U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 40.

B. T. GALLOWAY, *Chief of Bureau.*

COLD STORAGE, WITH SPECIAL REFERENCE TO THE PEAR AND PEACH.

BY

G. HAROLD POWELL,

ASSISTANT POMOLOGIST IN CHARGE OF FIELD INVESTIGATIONS,

AND

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POMOLOGICAL INVESTIGATIONS.

ISSUED SEPTEMBER 18, 1903.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable, Pathological, and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

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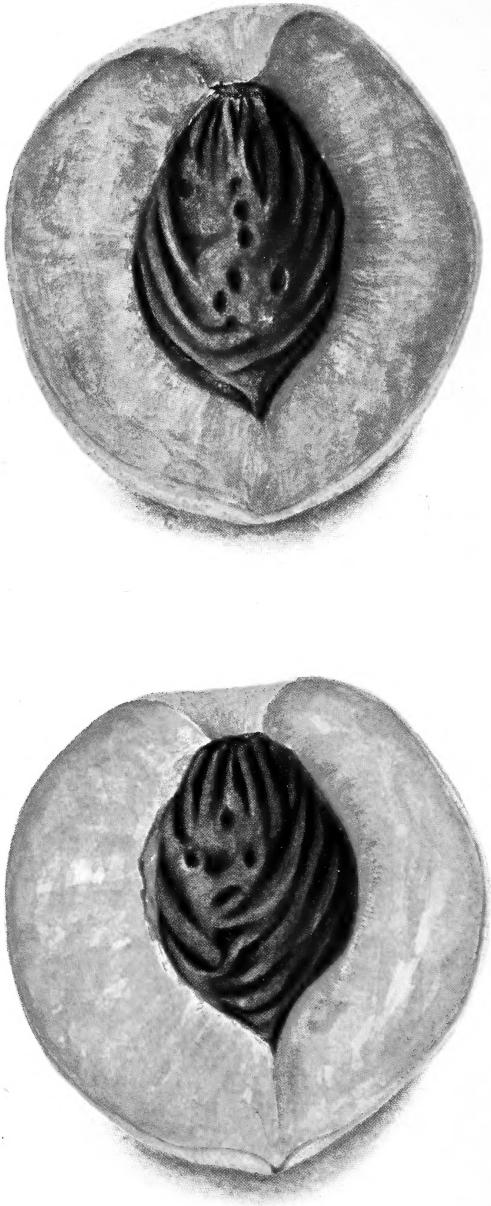

ELBERTA PEACHES, STORED FOR TWO WEEKS IN A TEMPERATURE OF 36° F. (UPPER FIGURE) AND 32° F. (LOWER FIGURE.) NATURAL SIZE.

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BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY, *Chief of Bureau.*

POMOLOGICAL INVESTIGATIONS.

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LETTER OF TRANSMITTAL

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 11, 1903.

Sir: I have the honor to transmit herewith a paper entitled "Cold Storage, with Special Reference to the Pear and Peach," and respectfully recommend that it be published as Bulletin No. 40 of the series of this Bureau.

This paper was prepared by Mr. G. Harold Powell, Assistant Pomologist in Charge of Field Investigations, and Mr. S. H. Fulton, Assistant in Pomology, and has been submitted by the Pomologist with a view to publication.

The illustrations which accompany this report, comprising five colored and two half-tone plates, are considered essential to a full understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The protection of fresh fruits, through the agency of low temperatures in cold storage houses, against their normal deterioration and decay has become in recent years one of the most important factors affecting the prosperity of the commercial orchardists of the United States. Practical experience has demonstrated the necessity for more complete and accurate knowledge regarding the possibilities of preserving fruit in wholesome condition in this way and the underlying principles that govern the behavior of fruits thus stored, as well as the effect of different cultural and climatic conditions upon the behavior of stored fruit.

