel, will fail to develop good eating quality, and are very susceptible to certain functional diseases that develop later, particularly bitter pit and scald. If they are not picked soon enough, they will not stand up well in storage and are subject to other functional diseases that often cause serious losses in storage, especially soft scald and internal break-down. The reason for these failures is that the apple is a living organism with a more or less definite potential span of life. If it "lives too fast" either before or after picking, its vitality is exhausted prematurely, and the time it remains in good eating condition is shortened proportionately.

While the apple is attached to the tree, it is part of the tree and is influenced by any factors that affect the growth of the tree. When the tree suffers from drought, for example, the apple responds by slowing down its rate of growth; and when the tree is so stimulated that it makes abnormally fast growth, the fruit grows vigorously and may become overgrown and punky. As the fruit grows it accumulates the various constituents which finally characterize a mature apple. Not all of these constituents are accumulated at the same rate, and only at maturity is the final desirable balance reached. As the apple grows, the fleshy part becomes essentially a reservoir for the materials upon which its potential storage life depends. These are chiefly carbohydrates, malic acid, water, small amounts of aromatic materials highly important in determining flavor, and vitamins and minerals important in determining dietetic value. As the apple approaches maturity, it continues to increase in size but loses acidity and increases in sweetness. The carbohydrates in the flesh of a green or immature apple are largely starch, which is almost all converted into sugar as the fruit ripens. Ripening may occur either before or after harvest and is accompanied by a softening of the flesh and an increase in juiciness and aroma.

Some of the sugar, a relatively small proportion, converted from starch in the apple is used in respiration, being broken down to carbon dioxide and water, which are given off to the atmosphere. The acidity is, however, reduced to a much greater extent during ripening than is the sugar; hence, the flavor becomes progressively more characterless and less desirable as the apple is held beyond its normal storage season. Everyone knows that if an apple is left on the tree or held in storage too long it eventually becomes mealy, flavorless, and soft. When the life processes of the fruit are carried so far that pectic materials finally dissolve out of the cell walls, permitting the cells to separate easily, the mealiness that characterizes the texture of overripe apples is produced. What remains at the end is an apple in the last stages of senility, entirely unsuitable for market and undesirable for either culinary or dessert use. Therefore, while it is essential to allow the fruit to become mature before harvest in order to develop best quality, the ripening for the most part should occur after harvest in order to insure good storage and market quality.

Criteria of Maturity

The most generally used criteria of maturity are ease of separation of the fruit from the spur, ground color, and firmness of the fruit (*9*).[1] However, none of these is entirely dependable under all conditions.

EASE OF SEPARATION FROM THE SPUR

When an apple is ready to pick, it can be separated from the spur without breaking the stem merely by lifting it in the hand with or without a slight rotating movement. Since the attachment of the fruit to the spur is like a hinge, picking should be an unhinging process. Instead of picking the fruit in this way inexperienced or careless pickers often pull the fruit from its attachment. This usually results in breaking the spurs, which cuts down the bearing surface and reduces succeeding crops, or in pulling out the stem of the apple and tearing the flesh, which open the way for decay to start.

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[1] Italic numbers in parentheses refer to Literature Cited, p. 39.

Under some conditions apples may start to drop before they are properly mature. In such cases, of course, they are harvested although they may not be sufficiently mature to develop the best quality after ripening. Recently there has been an increase in the use of the so-called hormone sprays, such as naphthalene acetic acid, to prevent fruit drop (*4*). Use of a preharvest hormone spray invalidates the ease of separation from the spur as a criterion of maturity. As a result of this treatment the fruit can be retained on the tree longer to become more mature and riper before harvest than if such sprays are not used.

GROUND COLOR

The blush or red color of an apple is not a reliable index of maturity, but with many varieties the ground color is. The quality of a red apple can ordinarily be judged by the proportion of red to green; the more red, the better the eating quality. But the ground color is important in determining maturity, or when the apple should be picked. As most varieties of apples become mature, the ground color changes from a green very much like that of the leaves to a lighter shade and eventually to yellowish. With most varieties the time to pick is when the first signs of yellowing begin to appear, and ordinarily there is no difficulty in determining when this time comes. However, this is not always true with some varieties (Grimes Golden, Jonathan, and Yellow Newtown as grown under certain conditions), particularly with the various red bud sports that have been developed in recent years. The latter usually become fully red before they are mature, with no uncovered ground color left for observation. The result has been that they have often been picked too soon and have suffered in popular esteem because they are judged to have poorer quality than the parent variety. Ground color cannot therefore ordinarily be used as an index of maturity in the red bud sports. However, it has been found that the red bud sports do not differ materially in their season from the varieties from which they have been selected. and it is therefore practicable to use the ground color of the parent varieties for determining when to pick apples of the sports.

PERIOD FROM BLOSSOMING TO MATURITY

The problem of determining proper maturity has been of the most concern to growers of the various red bud sports of the Delicious, particularly in the Pacific Northwest, where many plantings of the original Delicious variety have been entirely replaced by Starking, Richared, or other red bud sports. When the difficulty in determining maturity of these all-red varieties by customary indexes became apparent, the United States Department of Agriculture began an investigation to determine whether the length of time that must elapse from time of blossoming to optimum maturity for harvest might be used as suggested by Magness and others (*10*). The investigation has now been in progress for several years. The results have shown that for satisfactory eating and good storage quality at least 145 days must elapse from the time of the first petal fall until the time of beginning harvest. Limited observations in the section about Washington, D. C., have indicated the same thing. Therefore, if growers in these sections will observe the date when petals begin to fall from the earliest blossoms, they can, by adding 145 days, immediately tell when to plan on starting to pick the Delicious or any of its red bud sports. The study is now being extended to other varieties and other sections, and it is possible that eventually recommendations as to definite lengths of growing seasons can be made for all varieties.

FIRMNESS AS DETERMINED BY PRESSURE TEST

Firmness, as indicated by the pressure test, is another index of maturity that can be used. To date the pressure test has been used experimentally more than in a practical way. However, in conjunction with other criteria already mentioned, it is an additional useful index of maturity. Used independently of other criteria, it is of value chiefly in determining when apples are becoming overmature and too soft for storage rather than when picking should begin.

As apples approach maturity, they become progressively less resistant to pressure, a characteristic which makes it possible to utilize mechanical means of measuring the rate of softening. Several types of pressure testers have been evolved. The one most commonly employed is that developed by Magness and Taylor (*11*), which measures the pressure required to force a plunger seven-sixteenths of an inch in diameter into the flesh of the apple to a distance of five-sixteenths of an inch after paring off the skin. Haller (*5*) has presented the results of a long series of investigations on the use of the pressure test on apples and various other fruits and has reviewed the findings of many other workers. Pressure-test records have been transposed into the ordinarily accepted commercial designations of "hard," "firm," "firm ripe," and "ripe" by Haller, Lutz, and Mallison (*6*). The publications referred to should be consulted for detailed information as to the application and limitations of the pressure test.

WHEN TO PACK APPLES

Ideally, apples should be packed and stored or shipped immediately after being picked. Danger of blue mold infection is less if this can be done because the danger of injuring the apples during the packing operations is much less if the fruit is hard than if it has begun to soften. Scald can also be controlled much more effectively if oiled paper is applied soon after the apples are harvested. Unless the oiled paper is applied within a month, or 6 weeks at the most, it is ineffective in controlling scald. Another advantage of prompt packing is that it gives an opportunity to sort out the culls, which not only may be sources of infection by rot organisms but which also take up valuable storage space that may be needed for marketable fruit.

Practically, however, a large percentage of the crop is often kept from a few days to several months before it is packed for market. Sometimes this delay is due to lack of sufficient packing facilities to take care of the fruit as fast as it is picked, and sometimes packing is intentionally postponed or spread out. If the apples are particularly susceptible to bitter pit, it may be advisable to delay packing for a month or 6 weeks to give the disease a chance to become manifest so that affected apples can be sorted out. When the delay is for more than a few days, the fruit is ordinarily placed in storage and packed at the convenience of the owner. Although this has some advantages, especially from the standpoint of spreading labor, these are outweighed by the disadvantages. When packing houses are congested and cold-storage space is not available, it is ordinarily preferable to let the picked fruit remain in the orchard in the shade of the trees; the boxes should be spaced so that air can circulate freely about them, and the stacks should be covered so as to protect the fruit from direct sunlight and rain (fig. 1, *A*). The apples will ripen less rapidly than if stacked in the open in unprotected large piles at the packing house as is sometimes done (fig. 2).

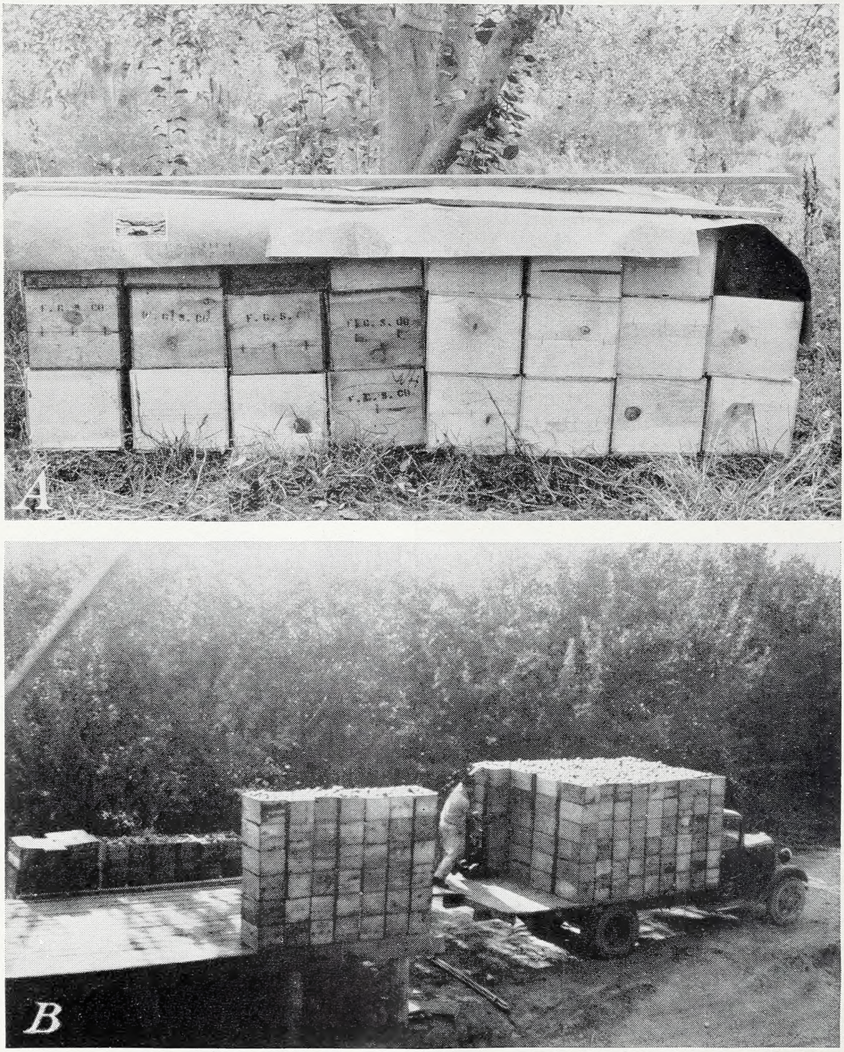

FIGURE 1.—*A*, Boxes of apples in the shade of a tree in an orchard. Note that the boxes are covered to protect the fruit from direct sunlight and rain and that the air can circulate freely about them. *B*, Hauling cull apples from the packing house. Frequent disposal of culls will reduce sources of infection by decay fungi.

FIGURE 2.—Holding apples in large compact stacks outside of a packing house is not recommended. In such piles, unprotected from sunlight and rain, ripening is accelerated.

FACTORS AFFECTING CONDITION DURING STORAGE

The sequence of changes in the harvested fruit is much the same as in apples that are allowed to remain on the tree until they become overripe, mealy, and insipid; that is, even fruit harvested at the proper stage of maturity will eventually become mealy and flavorless if held too long or under improper storage conditions. In fact, unless the fruit is placed in cold storage promptly, the approach of senility is more rapid after the fruit is picked than when it is left on the tree. The length of time that apples can be held in satisfactory condition in storage depends on three factors: (1) Maturity at harvest, (2) the storage temperature, and (3) the presence of diseases.

MATURITY AT HARVEST

Apples picked before they are sufficiently mature generally remain sour and astringent even after they have ripened and, except for the red bud sports, are poorly colored. They have a marked tendency to wilt or shrivel and are susceptible to scald and bitter pit during storage.

The apples most often picked before they reach the proper stage of maturity are the solid-color varieties, such as the Grimes Golden and Yellow Newtown among the green or yellow kinds and the red bud sports of the Delicious, as already mentioned. When picked at the proper stage of maturity, all these rate among the best for dessert quality; but when picked too soon, they are suitable only for culinary use, and the Delicious is not particularly good even for that.

When the weather remains warm at harvesttime, particularly at night, some varieties of red apples are slow to color and there is a tendency on the part of growers to delay picking until the apples do color, with attendant danger of loss from dropping and of the fruit's becoming too mature for storage. Because this is particularly true of Jonathan, Delicious, and Rome Beauty, red bud sports of these varieties have been eagerly sought and largely substituted wherever possible. Many large plantings of the original varieties will doubtless remain in heavy production, however, and in such cases there will continue to be problems of color, dropping, and overmaturity. Use of hormone sprays, which prevent apples from dropping, meets the problem of slow coloring only in part, since there is danger that apples thus held on the tree to color may become too far advanced in maturity or may be fully ripe at time of picking. Overmature apples are particularly susceptible to water core, soft scald, internal breakdown, and Jonathan spot and are more subject to stem punctures, bruising, and other mechanical injuries through which blue mold infection takes place. Blue mold infection through lenticels is also more likely to occur in overmature apples than in those picked at proper maturity.

Storage Temperature

The life processes of apples that have to be considered in the successful storage of the fruit after harvest are essentially chemical, and, as with other chemical processes, the rate at which they proceed depends largely upon the temperature at which they can be carried out; i. e., upon the temperature of the apples. Apples freeze at a temperature of about 28.5° F. (*17*); hence, it is necessary to keep them above this temperature. In practice, storage temperatures of 30° to 32° have been found most satisfactory (*15*).

Magness and others (*10*) found that the rate of respiration largely governs the rate of ripening and softening of apples in storage. They found that at 40° F. this rate is approximately twice as rapid as at 32°, at 50° it is almost double that at 40°, and at 70° it is about twice as fast as at 50°. At 30°, on the other hand, 25 percent longer time is required for apples to ripen than at 32°. From these results, therefore, the extreme importance of quickly cooling apples to the minimum safe temperature for storage is readily apparent, because the apples will ripen as much in 1 day at 70° as they will in 10 days at 30°. Holding apples at 70° for only 3 days after harvest thus will cut off about a month of their potential storage life at 30°. If 30° storage is not immediately available, every opportunity should be used to cool the fruit, such as stacking it in the shade and providing good ventilation, especially at night (fig. 1, *A*). The same principle applies after storage. It is therefore inadvisable to remove from cold storage at one time more apples than can be used or marketed before they deteriorate seriously. It must also be remembered that after storage the span of life remaining for the fruit is much shortened, and as the end point is uncertain, the gamble in holding at warm temperatures is much greater.

Cooling the fruit means the transfer of heat from the fruit to the air surrounding the fruit. The effectiveness of the cooling depends on the difference between the temperature of the air and that of the fruit and the rate at which the air moves over the fruit. In common storage, cooling is accomplished by transferring heat from the fruit to the outside air. A good ventilating system intelligently operated is necessary to make this method efficient; the vents should be opened when the outside air temperature is lower than that of the fruit and closed when conditions are reversed. In cold storage the heat is transferred from the air surrounding the fruit to refrigerated pipes or other artificially cooled surfaces and eventually is transferred to the outside air by the refrigeration system.

The cooling of the fruit ordinarily is not a rapid process, nor is its ripening checked instantaneously when it is placed in cold storage. Time is needed to remove the heat from the fruit because the rate of cooling is affected not only by the temperature but also by the type of package, the method of packing, the quantity of warm fruit placed in the room, the manner in which the packages are stacked, and the rate of air circulation around the fruit. Table 1 presents results of tests conducted at the cold-storage laboratory, United States Horticultural Station, Beltsville, Md., to determine the influence of the type of package on the rate of cooling. In this series of tests the temperature records were taken at the core of an apple at the center of each of the various packages. The packages were not stacked and, being freely exposed on all sides, cooled faster than they would under commercial storage.

TABLE 1.—*Influence of method of packing and storing apples in unstacked individual packages on their rate of cooling at 32° F. in still air*

Package	Packing material	Temperature at core of apple in center of package—					
		When stored	After 12 hours	After 18 hours	After 72 hours	After 7 days	After 10 days
		°F.	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*
Bushel basket	None	63	42	32			
Do	Liner, cushion, shredded oiled paper.	70	59	44.5	41	33.5	32.5
Barrel	None	66	64	59	55	41	36
Standard box	Liner, cushion, oiled wraps	71	67	60	54	41.5	37
1⅕-bushel eastern crate.	Liner, cushion, shredded oiled paper.	66	63	61	59	54	44

The results show that the use of liners, cushions, and paper for packing slows up the rate of cooling. Apples in an open bushel basket just as they came from the orchard, without liners, wraps, or shredded oiled paper, cooled from 63° F. to 32° in 18 hours, whereas fruit packed in lined baskets with a pad under the lid and shredded oiled paper well distributed throughout required about 10 days to cool from 70° to 32.5°. The relative thickness of the containers doubtless had an effect on the rate of cooling, but the size of the package or the mass of fruit enclosed and the tightness of closure apparently were important factors also as can be noted by comparing the results for apples packed in the barrel with those in the open bushel basket; it took only 18 hours to cool the fruit in the middle of the bushel basket from 63° to 32°, but it required 10 days to cool that in the middle of the 3-bushel barrel from 66° to 36°. Similar results can also be noted for the apples packed in the standard box and in the 1⅕-bushel eastern crate, the packing in both cases, however, including liners and pads as well as oiled wraps or shredded oiled paper. The eastern crate contained 20 percent more apples and was the tighter package, and after 10 days the fruit in its center had cooled only 22°, while that in the standard box had cooled 34°.

The results shown in table 1 should not be interpreted to mean that use of pads, liners, and other packing material is undesirable but rather that these materials insulate the fruit and increase the requirement for refrigeration if properly packed apples are to be cooled as quickly as is desirable.

In view of the results shown in table 1 the question arises as to what would be the effect of lowering the temperature of the air below 32° F. on the rate of cooling. This is done in precooling, which is the term applied to the rapid lowering of the temperature of a commodity to any desired level. While apples are not commercially precooled to the same extent as are peaches, pears, plums, and certain other fruits, in many cases it would undoubtedly be beneficial to precool them, Delicious in particular because it is so prone to become mealy and overripe. Records of fruit temperatures, if taken in many storages, would disclose that most of the fruit is not cooled to 32° for several weeks after harvest. Meanwhile, the rate of ripening is being arrested only in proportion to the rate of cooling. The slow cooling is often due to lack of sufficient refrigerating capacity of the cold-storage plant, but it may also be due to faulty stowage in the room, particularly failure to leave space for air circulation through the stacks and to spread out large receipts of warm fruit.

The greater the difference between the temperatures of the commodity and of the cooling medium and the more rapid the rate of air movement the more rapid the rate of cooling will be. However, as the temperature of the commodity approaches that of the cooling medium the rate drops off. These effects are shown in figure 3, which presents data obtained in another series of experiments conducted in the United States Department of Agriculture cold-storage laboratory at Beltsville, Md. The records were taken in the top layer of packages held at 32° F. and stowed as they would be in commercial practice. In the middle of the stacks the rate of cooling was slower be-

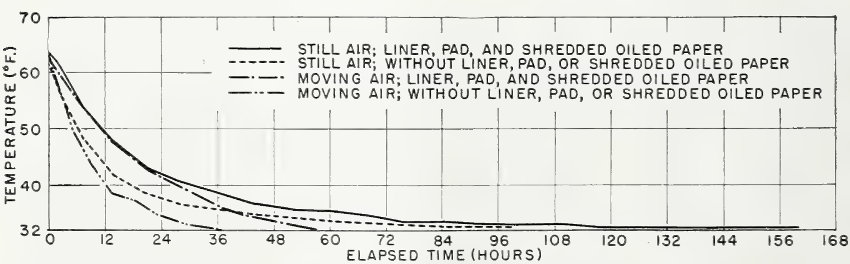

FIGURE 3.—Rates of cooling of apples packed in bushel baskets and stored at 32° F. in still and in moving air. Velocity of the moving air was approximately 200 feet per minute. The thermometer was located in centermost fruit in each container.

cause the air could not circulate as freely as over the top of the stacks. From figure 3 it will be seen that the apples cooled more in the first 12 hours than in the next 12 and that the rate of cooling fell off progressively thereafter as the temperature of the fruit approached that of the air in the storage room. The insulating effect of the liners, pads, and the shredded oiled paper ordinarily used is brought out in these results as well as in those in table 1. The effect of air movement in increasing the rate of cooling is also brought out clearly in figure 3. When the rate of air movement was about 200 feet per minute, the apples without packing material cooled to 32° in 36 hours, while in still air they required more than 96 hours to reach this temperature. In the baskets with liners, pads, and shredded oiled paper similarly packed apples required 57 hours in the air moving at 200 feet per minute and more than 156 hours in still air.

Some people are afraid of possible ill effects of cooling fruit too quickly; they fear that it may produce some kind of "shock" from the rapid change of temperature. No apprehension of such effects is justified. The more rapidly fruit can be cooled to the proper storage temperature, the more quickly will the deteriorating processes of ripening be arrested, and the longer the fruit can be kept in good condition.