The investigation of different phases of this subject was begun in the summer of 1901 and is still in progress. While the completion of these important investigations, which involve repeated experiments with different varieties of fruit grown under the varying climatic conditions of different parts of the country and stored in different warehouses, will of necessity extend over a considerable period of time, the important economic results thus far attained make the publication of this preliminary report upon the subject advisable at this time. In this report certain general principles are stated for the benefit of fruit growers, dealers, and storage men, and such specific application is made of these principles to the peach and pear in storage as experience thus far has proved desirable. Other phases of the work are in progress and will be discussed in future publications.

This bulletin has been prepared by Mr. G. Harold Powell, Assistant Pomologist in Charge of Field Investigations, and Mr. S. H. Fulton, Assistant in Pomology, as the result of investigations made by them under the direction of Mr. William A. Taylor, Pomologist in Charge of Field Investigations. The work, in so far as these fruits are concerned, has been closely associated with the experimental export shipments of fruits, which will be reported upon in a future bulletin.

G. B. Brackett,
Pomologist.

Office of Pomological Investigations,
Washington, D. C., March 19, 1903.

CONTENTS.

ILLUSTRATIONS.

COLD STORAGE, WITH SPECIAL REFERENCE TO THE PEAR AND PEACH.

THE FUNCTION OF COLD STORAGE.

Fruit is placed in cold storage to retard the life processes which as they progress cause it to ripen and decay. The ripening goes forward more slowly in low temperatures, but still continues in the lowest temperatures in which the fruit may be safely stored. Fruit is stored also to prevent the rapid spread of fungous diseases which cause its premature decay.

A fruit is a living organism, with a life history extending from its earliest growth to final decay, and the cold-storage treatment is designed to retard development without injuring its usefulness in other respects. The rapidity of ripening in the storage temperature depends principally on the habit of the fruit, the degree of maturity at which it enters the storage house, and the temperature and other conditions in which it is stored. It is influenced also by other factors during its growth and by the treatment it receives before it reaches the storage house.

The warehouse is expected to supply a uniform temperature of the desired degree of cold through the storage compartments during the storage season. It is expected to be managed in other respects so that an unusual loss in the aroma and flavor of the fruit, in texture or in color, or through decay, may not be attributed to a poorly constructed or installed plant, or to its negligent or improper management. If the temperatures are maintained reasonably uniform at the point desired by the fruit storer, if the rooms are kept pure and sweet and laden with sufficient moisture, and if the fruit is handled properly within the warehouse, the storage house fulfills its function in the preservation of fruits. If, on the other hand, the temperatures fluctuate unduly and the fruit freezes to the point of injury, or is made to ripen prematurely, or the rooms are not properly managed, or if ordinary care is not exercised in other respects in the management of the house or the handling of the fruit, the storage house fails to fulfill its proper function.

The warehouseman does not insure the fruit against natural deterioration. He holds it in storage as a trustee, and in that relation is bound to use only that degree of care in the management of the warehouse

that a man of ordinary prudence would exert under the circumstances in protecting the goods if they were his private property.

It is frequently assumed that the cold-storage house in some mysterious way levels the differences that naturally exist in the fruits of a given kind, causing all the apples of a variety, for example, to keep alike. No assumption, however, could be more fallacious, and it is probable that no one aspect of the storage business has led to more misunderstandings between the men who store fruit and the warehousemen than this unfortunate impression. Cold storage can not improve the physical condition of fruit, and is in no way responsible for the deterioration that may arise from improper picking, grading, packing, and handling before the storage house is reached.

Fruits of all kinds are profoundly modified by the climate, the soil, the age and health of the trees, and the conditions to which they are subjected during their development, and these acquired differences will manifest themselves in the storage rooms just as they do in normal storage ripening, except that they usually appear later.

THE PURPOSES OF FRUIT STORAGE.

In the consideration of any storage problem it is important to pay due attention not only to the influences which affect the keeping quality of fruits and to the function of the cold-storage plant, but also to the purpose for which the fruit is stored. The fruit dealer may not always desire to retard the development of the fruit to the greatest possible extent. For the Holiday trade it may be advisable to have certain varieties of apples or pears in condition for immediate consumption during the Christmas season, though the same varieties might be retarded until April if stored in a lower temperature. The fruiterer who takes the fruit from the storage house to the fruit stand from day to day may desire it to ripen and color considerably before it leaves the storage house. The dealer, on the other hand, who stores the same varieties in large quantities for export trade or for late domestic markets has a different object in view, and the two distinct purposes would influence the storage treatment of each.

It is equally important to consider the requirements of the market in the storage of different fruits. The commercial use of a particular fruit is limited principally to the season when people are in the habit of buying it, and beyond that period the demand is restricted, unless there is a failure in the supply of other fruits that normally fill the market at that time. It is possible to hold many varieties of pears till late winter or early spring, but the usual demand for them at that time would not warrant their storage in large quantities, as apples and oranges are then at the height of their season. In fact, it is doubtful whether it is advisable to store pears of any kind in large quantities

after the middle of November. For the same reason it is usually not a good plan to hold apples in large quantities later than the 1st of May, when fresh vegetables and the new crop of Southern fruits begin to fill the markets. The general principles, therefore, which govern the preservation of fruits and their relation to the markets can be understood only when these various factors are considered together.

INFLUENCE OF COLD STORAGE ON THE PEAR INDUSTRY.

Before the advent of the cold-storage business the supply of summer pears frequently exceeded the demand. This condition of the markets, which were demoralized in hot, humid seasons, pertained especially to the early varieties, like the Bartlett, which ripen in hot weather and need to be sold in a short time to prevent heavy losses from rapid decay. The introduction of the refrigerator car and of the cold-storage warehouse, together with the rapid growth of the canning industry, has done much to improve the pear situation by artificially establishing a well-regulated and more uniform supply of fruit throughout a longer period of time. The pear acreage of the country has more than doubled within a decade, and is enlarging the relative importance of cold storage to the pear-growing business, though a large part of the increase, especially in California, along the Atlantic coast from New Jersey southward, in Texas, and in the Central West, is primarily related to the canning industry.

Pear storage has developed most largely in the East. In New York and Jersey City from 60,000 to 100,000 bushels of summer pears, 30,000 to 60,000 bushels of later varieties, and many cars of California pears are stored annually. In Boston, since 1895 there have been stored each year from 5,000 to 15,000 bushels of early pears, principally Bartlett, and from 7,000 to 20,000 bushels of later varieties, such as Anjou, Bosc, Angouleme (*Duchess*), Seckel, and Sheldon. In Buffalo 10,000 bushels are sometimes stored in a single season, and in Philadelphia from 30,000 to 35,000 bushels. While there are no accurate statistics available and the quantity fluctuates from year to year, it is probable that as many as 300,000 bushels are stored in a single year throughout the country at large.

PRACTICAL DIFFICULTIES IN PEAR STORAGE.

There are many practical difficulties in pear storage. The early-ripening varieties which mature in hot weather, like the Bartlett, often "slump" before they reach the storage house, or are in soft condition, especially if they have been delayed in ordinary freight cars in transit. They may afterwards decay badly in storage, break down quickly on removal, or lose their delicate flavor and aroma. When stored in a large package like the barrel, the fruit, especially of

the early varieties, often softens in the center of the package, while the outside layers remain firm and green. Frequently no two shipments from the same orchard act alike, even when stored in adjoining packages in the same room, and the warehouseman and the owner, not always knowing the history of the fruit, are at a loss to understand the difficulty. It has been the aim in the fruit-storage investigations of the Department of Agriculture to determine as far as possible the reasons for some of the pear-storage troubles, and to point out the relation of the results to a more rational storage business.

OUTLINE OF EXPERIMENTS IN PEAR STORAGE.

The investigations in pear storage are of a preliminary nature only. The experiments undertaken have been planned with a view to determining the influence in the storage room of various temperatures, of the character of the storage package, of a fruit wrapper, of the degree of maturity of the fruit when picked, and of other factors in relation to the ripening processes in the storage house, and also to ascertain the behavior of the fruit and its value to the consumer when placed on the market.