Gas Storage

In England, some varieties of apples, particularly the leading culinary variety, Bramley's Seedling, will not endure ordinary cold storage without developing low-temperature break-down. The same situation exists to a limited extent in certain parts of the United States, particularly with Yellow Newtown apples grown in the Pajaro Valley, Calif., and with McIntosh grown in New York State, in which brown core may develop excessively during storage at 32° F. The so-called gas-storage method was developed by Kidd and West (*7*) in England to meet this problem. To utilize this method an airtight storage chamber is required and the carbon dioxide produced in the respiration of the apples is allowed to build up to the desired concentration while the oxygen content of the storage air is reduced. The temperature of the storage room is usually held at 40° to 45°; so ordinarily some refrigeration is required in addition to the gas treatment. Since different varieties respond best to different ratios of carbon dioxide to oxygen, different chambers may be required for different varieties. The desired ratio is obtained either by pumping the storage air through a lye solution to absorb the excess carbon dioxide or by ventilating the chamber periodically to admit fresh air and build up the oxygen. Since the vast bulk of the American apple crop can be held satisfactorily in cold storage and most varieties are not benefited by the gas treatment, it is not likely that this method of storage will have wide application in this country because of the added cost and extra work that it entails. However, for special situations it may be utilized profitably despite the extra cost. Several gas storage rooms have been put into operation in New York for the storage of McIntosh apples in accordance with the recommendations of Smock and Van Doren (*16*).

Atmospheric Humidity

Keeping the apples from wilting and shriveling is as important as keeping them from getting overripe and can be done by controlling the humidity in the storage space. A certain amount of moisture is continuously lost by the apples through the process of transpiration (evaporation).

Although it can be cut down by reducing the temperature, it is particularly serious in apples which are not properly matured and on which lenticels are not normally corked over and the wax coating is not sufficiently developed. The natural barrier to loss through evaporation is the waxy skin of the fruit. Any injury to the skin or the removal of the wax, as in some washing processes, facilitates moisture loss and increases the severity of wilting. Careful handling to avoid bruising and injury of the skin and the use of proper washing processes are important therefore in preventing excessive wilting or shrinkage in storage as well as blue mold rot and other types of decay. The drier the air the greater is the degree of wilting. The faster the air is moved over the apples the more moisture will be removed from the fruit. The extent to which this occurs in apples has not been determined exactly, but in grapes Allen and Pentzer (*1*) found that doubling the air movement increased moisture loss by about one-third and was equivalent to about a 5-percent drop in relative humidity. If the relative humidity of the storage is maintained at 85 percent or higher, which is the approximate water content of apples, the "pull" on the fruit for moisture or the evaporating power of the air will be slight and shrinkage of the fruit will be correspondingly lessened. Observations in commercial cold storage plants have shown that the relative humidity in the apple storage rooms is frequently less than 85 percent, sometimes as low as 70 percent.

To maintain desirable humidity conditions and to reduce chances of wilting, it is always desirable to fill the storage rooms, thus reducing as much as possible the ratio of air to fruit. In such cases, however, it is essential to have a gentle air movement through and around the stacked fruit to insure proper cooling. This is not a serious problem when apples are packed in bushel baskets (fig. 4), but it is when boxes or crates are used. In the latter event, the stacks should be spaced an inch or two apart and laths or other dunnage strips should be used to separate the boxes or crates in each stack. When a storage room is completely filled with apples, the humidity will be almost automatically adjusted at the desired level.

It is desirable to have sufficient coil surface in a cold-storage room to provide the desired cooling without using excessively low temperature in the cooling medium. The greater the difference in temperature between the cooling surface and the air of the storage room, the more the air will be dried by the freezing out of moisture and the greater will be the pull on the fruit with corresponding wilting effects. If there is sufficient coil surface to permit use of the cooling medium at not more than 7° or 8° F. below the desired temperature of the room, the freezing out of the moisture from the air onto the coils will be minimized.

FIGURE 4.—Method of stacking bushel baskets of apples and staggering them by placing each basket on the edges of those beneath to keep pressure away from centers of lids. Stacking baskets as shown, instead of putting alternate baskets upside down as is sometimes done, permits better air circulation. Permitting the workmen to stand or walk on the baskets is not desirable.

It is difficult to raise the humidity in a cold-storage room kept within the most desirable temperature range for apples, 30° to 32° F., because the moisture is so quickly condensed and frozen. However, if it becomes necessary to raise the humidity, it can be done best by using a humidifying apparatus that introduces steam into the air of the storage room. A simple humidifier of this type can be made by placing a shallow pan on some strip heaters, operation of which is controlled through a humidistat. An electric fan should be arranged to blow over the surface of the water. The efficiency of the apparatus can be increased somewhat if absorbent toweling is looped into the water from a series of parallel supports placed 8 to 10 inches above the surface of the water. In this arrangement the air current from the fan should pass through the loops of the wicking. Adding moisture to raise the humidity by any method must be regarded as only an expedient rather than as the most satisfactory method of controlling wilting and shrinkage. All that can be accomplished by evaporating moisture into the storage air is to supply some of the moisture requirement of the air rather than to permit it all to be taken from the apples. The moisture requirement of the air cannot be satisfied so long as the temperature of the cooling surfaces remains markedly lower than that of the air.

Storage With Other Products

Apples absorb odors very readily, and it is therefore undesirable to store them with other products that have pronounced odors. This is particularly true of potatoes and other root crops, which often impart an "earthy" flavor to apples. Since apples give off ethylene, a gas that stimulates respiration and ripening, the potential keeping quality of other products stored with apples may be adversely affected. This is particularly true of cut flowers, which may be caused to shed their petals or are otherwise injured by ethylene (*18*).

Fungus Diseases

There are many fungus diseases of apples that can cause serious losses under certain conditions. Fortunately, however, most of these are primarily orchard diseases and are controlled on the harvested fruit by the sprays that good growers apply to control them in the orchard. However, if they are present on the stored fruit, they respond to storage temperatures about the same as do the physiological processes of the fruit already discussed (p. 8). All of them develop rapidly and are most destructive at warm temperatures, whereas at 30° to 32° F. many will not develop at all, or at the most very slowly, particularly if the apples are not ripe. The spores of most rot organisms will not germinate at 30° to 32°, but if infection has already occurred when apples reach this temperature, most of the rots will persist during storage and the causal organism will resume growth after the fruit is removed to a warm temperature. Detailed information regarding the diseases of apples in storage can be found in United States Department of Agriculture Miscellaneous Publication 168 (*13*) and Farmers' Bulletin 1160 (*3*). Discussion can be limited here to a relatively few diseases that are especially influenced by harvesting, handling, and storage operations; most of these are not due to fungi but are functional or physiological in nature.

The storage disease responsible for most of the decay in apples after harvest is blue mold rot, caused by the fungus *Penicillium expansum* Link. It is primarily a wound parasite and ordinarily requires some kind of mechanical injury to infect an apple. This rot is very soft and watery and has a pronounced musty odor. It gets its name from the bluish masses of spores that appear on the surface of affected areas (fig. 5, *A*). This fungus is omnipresent wherever apples are grown, and its spores are found in large numbers on the surfaces of apples as they are picked and brought in for packing. Since the fungus is ordinarily incapable of penetrating the sound, uninjured skin of the apple, careful handling of the fruit at all times is a prime requisite in preventing infection. Bruising and other mechanical injuries lead to blue mold infection.

Although blue mold enters apples most often through mechanical injuries, it sometimes enters through open lenticels in the skin, through the stem, especially when this is enlarged or fleshy and has

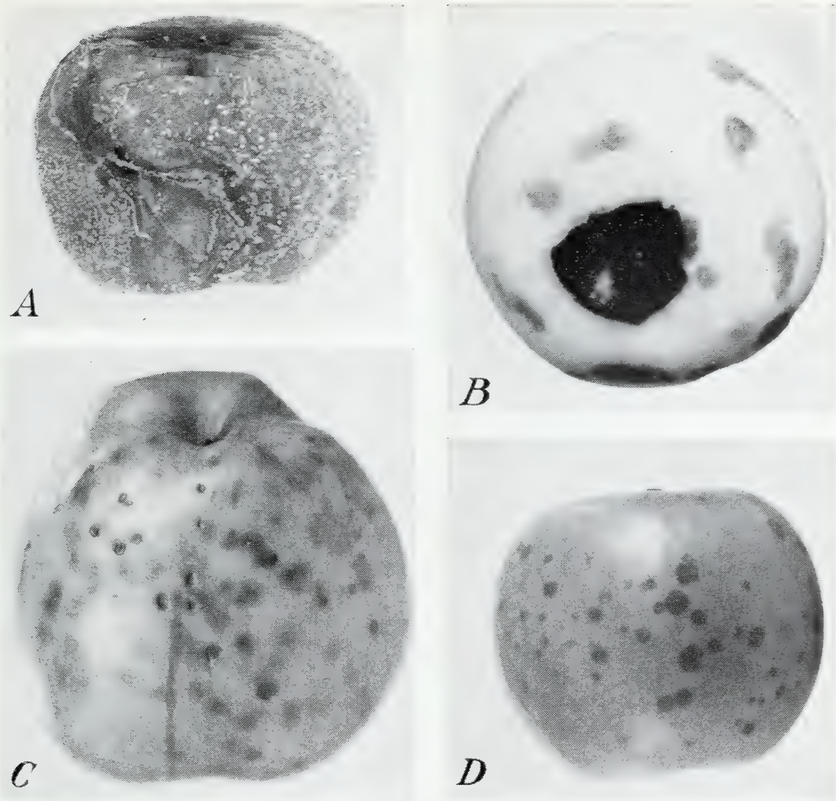

FIGURE 5.—*A*, Blue mold rot, which is soft and watery, has a pronounced musty odor and frequently is covered with bluish masses or spores. *B*, Very slight bruises, which show prominently on a peeled apple, the emphasizing need for careful handling at all times to keep the apples from being bruised. *C*, Bitter pit, which occurs as brownish spongy or corky spots or pits in the flesh just under the skin and usually is most prevalent on the blossom end. *D*, Jonathan spot, a superficial skin disease that gives the apple a freckled appearance.

been broken or injured, and also through dead calyx lobes resulting from spray injury, washing injury, or other causes. Infection is more likely to occur in ripe apples than in those which are still hard, and also it is most likely to occur at points of contact with another fruit. When apples are washed, the spores of decay organisms, especially blue mold, accumulate in the washing solutions and infection of both mechanical injuries and open lenticels is increased. The spore load of the washing solution should be kept as low as possible by sorting out rotten apples before washing, by careful handling to avoid injuries, by the periodic renewal of the washing solution, and, where possible, by the use of a copious fresh water rinse.

In the reduction of loss from blue mold rot good sanitation in and around the packing house and storage rooms is important. Since culls are potential sources of infection for other fruit, they should be stacked outside of the packing house and then disposed of to byproduct plants or otherwise at frequent intervals (fig. 1, *B*). Storage rooms should be kept clean and sanitary at all times, and prior to each season's use they should be either whitewashed or well disinfected or otherwise thoroughly cleaned and aired before any apples are brought in. Whitewashing is simpler and generally preferable to other measures that can be taken. If copper sulfate is added to the whitewash, its disinfectant properties can be increased somewhat, but from a practical standpoint this is of questionable value. It is especially desirable, however, to clean and disinfect the floor, which is not whitewashed. Thorough scrubbing with water containing 2.5 percent sodium hypochlorite and a suitable wetting agent is recommended. There are a number of commercial preparations on the market suitable for this purpose.

For disinfection sulfur dioxide, the gas produced by burning sulfur, can be used. The proportion ordinarily used is 1 pound of sulfur to 1,000 cubic feet of space. It should be burned in a metal vessel placed on bricks or otherwise held off the floor. All openings should be kept tightly closed for an hour or so in order to permit the maximum concentration of sulfur dioxide to be utilized. Ordinarily formaldehyde candles can likewise be burned as in household disinfection, but formaldehyde is less satisfactory than sulfur dioxide because of the persistence of the odor, and thorough airing out for a considerable period afterward is required. **Both sulfur dioxide and formaldehyde are toxic and injurious to apples, and no fruit should be placed in the rooms until all traces of gas have disappeared. They are likewise strong irritants to eyes and mucous membranes, and care must be exercised to avoid contact with the fumes during or after fumigation. Doors or windows should be opened to air the rooms thoroughly after fumigation and before they are entered by workmen. For this reason it is feasible to fumigate only during the season when the storage space is not in use.**

Bruising and Other Mechanical Injuries

The importance of bruising and other mechanical injuries in blue mold infection emphasizes the need for preventing such injuries. Pickers, sorters, and packers should wear gloves or cut their fingernails closely to prevent fingernail punctures, and care should be exercised to remove all sand, splinters, and projecting nails in the fruit boxes or baskets. Pickers should be provided with containers having rigid sides rather than with picking bags (fig. 6) in order to prevent bruising the apples when the picker leans against the container, as he often does in picking from a ladder or in the tree. Pickers should be required to empty the fruit carefully into the field boxes and should never be allowed to drop apples more than an inch or two. Field boxes should be filled less than level full, in order to prevent bruising the fruit when stacked (fig. 7), and care should be exercised in lidding the market packages to prevent the apples from being cut or badly bruised. Use of adequate grading and sizing machinery, which moves the fruit gently on belts or rollers, is an important factor in the reduction of bruising damage (fig. 8). Bad bruising often results from not taking adequate precautions in handling the fruit in the packing

FIGURE 6.—Picking buckets are preferable to picking bags, because they afford more protection against bruising and stem punctures. In emptying, the containers should be lowered to bottom of the field box so that the apples will slip out gently. The boxes should not be filled so full that they cannot be stacked without injuring the apples as would happen with the improperly filled box shown.

house, particularly when the fruit is dumped into the washing or sizing machinery. If it is poured out of the field crates and allowed to drop or if it is poured or rolled around in large piles, it is likely to be bruised and stem-punctured. Unless the apple-handling machinery is properly adjusted bruising may also occur.

A certain amount and degree of bruising during packing and handling probably are inevitable, but most of the bad damage can be eliminated by careful handling, which in turn can ordinarily be secured only by adequate supervision and the use of proper equipment. As an illustration, the records obtained in some of the United States Department of Agriculture's studies in the Pacific Northwest on damage during picking are cited in table 2.

In orchard A the pickers were working without special supervision. In orchard B there was a picking foreman exercising close supervision over the work; the very marked reduction in bad bruises and skin punctures is doubtless due in some measure to this fact. However, it is probable that it was due in even greater measure to the use of picking buckets. This is brought out strikingly in the results for orchard C where there was also a picking foreman exercising as close supervision of the pickers using bags as of those using buckets (fig. 6). The advantage of the bucket was very great in the prevention of bruising and skin punctures.

FIGURE 7.—Field boxes properly filled and stacked to prevent damage to the fruit and to facilitate cooling on the receiving platform of a packing house. Note that the individual lots are identified by tags held to the top box by a spring clothespin.

TABLE 2.—*Comparison of injuries to apples picked into bags and into buckets*[1]

Orchard	Picking container	Not injured	Slightly bruised	Badly bruised	Skin-punctured
		Percent	*Percent*	*Percent*	*Percent*
A	Bag	34.1	13.9	50.2	1.8
B	Bucket	96.1	2.3	1.3	.3
C	Bag	30.1	24.2	41.2	4.5
	Bucket	92.5	7.1	.3	0

[1] Unpublished data obtained by R. R. Pailthorp, senior marketing specialist, Agricultural Marketing Administration.

The apples with slight bruises (table 2) would not be discriminated against on the market, for all such bruises were small and shallow and did not damage the outward appearance or the keeping quality of the fruit; however, even slight bruises show up rather prominently when an apple is peeled (fig. 5, *B*). The bad bruises and skin punctures, on the other hand, were serious hazards to the keeping quality of the apples. Even if they did not decay, consumers would be dissatisfied with them because so much of the fruit would be unfit to eat. Skin-punctured apples are generally regarded as culls because it is well known that they are likely to become infected with blue mold and in consequence are suitable for immediate use only. It is not

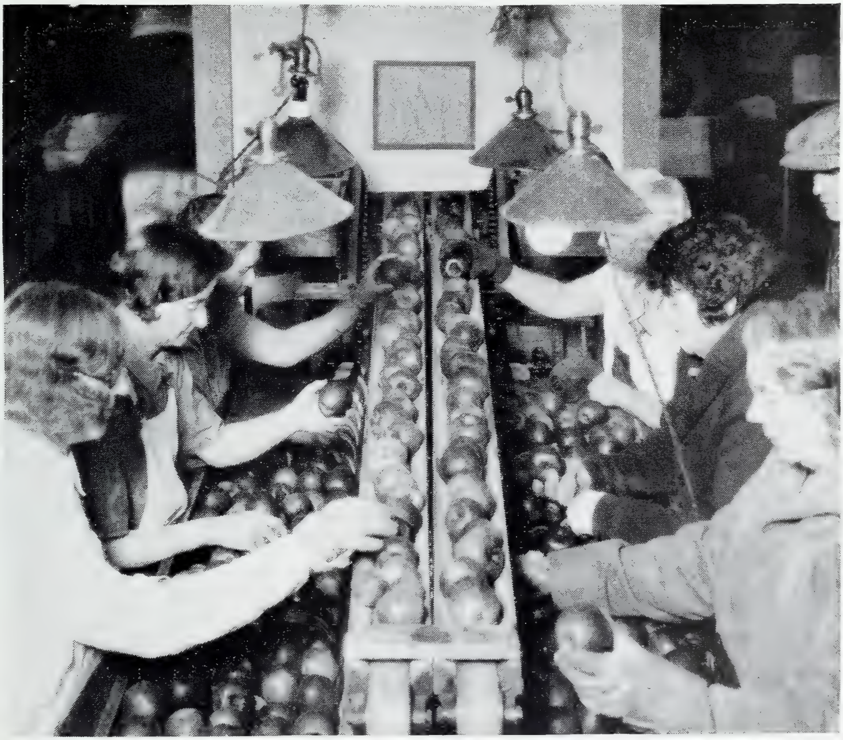

FIGURE 8.—Use of adequate grading and sizing machinery, an important factor in the reduction of bruising. All the sorters should wear gloves.

as commonly recognized that apples with bad bruises should be culled out. Bad bruises not only detract from the sales appeal of the fruit but are also potential avenues of blue mold infection to almost the same extent as are skin punctures.

Physiological Diseases

BITTER PIT

Bitter pit, Baldwin spot, or stippin, as it is variously called, is a physiological disease that is found all over the world where apples are grown. It occurs as brownish spongy or corky spots or pits in the flesh just under the skin and usually is most prevalent at the blossom end (fig. 5, *C*). Occasionally the pits are deep-seated and are not evident without cutting the apple. The affected part often has a somewhat bitter taste, which accounts for the name "bitter pit." Bitter pit does not impair the keeping quality of the apples, but since the affected parts have to be pared away it reduces the value of the fruit and of course detracts from its appearance.

No variety is entirely immune, but bitter pit is particularly prevalent in Baldwin, Gravenstein, Arkansas (Mammoth Black Twig), Delicious, Yellow Newtown, Rhode Island Greening, and Northern Spy. The disease is most likely to occur in light-crop years, and apples grown on young trees are particularly susceptible. Susceptibility to the disease is also increased when late-season growth is stimulated by heavy irrigation or rains, fertilization, heavy pruning, or other means. Bitter pit may begin to appear before the apples are picked and seems to develop to the greatest extent if they are picked before they reach proper maturity, but as the disease is seldom fully manifested by the time of harvest it is impossible at that time to sort out all of the apples which will show the pitting. Ordinarily, however, the diseased apples can be detected within a month or 6 weeks after they are picked, and if susceptible crops are held until then before sorting and packing the pitted fruit can be eliminated. If this procedure were more generally followed, there would be less likelihood of having to repack affected lots or suffer heavy market losses because of bitter pit.

JONATHAN SPOT

Jonathan spot is a superficial skin disease characterized by small black or brown spots resembling "freckles" scattered over the apple, particularly on the well-colored part (fig. 5, *D*). In later stages these spots may become sunken and the flesh immediately beneath becomes brown and spongy as the tissue dries out. This disease affects the appearance and sales value of the fruit rather than its keeping quality. Jonathans are very susceptible, but the disease occurs also on many other varieties. The same kind of spot or one closely resembling it often seriously detracts from the appearance of Rome Beauty apples. Jonathan spot is only skin deep except in late stages when underlying flesh tissue becomes brown and dried.

Jonathan spot is a physiological or functional trouble. It occurs to some extent on highly colored apples left on the tree until they become overripe, but primarily it is a storage disease that is most serious on apples held at warm temperatures. Ordinarily its presence is an indication that the apples are ripe or well advanced toward full ripeness and that their further potential storage life is not long. It can be prevented almost entirely by picking the apples at the proper stage of maturity and storing them promptly at a temperature of 30° to 32° F. The greater the delay in reaching cold storage the more serious the disease. Storage at temperatures higher than the range 30° to 32° tends to increase the severity of the disease.

WATER CORE

Water core is a functional disease that appears in the apples before harvest and gives the flesh a water-soaked or glassy appearance due to the gorging of the tissues and intercellular spaces with sap (fig. 9, *A*). Since it usually becomes worse as the apples reach maturity, its appearance sometimes causes growers to pick the fruit earlier than would otherwise be desirable. It is usually most severe on the highly colored and most exposed apples in the tops of the trees, while the poorly colored shaded fruit may be entirely free.

When water core extends to the skin of the apple it is easily detectable and such fruit is seldom packed. However, it is often hard to detect slight water core, especially if it does not come to the skin, and consequently affected apples sometimes get into storage unintentionally. Growers who are not aware of the hazard likewise may store water-cored crops.