The Bartlett and the Kieffer pears principally were used in the experiments, but several other kinds have been under limited observation. The Bartlett represents the delicate-fleshed, tender pears, ripening in hot weather, which are withdrawn from storage before the weather becomes cool. The Kieffer, on the other hand, is a coarse, hard pear, ripening later in the fall in cooler weather, and in which the normal ripening processes are slower. It is a longer keeper, and like other fall varieties is withdrawn in cool weather.

The Bartlett experiments extended through the season of 1902. The fruit was grown by Mr. F. L. Bradley, Barker, N. Y., in a twelve-year-old orchard on a sandy loam, with a clay subsoil. The orchard is a half mile from Lake Ontario and is 50 feet above the level of the lake. The fruit, which was full grown, but green, was picked early in September, and was packed in tight and ventilated barrels, in 40-pound closed boxes, and in slat bushel crates. Part of the fruit in each lot was wrapped in unprinted news paper, and an equal amount was left unwrapped. Part was forwarded at once by trolley line to the warehouse of the Buffalo Cold Storage Company at Buffalo, N. Y., and a similar quantity was held four days before being stored. The fruit reached the storage house within ten hours after leaving the orchard.

The Kieffer experiments have extended over two years. In 1901 the fruit was grown by Mr. M. B. Waite, Woodwardsville, Md., in a Norfolk sandy soil, on rapidly growing five-year-old trees, from which the fruit was large, coarse, and of poor quality. It was stored in the cold-storage department of the Center Market at Washington, D. C. In

1902 the fruit with which the experiments were made was grown by Mr. S. H. Derby, Woodside, Del., on heavy-bearing ten-year-old trees on sandy soil with a clay subsoil. The fruit was smaller, of finer texture, and of somewhat better quality than that used the previous year. It was stored in the cold-storage department of the Reading Terminal Market in Philadelphia, Pa.

The Kieffers were picked at three degrees of maturity: First, when two-thirds grown, or before the fruit is usually picked; second, ten days later, or about the time that Kieffers are commonly picked, and third, ten days later, when the fruit was fully grown and still green, but showing a yellowish tinge around the calyx. In each picking, part of the fruit was shipped to storage and was placed in rooms with a temperature of 36° and 32° F. within forty-eight hours. Equal quantities stored in each temperature were wrapped in parchment paper, in unprinted news paper, and were left unwrapped. A duplicate lot of fruit remained in a common storage house ten days in open boxes, when it was packed in a similar manner and sent to storage. This fruit colored considerably during the interval, but was still hard and apparently in good physical condition on entering the storage house. The pears were stored in 40-pound closed boxes and in five-eighths bushel peach baskets. One hundred and fifty bushels were used in the experiments.

THE INFLUENCE OF THE DEGREE OF MATURITY ON KEEPING QUALITY.

The experiments with the Kieffer pear show that under conditions similar to those in Delaware and eastern Maryland this variety may safely be picked from the same orchard during a period of at least three weeks, or when from two-thirds grown to full size, and that the fruit in all cases may be stored successfully until the Holidays, or much longer if there is still a demand for it. It is absolutely essential that the fruit be handled with the greatest care, that it be sent at once to storage after picking, that it be packed carefully to prevent bruising (preferably in small packages, like a bushel box), and that it be stored in a temperature not above 32° F. if it is desired to hold it for any length of time. If stored by the middle of October, the fruit, by the latter part of December, will take on a rich, yellow color when kept in a temperature of 32° F., and earlier if a higher temperature is used. The fruit may be withdrawn during the Holidays, and will stand up, i. e., continue in good condition, for ten days or longer if the weather is cool, and will retain its normal quality if the rooms have been properly managed. While the later picked fully grown pears keep well, they are already inferior in quality at the picking time, as the flesh around the center is filled with woody cells, making it of less value either for eating in a fresh state or for culinary purposes. These coarse cells in the Kieffer and some other late varieties do not develop

in the early-picked fruit to so large an extent. Pears of all kinds need to be picked before they reach maturity and to be ripened in a cool temperature if the best texture and flavor are to be developed. It is a matter of practical judgment to determine the proper picking season, but for cold storage or other purposes the stem should at least cleave easily from the tree before the fruit is ready to pick. Many trees bear fruit differing widely in the degree of maturity at the same time, and in such cases uniformity in the crop can be attained only when the orchard is picked several times, the properly mature specimens being selected in each successive picking. This practice not only secures more uniformity in ripeness, but the fruit is more even and the average size is larger than when all the pears are picked at the same time.