Since water core predisposes apples to internal break-down (fig. 9, *B*), it is always hazardous to store affected fruit for late marketing. Slight water core in the long-season, hard-textured varieties, Winesap and Yellow Newtown particularly, may disappear in storage without leaving any trace; but in the shorter season, softer varieties, even slight water core is usually followed by internal break-down, and this almost always happens with more severe water core in even the harder varieties.

INTERNAL BREAK-DOWN

Internal break-down is a senility disorder that marks the end of the storage life of apples. It is characterized by brownish discoloration of the flesh, development of mealiness, and loss of flavor. In advanced stages the skin of the apple cracks as though from internal pressure and one can easily press the thumb deep into the flesh. In earlier stages, however, there may be no outward symptoms except possibly a dull color of the skin, often confined to the affected area. Upon cutting, however, a brown discoloration will be found in the flesh (fig. 9, *B*), sometimes only in the core region, sometimes throughout the whole interior, and sometimes localized on only one side of the fruit. Sometimes, also, the break-down will be found at severe bruises. In such cases it doubtless is due to the localized stimulation of respiration, which follows the injury. This is another reason for careful handling to avoid bad bruises or for sorting out badly bruised apples.

Since internal break-down is a senility disease, its presence in a storage lot can ordinarily be taken as an indication that the apples either were overmature when picked or have become overripe in

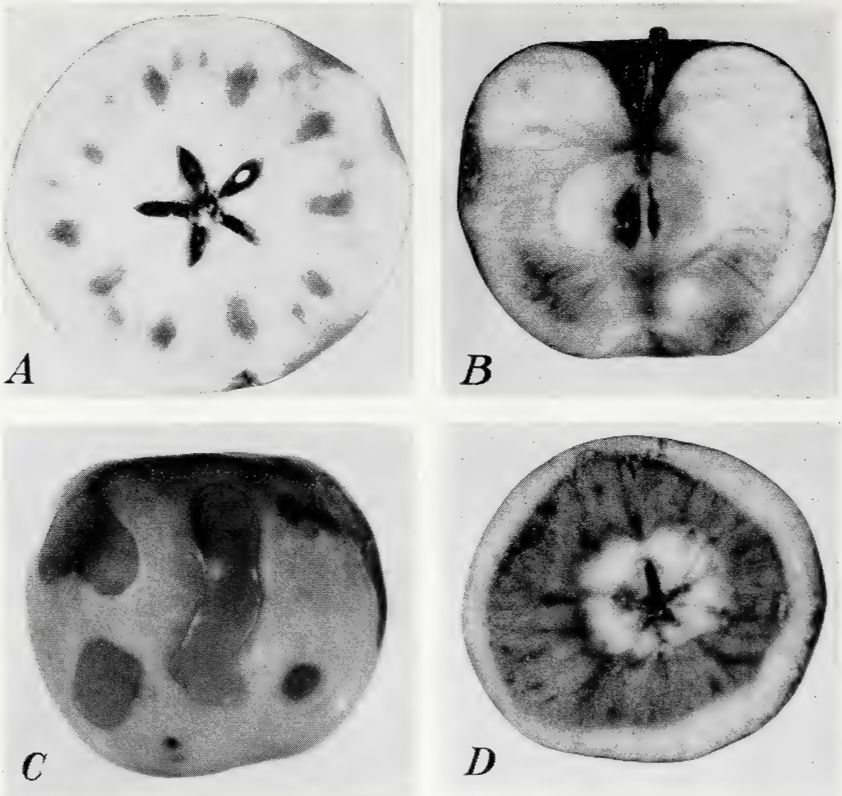

FIGURE 9.—*A*, Water core, characterized by a glassy or water-soaked appearance of the flesh around the core or main vascular bundles. Such affected apples are predisposed to internal break-down. *B*, Internal break-down, characterized by a general mealiness and brownish discoloration of the flesh. *C*, Soft scald, which makes apples look as if they might have been rolled on a hot stove. *D*, Soggy break-down, which is brought about by causes similar to those which produce soft scald.

storage. Further holding of such lots is hazardous. As already suggested, the best means of preventing internal break-down is to harvest the fruit at the proper stage of maturity and to retard its life processes as much as possible thereafter by holding it at a temperature of 30° to 32° F.

SOFT SCALD AND SOGGY BREAK-DOWN

Some varieties of apples are particularly subject to soft scald or soggy break-down in cold storage. These diseases are very similar in nature and cause but differ in their manifestation.

Apples affected by soft scald look as if they might have been rolled on a hot stove (fig. 9, *C*). Strips or large spots of the outer tissues are affected; the skin is dead and brown but tightly stretched with a very definite demarcation of the margin. The underlying flesh is brown and discolored but only in late stages is it more or less dried out. Earlier, it is soft and juicy. Frequently, rot fungi invade the fruit through the dead skin. They make black or brown spots of decay and soon destroy what is left of the apple. Blue mold and *Alternaria* are the most common invaders of soft scald tissue. Jonathan, Rome Beauty, and McIntosh are the varieties most often affected with soft scald, but it occurs sometimes on other varieties as well.

While much experimental work has been done on this disease, very little has been discovered to explain its nature and cause, except that it is a low-temperature disorder. As a result, no categorical statements can be made regarding its control. In general, however, its incidence appears to be reduced or prevented by early harvest and prompt cold storage at 30° to 32° F. Delay up to 10 days or 2 weeks in placing the fruit at 30° to 32° seems to increase the tendency to the disease, but after longer delays the susceptibility of the fruit decreases. Well-matured or overmature fruit is more susceptible to soft scald and should not be stored at temperatures below 36°. The disease is erratic in its occurrence and may be bad one year and absent the next.

Soggy break-down is most serious in Grimes Golden and Golden Delicious and appears to be the manifestation in these varieties of the same disorder exhibited by soft scald in others. Soggy break-down differs from soft scald chiefly in its location, being typically a disease of the flesh, whereas soft scald is confined to the skin and adjacent flesh. Soft scald has a sharply defined margin in the skin; in soggy break-down there is a more extensive involvement of the flesh beneath, without the sharp margin between the sound and the affected tissues (fig. 9, *D*). It seems to be associated with the same storage conditions under which soft scald occurs.

SCALD

Scald occurs in storage and is a more or less generally diffused browning of the apple skin. At first it is superficial, but eventually the skin may become soft and slough off and then the flesh beneath either dries out or is opened to infection by rot fungi. The green or unblushed portions of the fruit are most affected, and immature apples are more susceptible than those picked later.

Scald can be understood best by thinking of it as a disease induced by suffocation or auto-intoxication; that is, it appears to be caused by products given off by the apple itself. The particular products involved apparently are connected with the odorous constituents of the apples.

Scald itself affects the appearance and not the dessert or culinary quality of the fruit. However, when scald is found, it means that the further storage life of the fruit is limited because scalded skin is dead and offers no further protection to the fruit. The disease is likely to spread rapidly until almost all the surface, particularly the green-colored areas, is involved. It does not ordinarily begin to appear until 60 days or more after harvest and commonly is more serious on apples in cold storage than on those in common storage. Sometimes it does not become manifest until after the apples are removed to a warmer temperature and usually it becomes more serious

FIGURE 10.—Control of scald on Grimes Golden apples by use of wraps carrying odorless, colorless mineral oil to at least 15 percent of their dry weight.

after such transfer, but in such cases it is due to conditions that prevailed during storage, just as when it is found during cold storage.

In the prevention of scald, picking the fruit at proper maturity is important; selecting only the best-colored fruit for long-time storage is also important, but in preventing loss from the disease further measures must be taken. Since it is due to auto-intoxication effects in storage, storage practices must be adapted to prevent its occurrence. If it were practical to provide continuous aeration of every apple, the injurious odorous emanations could be removed in this way and scald control could be secured, but it is not possible to do this in commercial packages or under commercial cold-storage practices. The only feasible method of scald control is the use of oiled paper (fig. 10) as developed by Brooks, Cooley, and Fisher (*2*). The oiled paper can be used either in the form of fruit wraps or shredded. The oiled paper absorbs the odorous emanations from the fruit and at the same time to some extent reduces moisture loss from the fruit. Its use is recommended for all fall and winter varieties of apples. For best results the apples should be packed in the oiled paper as soon as possible after harvest. Oiled paper for this purpose is now obtainable in all apple-growing districts, but growers should make sure that it is properly prepared and properly used. It should carry at least 15 percent of its dry weight in an odorless and tasteless mineral oil. When shredded oil paper is used, at least ½ pound per bushel is required, and it should be well distributed through the package so that every apple is in contact with it.

EFFECTS OF PACKAGING

Packaging practices have an important bearing on the subsequent condition of apples especially as to bruising, and particularly when apples are displayed to the consumer. It is a strange commentary on the apple industry that after exercising great care to cull out all skin-punctured and badly bruised fruit, many packers package their apples in such a way as to bruise and puncture a large proportion of the good fruit remaining. Surveys conducted in retail stores in various parts of the country reveal that the outstanding defect in the apples offered for sale is bruising—often very bad bruising. In self-service stores customers naturally do not select badly bruised apples and in other types of stores such apples are heavily discounted. The offering of bruised fruit discourages the interest of both seller and buyer, at the expense of the producer. Often the industry as a whole suffers in consequence, not only because of low profits but also because consumers turn to more attractive competing fruits, fresh, frozen, or canned. which may be available in the same store.

Examination of the apples before they are removed from the original container shows that much of the bad bruising occurs after the fruit is packed. The greatest single factor in producing this damage is the insistence of "the trade" on a high bulge or heavy pack so that apples can be bought by the package and sold by the pound. A high-bulge pack will usually bring the producer a few cents more than one that is merely tight (as distinct from a slack pack); so many growers make it a rule to put on the high bulge. Since such packs are favored in the wholesale trade but ultimately result in slowing down retail sales. their widespread use points to a notable lack of coordination among the various factors concerned in the handling of the commercial apple crop. However, for the reasons indicated, it is not likely that this situation can be corrected without an industry-wide effort. If the grower or packer could reach the consumer directly, the practice would be abolished very quickly, but when they contact each other only remotely, and then through intermediaries whose interest in apples as such is only incidental, the problem is made very difficult.

Results of a survey conducted in the winter of 1940–41 by P. C. Crandall [2] in the retail stores of Columbus, Ohio, reported as follows, show the extent to which bruising is found in apples offered for sale in retail stores:

In determining the various types of damage, the following classification was used: 1. *Slightly bruised*—(Enough damage to affect the external appearance); 2. *Severely bruised*—(Many small bruises or large bruises an inch or more in diameter); 3. *Undecayed skin breaks;* 4. *Decayed skin breaks.*

. . . the average grocer's display [of apples was found to contain the following:]

Sound fruit	57.9%
Slightly bruised	21.9
Severely bruised	11.4
Skin breaks, undecayed	5.2
Skin breaks, decayed	3.6

. . . Since almost all of the fruit examined came either from the West Coast or from Ohio, a check was made of the extent and type of damage prevalent on the fruit from these two regions.

	Ohio	*Western*
Slightly bruised	20.2	24.1
Severely bruised	8.0	15.3
Skin breaks	6.6	3.5
Decayed skin breaks	4.4	2.7
Sound	60.9	54.3

[2] Reported in: NOLD, TRUMAN. HOW APPLES DECLINE IN VALUE. National Apple Institute, Columbus, Ohio, Bul. 35, [3] pp. 1941. [Processed.]

. . . The Western fruit showed a large percentage of bruises caused by high pressures . . . Some boxes of fruit came through with very few if any pressure bruises while others had as high as 50 percent severe bruising. Much of the damage is due to over-packing the boxes in an effort to secure a heavy pack . . .

The Ohio-grown apples showed severe bruises that were evidently caused, for the most part, by careless handling. Some of the severe bruising can be attributed to the packing methods and containers . . .

The practice of overpacking alone accounts for many of the bruises present on the apples in the grocers' displays. For every apple added to form an extra large bulge, there is at least one severely bruised apple and several slightly bruised ones. The extra weight added in the form of a large bulge is more than off-set by the waste and falling-off in condition due to over-packing . . .

The type of package used has an important bearing on the prevalence and severity of bruising that occurs in the handling of packed fruit. The continuous stave bushel basket is so generally recognized as being unsuitable for fruit that it is not necessary to cite experimental results to prove the point. Nevertheless, this package is still used to some extent for apples. It is impossible to get and keep a firm tight pack in this type of basket. The nonrigidity of any side of the package makes it give under pressure and permits the apples to be bruised or punctured in much the same way that they are when a bag is used as a picking container (p. 16). The nonrigidity of such baskets is especially objectionable when they are stacked in storage or during transit.

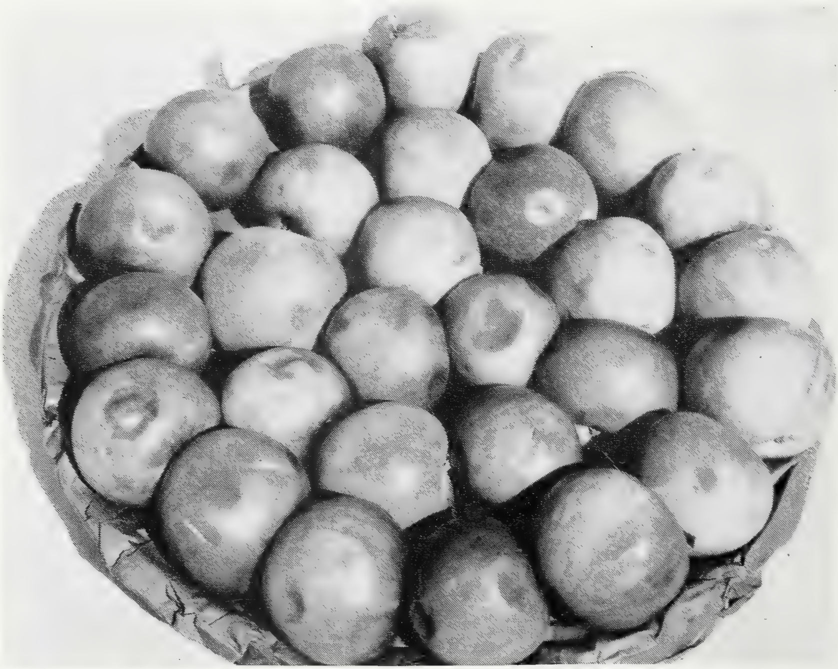

FIGURE 11.—Bruised and cut Stayman Winesap apples from the top layer of tub type bushel basket that was packed too tightly. Note that all apples except one, which are arranged to show injuries, were cut or badly bruised.

The export tub is much superior to the continuous-stave type of bushel basket. It has rigid sides and bottom, and the lid provides enough tension to keep the pack tight when it is properly packed. Overfilling this package is likely to result in rim cuts as well as in bad bruising from pressure of the lid (fig. 11). Use of a liner around the sides and a cushion or pad under the lid, although retarding cooling as shown in table 1, is always desirable with bushel baskets, in order to reduce the hazard of puncturing the apples by sharp edges of the staves and the ends of the staples, which sometimes project on the inside.

Close sizing of the fruit and "place packing," or regular alinement, of the fruit in the box are important in reducing the amount of bruising in packed apples (fig. 12,*B*). Western apple packs are far superior to the usual eastern packs, because for the most part mechanical sizing machines are used in the West and variations of more than one-fourth of an inch in the diameter of apples in a package is rare. Each size is packed according to a mathematical pattern. Also each apple is wrapped separately; this affords considerable protection against bruising. In the East, on the other hand, apples are often separated into not more than two sizes, those larger or smaller than a stated minimum, usually 2½ inches, 2¾ inches, or 3 inches in diameter. Packages may be faced with apples of approximately the same size, but the "jumble fill" gives opportunity for a good deal of bruising both because the apples are not placed and because when different-sized apples are packed together there is an uneven pressure of one fruit against another that results in bad bruising of some of the apples. Table 3 presents typical results obtained

TABLE 3.—*Comparison of bruising of Stayman Winesap apples packed in standard apple box (northwestern box) and 1⅕-bushel eastern crate*

Package	Apples badly bruised—	
	Against each other	Against package
	Percent	*Percent*
Standard box	4	[1] 14
1⅕-bushel eastern crate	12	[2] 29

[1] The distribution of this bruising was as follows: Top and bottom layers (against padded lids), 1 percent; sides and ends (no pads, but paper liners over sides), 13 percent.
[2] The distribution of this bruising was as follows: Top layer (against pad), 1 percent; bottom layer (no pad), 12 percent; sides and ends (cardboard liners but no pads), 16 percent.

in studies made by the United States Department of Agriculture of bruising of apples packed in a 1⅕-bushel eastern apple crate as compared with packing in a standard apple box. The apples were from the same lot and were packed at the same time in a Virginia orchard, after which they were hauled by truck to Washington, D. C., and held in cold storage for several months before final examination. Those packed in the standard box were sized to pack 100 per box, whereas those in the eastern crate were sized "3 inches larger" in accordance with commercial practice. In the standard box the apples were wrapped in oiled paper, while in the eastern crate shredded oiled paper was used. Both packages had liners. Both likewise

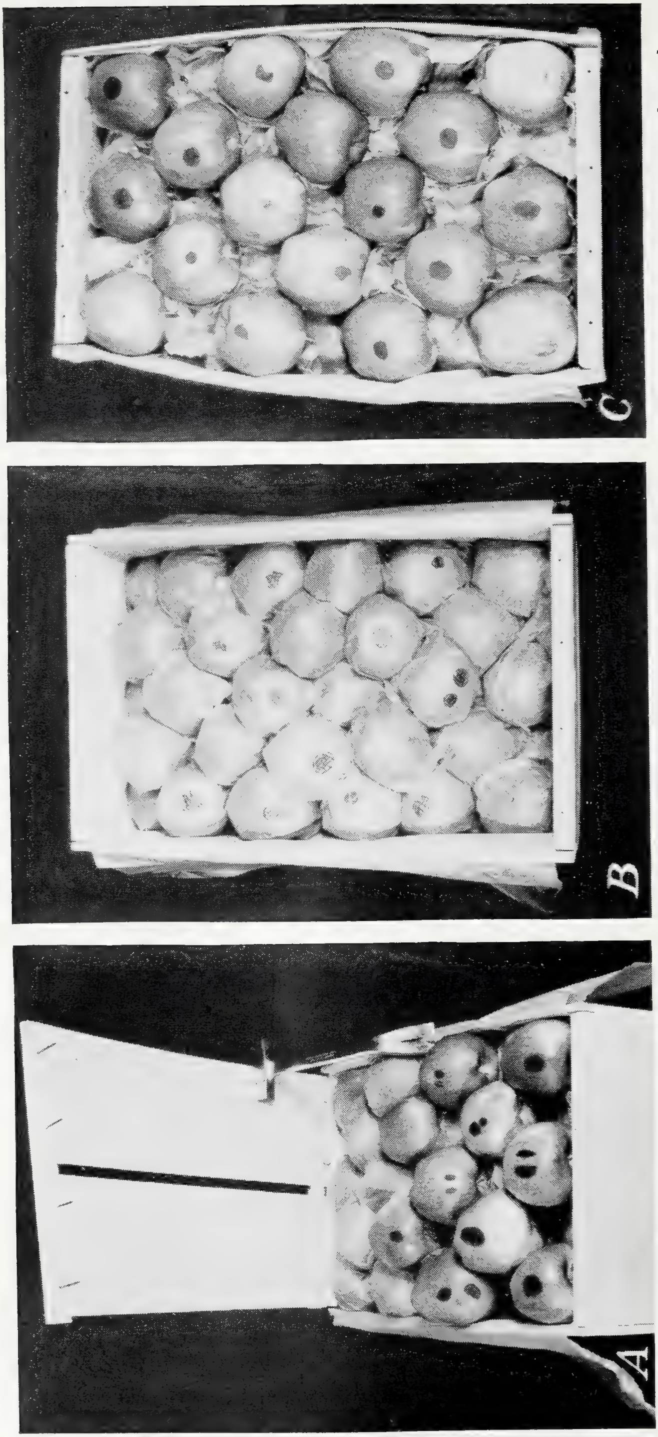

FIGURE 12.—Bruised apples from overfilled standard box, like those in figure 13: *A*, Severely bruised top layer, which could have been protected by a pad; *B*, second layer showing outlines of bad bruises caused by pressure of first layer but increased by uneven sizing of the fruit; *C*, side layer showing bruises caused by stacking boxes on bulged sides.

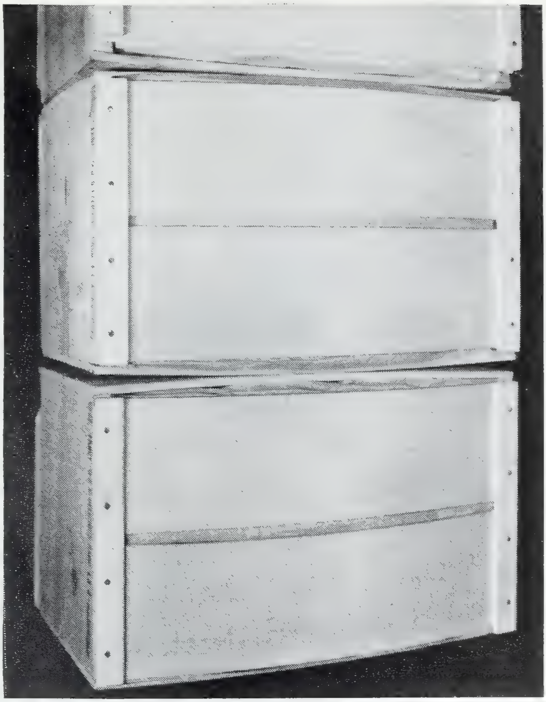

FIGURE 13.—Bulging of top, bottom, and sides of standard boxes because of overfilling. When such overfilled boxes are put under pressure in a stack serious bruising results on apples in contact with the sides as well as the lids.

had pads under the lids, but only the standard box had a pad in the bottom, in accordance with customary practice in the eastern United States. The data in the footnotes of table 3 indicate clearly that to prevent bruising it is beneficial to place a pad on the bottom as well as on the top of the package.

When western apples are found to be badly bruised, it is usually because of poor sizing, poor alinement, or overfilling the boxes (fig. 13), as already pointed out, or because of the jolting which they experience in the bottom layers of the car during shipment. It is not uncommon to find every apple in contact with the bottom side of the bottom layer flattened by the vibration or pounding of the floor of the car (fig. 14). As pointed out by Rose and Lutz (*14*), this type of injury, sometimes mistaken for freezing damage, can be prevented by use of a resilient cushion liner between the apples and the side of the box. Some packers customarily use the so-called 4-way pads that are effective in preventing this damage.

Sometimes apple boxes are overfilled to such an extent that they bulge on the sides, which are supposed to be rigid, as well as on the top and bottom (fig. 13). When a standard apple box rocks in a stack, the fruit is sure to be badly bruised before it reaches the market. Figure 12, *A* and *C*, shows the common appearance of such fruit when it is unpacked for sale.

Various types of fiberboard containers are likewise in use to some extent. Some of these are packed similarly to the standard box and are especially designed to eliminate bruising due to pressure of top and bottom lids (fig. 15). Others, particularly in eastern sections, have egg-crate-type cells for the individual apples (fig. 16). These probably afford maximum protection against bruising, but because of the diversity of shape required to package different-sized apples it is difficult to load these satisfactorily in refrigerator cars or trucks for shipment or to stack them economically in cold storage. Corrugated fiberboard is a good insulating material and, conse-

FIGURE 14.—Rome Beauty apples showing typical flattened bruises produced by jolting or vibration of the standard box against the car floor. Such injury can be prevented by a cushion liner.

quently, it is somewhat harder to cool apples packed therein than in ordinary wood boxes, especially when they are sealed up tightly (fig. 15).

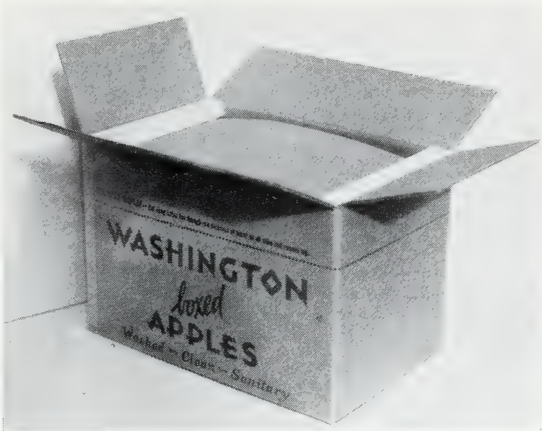

FIGURE 15.—Corrugated fiberboard box, packed in the same way as the standard box. Note how this container takes care of the bulge and that when the package is closed there is no opportunity for ventilation.

This is especially true when the cartons are stacked tightly together like bricks, with no chance to get cold air around each package. Another objection which militates against the widespread use of fiberboard packages is the fact that containers made of this material hold the fruit less rigidly in place than wooden containers. Since they are not ordinarily moistureproof, the high humidity desirable for apple storage causes fiberboard containers to soften during the storage season. Thus when the apples come out ripe and in greatest need of protection against pressure, fiberboard containers are usually even less rigid than in the fall and are less capable of affording protection than those made of wood.

Prepackaging for the Consumer

There have been recurrent attempts to market apples packed in small containers of various sizes. These have varied from one-half bushel down to six or eight individual apples packed for the retail trade. As a rule, apples so packed are not subjected to as much hazard of bruising as in larger containers, but they are likewise more difficult to cool quickly and adequately and often are not protected against scald by use of oiled paper. Ordinarily the fruit is not displayed as well as in larger packs, and, unless the packages are opened for examination, customers do not know the condition of the fruit until it has been taken home. In consequence of these and other factors, unless the apples are freshly packed it is not probable that use of such packages can be looked to as a solution of the problem of getting apples to the consumer in the best condition.

THE SHIPPER'S RESPONSIBILITY

Many apples are shipped to markets long distances from producing areas and frequently are in transit from 1 week to 2 or 3 weeks before being unloaded. Most of the shipments are made in refrigerator cars. The type of protective service that they receive in transit depends on what is ordered by the shipper. It may be ventilation, refrigeration, or protection against freezing by heater service.

Because apples are not a highly perishable fruit, like the peach or strawberry, for example, and move during the cool seasons of the year, many shippers order their cars shipped under ventilation. Under this service no particular control of the temperature of the load is possible, the vents being kept open at all times when the outside temperature is above a stated minimum, usually 32° F., and are closed when the outside temperature drops to this minimum. If the fruit is warm when it is loaded, cooling in transit depends entirely on encountering colder outside temperatures. If the fruit is colder than the outside temperature,

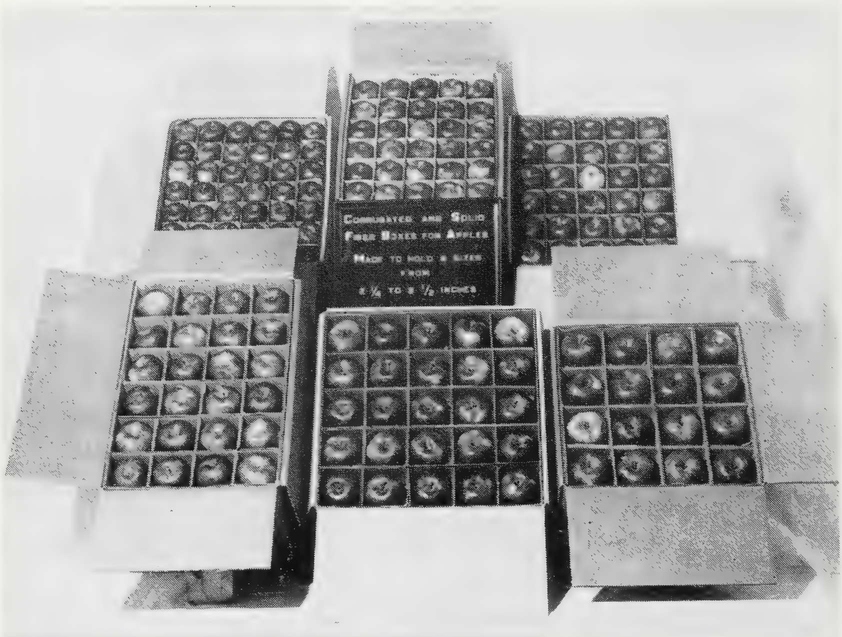

FIGURE 16.—Egg-crate type of fiberboard containers, which afford maximum protection against bruising. The diversity of shapes required for different-sized apples is a disadvantage.

the load will warm up. This is particularly likely to occur with shipments from cold storage. Such shipments should never be forwarded under ventilation service. If transit refrigeration is not desired, they should be billed "Plugs in. Vents closed to destination." Thus the refrigeration stored up in the cold load can be utilized throughout the trip.

Movement under ventilation is the cheapest service available to the shipper. From the standpoint of the condition of the fruit, the use of ventilation is justified only with apples that are intended for immediate use. With apples intended for storage at destination, ventilation service jeopardizes their potential storage life because of the rapidity with which the ripening process proceeds at warm temperatures, as already pointed out (p. 8). Consequently, as a rule, apples that move under ventilation are not worth as much as those that are refrigerated in transit. This does not mean that ventilated shipments necessarily sell for less than refrigerated consignments, but it does mean that they are likely to give less satisfaction to the consumer, thereby doubtless indirectly affecting the market for apples in general. Shippers who use ventilation service indiscriminately are to that extent increasing the hazards of the industry and inviting dissatisfaction among consumers, which must affect the demand for apples.

Shipments can be billed to move under standard refrigeration or various modifications thereof. Under standard refrigeration the bunkers of the car are initially iced to capacity and are refilled at all regular icing stations en route (usually at least once every 24 hours), and the car is delivered with bunkers at least three-fourths full. When shipments are precooled or are loaded out of cold storage and move under standard refrigeration, maximum protection is secured.

Sometimes modified refrigeration services can be utilized to effect savings in cost without sacrificing efficiency of refrigeration, and shippers are utilizing such services to an increasing extent. It is possible, however, that some apple shippers are going too far in this direction. The apple does not ripen as rapidly as some other fruits, but every day that it is kept above the optimum storage temperature means a progressive shortening of the time before it will become full ripe, and presently thereafter, overripe and undesirable or unsalable. Consequently, the use of protective services providing relatively warm temperatures during the transit period interjects an element of hidden damage to the potential storage quality of the fruit. The degree to which this damage may be hidden, or the time at which it will become apparent in the ripening of the fruit depends on the condition of the apples at time of shipment and their temperature while in transit. It is more likely to be serious with varieties like the Jonathan, Rome Beauty, and Delicious, which are often left on the trees until past proper picking stage in order to get more red color, than with later keeping varieties, such as Winesap and Yellow Newtown.

The effects of hidden damage of the type described are probably seen to the greatest extent in shipments that move under heater service. Mallison, Gorman, and Hukill (*12*) found that the use of heater service often means the occurrence of temperatures in the car during cold weather that call for the use of refrigeration during warmer weather. Such inconsistency is due to the impossibility of closely regulating the amount of heat supplied and the distribution of that heat in the car with ordinary heating devices and the method of using them now commonly employed. As pointed out by Mallison and others (*12*), much improvement should be possible in heater service by the use of thermostatically controlled car heaters or of manually controlled heaters operated upon the basis of temperatures inside the car, rather than of outside temperatures. Under present practices freezing temperatures are sometimes found in the bottom of the load when temperatures are up to 60° F. or higher in the upper layers. Unquestionably a great deal of damage has been done to winter shipments of Delicious and other varieties, which are especially prone to become mealy, by the heater service used to protect the fruit against freezing while in transit. This is particularly true of apples grown in the Pacific Northwest and shipped to eastern markets.

THE DEALER'S RESPONSIBILITY

From the foregoing discussion it might appear that the condition and quality of the apples have been predetermined by what has happened to the fruit before it reaches the dealer. This is true in large measure, but there are a number of things that the dealer can do to reduce deterioration of the apples that he buys for resale. To list them would be for the most part to repeat the factors already enumerated, but with special application to conditions under the dealer's control.

It should be unnecessary to emphasize further that apples begin to deteriorate as soon as they are mature and begin to ripen. The rate of deterioration varies with the variety and particularly with the way in which the individual lot of apples is handled, especially with the temperature at which it is held. It should be axiomatic then that apples do not improve in storage and that the best that can be done is to slow up the rate at which they will deteriorate. Even if they are good and sound when stored, they are bound to be less so when they are removed for sale.

The first responsibility of the dealer should be to buy good fruit, but this does not necessarily mean buying fruit marked "Extra Fancy" or "U. S. No. 1." These grade designations, even though they may have honestly described the quality of the fruit at the time of packing, do not reflect changes in condition, such as ripeness, decay, and scald, that have taken place during the storage period. The buyer

FIGURE 17.—Retail display of apples mostly in their original containers, in which they keep best, and away from potatoes and root crops, from which they may absorb odors, and from leafy vegetables, which are sprinkled to keep them fresh.

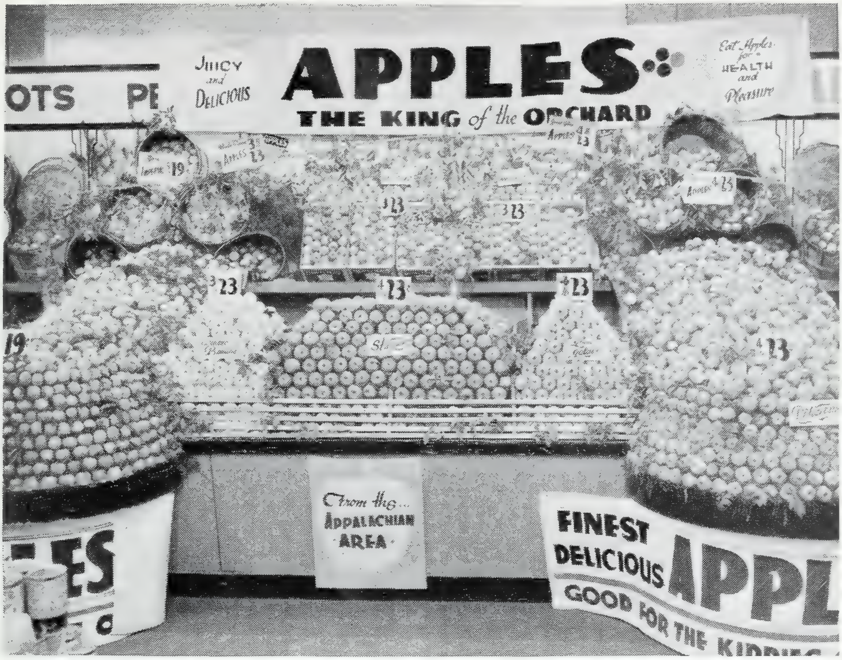

FIGURE 18.—Attractive mass display of apples. Careless handling and piling of such large masses of apples may cause bad bruising and stem punctures and result in decay unless the fruit is consumed quickly.

should have the apples inspected at the time he intends to purchase them in order to determine the extent to which deterioration has progressed since the apples were graded and packed. Most dealers make such inspections themselves or have the opportunity to do so. Hence, if they buy fruit that is badly bruised, overripe, more or less decayed, misshapen, wormy or scale infested, or culls, presumably they do it with the intent to offer that class of fruit to customers.

Next to bad bruising, overripeness is the greatest cause of complaint among retail purchasers. How often is heard the criticism: "Nice-looking large red apples, but mealy and tasteless." That always means overripe apples. How fast do apples get overripe? The answer depends on the temperature—in the retailer's store as well as in commercial storage or in the hands of the grower after harvest. As pointed out earlier (p. 8), apples ripen about twice as fast at 70° as at 50° F., twice as fast at 50° as at 40°, and twice as fast at 40° as at 32°. If they are ripe when bought for sale, some kinds (Delicious in particular) can become overripe and mealy in 2 or 3 days at ordinary store temperatures and in even less time if they are piled behind windows for display and are not protected against hot sunshine. The safest procedure for a retail merchant is to regard apples from cold storage late in the season as being as perishable as peaches at the height of their season and to move the apples into consumers' hands before they have a chance to get overripe and out of condition.

Apples purchased in small lots usually cost more than those obtained in large quantity; hence, retailers may buy more than they can dispose of before the fruit gets overripe. Unless refrigeration facilities can be utilized, the merchant who would sell only apples not beyond their prime should obtain fresh stock from cold storage at intervals of not over 2 or 3 days rather than hold a surplus at warm temperature. If some of the fruit must be held over, especially during warm weather, the best place to keep the apples is in a refrigerator. Some stores have a special walk-in refrigerator for fruits and vegetables; others utilize space in the meat cooler. If refrigeration is not available, the apples will benefit by being held in a cool, well-ventilated place, perhaps in the stockroom where screened or barred windows can be left open or in a cool basement room.

Packed boxes should always be stacked on the side (fig. 13), never on the top, which is bulged to hold the fruit in place, or on the ends, as this will concentrate the weight on a smaller area and increase the chances of bruising. Only when the top is removed and pressure is released, is it safe to let the boxes rest on the bottom lid. Bushel baskets should be staggered by placing one basket on the edges of two others, keeping all pressure away from the center of the lids (fig. 4). To provide good air circulation, which is needed to keep the fruit cool in warm weather, containers of apples should be kept away from outside walls and should be placed on a false floor or slatted platform with 3 or 4 inches of air space beneath. These measures will also reduce danger of freezing damage in cold weather.

In displaying apples the fruit should be kept away from potatoes, onions, and other root crops from which they may absorb odors. Apples should also be kept away from wet, green leafy vegetables that are sprinkled to keep them fresh, and of course the apples themselves should never be sprinkled, as this may stimulate decay. However, apples deteriorate rapidly when exposed in warm, dry air; hence, most of the stock should be kept in the original containers (fig. 17). Displays should not be made near radiators, stoves, or sunny windows, and they should be of such size that they will have to be renewed frequently with fresh stock.

Frequently dealers make mass displays of apples (fig. 18), removing them from the containers and piling the fruit in pyramids or otherwise in large lots. This contributes to bruising damage unless very carefully done. In self-service stores, where customers are free to select the fruit that they purchase and where in consequence it may be handled over a good deal, the bruising is increased considerably after the apples are put on display. The extent of this damage, of course, varies, but that it may be serious is shown by the conditions observed in one of the stores covered by Crandall in his survey.[3] He examined the fruit in original containers just as it was delivered to the store and also some of the same lots as they were displayed for sale. The results presented in table 4 show that, although handling in the store increased the damage considerably, most of the bruising was present when the apples were unpacked.

These results reported by Crandall are in general agreement with those reported by Kross and Slamp,[4] who made a somewhat similar study in New Jersey. They examined apples on display in retail

[3] See footnote 2.

[4] Kross, John I., and Slamp, K. R. SELLING APPLES DIRECTLY TO RETAIL STORES. N. J. Agr. Col. Ext. [unnumbered], 9 pp. New Brunswick, N. J. 1941. [Processed.]

TABLE 4.—*Condition of apples before they were unpacked and after display for sale*

Variety	Sound in original package	Sound when on display
	Percent	*Percent*
Jonathan	64	54
Golden Delicious	72	48
Baldwin	93	43
Greening	71	56

stores and found that 42 percent of the apples showed old bruises and only 8 percent had fresh bruises, apparently as a result of handling in the stores.

If the retailer would give his trade the kind of apples that will stimulate demand, he must consider the variety as well as grade and condition. In order to make even such a rough classification as eating apples and cooking apples, as is frequently done in grocery stores, the dealer needs to know something about the principal commercial varieties so that, for example, Rome Beauty, York Imperial, or even Ben Davis will not be offered as eating apples or Delicious as a good baking apple because it has good size. He also needs to know when each is in season. It is not uncommon to find Jonathans and Winesaps offered together. In the fall only the former could give satisfaction, but in late spring the Winesap would be preferred.

While there are upwards of 200 varieties of apples grown more or less in the United States, the list of those that may be regarded as the principal commercial kinds is comparatively short and is given in table 5 where they are classified as to color, whether they are best for eating or cooking, whether their flesh is soft or firm, and when they are in season or can be expected to be at their best. More information on apple varieties can be found in Farmers' Bulletin 1883 (*8*).

The information in table 5 is needed for the intelligent buying and handling of apples. Some of the varieties listed are good for both eating out of hand and for sauce, pie, or other culinary purposes, but others are best adapted to one or the other of these uses. Yellow Transparent, for example, is too acid to be appreciated by most people

TABLE 5.—*Characteristics of principal commercial varieties of apples*

Variety	Color	Principal use	Flesh when ripe	Marketing season
Yellow Transparent	Yellow	Cooking	Soft	July to August.
Gravenstein	Striped	Eating and cooking	do	July to September.
Wealthy	Red	do	do	September to December.
McIntosh	do	do	do	September to January.
Grimes Golden	Yellow	do	Firm	Do.
Jonathan	Red	do	do	September to February.
Delicious	do	Eating	do	September to April.
Rhode Island Greening	Green	Cooking	do	October to March.
Golden Delicious	Yellow	Eating and cooking	do	October to April.
York Imperial	Red	Cooking	Hard	October to March.
Stayman Winesap	do	Eating and cooking	Firm	November to April.
Baldwin	do	do	do	Do.
Rome Beauty	do	Cooking	do	November to May.
Yellow Newtown	Green or yellow.	Eating and cooking	Hard	January to June.
Winesap	Red	do	do	Do.

for eating out of hand, but for sauce or pie it is considered one of the best. Delicious, on the other hand, is so lacking in acidity that it is not adapted for most culinary uses but is the leading variety for the fruit-stand trade.

The character of the flesh of a variety when ripe is an important consideration for all handlers of apples, since in general it indicates the susceptibility of the fruit to bruising and how it will withstand handling, especially in bulk or in the retailer's bins. Important in this connection also is the color of the fruit. Those listed as "soft" in table 5 are most likely to become badly bruised, while those listed as "hard" are less likely to be damaged by ordinary handling. Those marked "firm" are intermediate in this respect. As a rule varieties that are solid yellow or green show bruising much more readily than red or striped varieties, although actually they may not be bruised to any greater extent. Consequently they have to be handled much more carefully if the appearance of the apples is not to be affected.

The marketing season indicated for the different varieties in table 5 is the period during which commercial supplies of these apples should be at their best. If found on the market earlier the apples are likely to be unsatisfactory either because of immaturity (being picked too soon) or because they have not had a chance to ripen sufficiently. If they are offered later than their normal marketing season they may still be in good condition and may still give consumer satisfaction if they have received exceptional care in handling and storage but the hazards of their soon becoming overripe or of quick breakdown are greatly increased. Much of the complaint about overripeness in apples is due to their being stored beyond their normal marketing season.

THE INDUSTRY'S RESPONSIBILITY

The most practical approach to the problem of getting good apples to the consumer seems to lie in a close coordination of all elements in the industry to apply good handling methods at all times during the marketing process according to the principles outlined herein. For any such effort to succeed will doubtless require the initiative to be taken by apple producers and shippers. They are not only the most immediately concerned but also possess the requisite knowledge and appreciation of the technical requirements in handling the apple. Their business is often tied up closely with apples alone, whereas to others in the trade apples are only one item of merchandise. Success of such an undertaking also is dependent on sustained industry-wide cooperation rather than on the sporadic initiative of individuals. It can perhaps best be attained through the specialized organizations that have been set up for the purpose of promoting the sale of apples generally. With adequate support of these organizations by growers and shippers, and close-knit cooperation between such organizations in different parts of the country particularly, much could be done. Success would require an educational or demonstration program based on two fundamentals that apply to all in the industry: (1) The intrinsic worth of the apple as an article of diet and (2) the necessity of keeping apples in good condition to maintain their intrinsic worth as food.

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