THE INFLUENCE OF DELAYED STORAGE ON KEEPING QUALITY.

Pears ripen much more rapidly after they are picked than they do in a similar temperature while hanging on the tree. The rapidity of ripening varies with the character of the variety, the maturity of the fruit when picked, the temperature in which it is placed, and the conditions under which it has been grown. If the fruit is left in the orchard in warm weather in piles or in packages, if it is delayed in hot cars or on a railroad siding in transit, or if it is put in packages which retain the heat for a long time, it continues to ripen and is considerably nearer the end of its life history when it reaches the storage house than would otherwise be the case. The influence of delay in reaching the storage house will therefore vary with the season, with the variety, and with the conditions surrounding the fruit at this time. A delay of a few days with the quick-ripening Bartlett in sultry August weather might cause the fruit to soften or even decay before it reached the storage house, though a similar delay in clear, cooler weather would be less hurtful. A delay of a like period in storing the slower-ripening Kieffer would be less injurious in cool October weather, though the Kieffer pear, especially from young trees, can sometimes be ruined commercially by not storing it at once after picking.

From the experiments with the Bartlett and the Kieffer pears, from which these general introductory remarks are deduced, it was found that the Bartlett, if properly packed, kept in prime condition in cold storage for six weeks, provided it was stored within forty-eight hours after picking in a temperature of 32° F.; but that if the fruit did not reach the storage room until four days after it was picked there was a loss of 20 to 30 per cent from softening and decay under exactly similar storage conditions.

The Kieffers stored within forty-eight hours in a temperature of 32° F. have kept in perfect condition until late winter, although there is little commercial demand for them after the Holidays. The fruit

grown by Mr. Waite on young trees in 1901, which was still hard and greenish-yellow when stored ten days after picking, began to discolor and soften at the core in a few days after entering the storage room, though the outside of the pears appeared perfectly normal. After forty to fifty days the flesh was nearly all discolored and softened, and the skin had turned brown. The fruit from the older trees on the Derby farm in 1902, which was smaller and finer in texture, appeared to ripen as much as the Waite pears during the ten days' delay. This fruit, however, did not discolor at the core and decay from the inside outward, but continued to ripen and soften in the storage house and was injured at least 50 per cent in its commercial value by the delay. Plate II shows the condition of the Kieffer pears stored in a temperature of 32° F. as soon as picked and withdrawn in March. Plate III shows the condition of fruit picked at the same time and stored in the same temperature ten days after picking, when withdrawn in January. (See also Pl. IV, fig. 1.)

The results of the experiments point out clearly the injury that may occur by delaying the storage of the fruit after it is picked, and emphasize the importance of a quick transfer from the orchard to the storage house. If cars are not available for transportation and the fruit can not be kept in a cool place, it is safer on the trees so far as its ultimate keeping is concerned. It is advisable to forward to storage the delicate quick-ripening varieties, like the Bartlett, in refrigerator cars. The common closed freight car in warm weather soon becomes a sweat box and ripens the fruit with unusual rapidity. The results show clearly that the storage house may be responsible in no way for the entire deterioration or even for a large part of the deterioration that may take place while the fruit is in storage, and that the different behavior of two lots from the same orchard may often be due to the conditions that exist during the period that elapsed between the time of picking and of storage.

THE INFLUENCE OF DIFFERENT TEMPERATURES ON KEEPING QUALITY.

There is no uniformity in practice in the temperatures in which pears are stored. Formerly a temperature of 36° to 40° F. was considered most desirable, as a lower temperature was supposed to discolor the flesh and to injure the quality of the fruit. The pears were also believed to deteriorate much more rapidly when removed to a warmer air. In recent years a number of storage houses have carried the fruit at the standard apple temperatures, i. e., from 30° to 32° F. Large quantities of Bartlett, Angouleme, and Kieffer pears have been stored in 32° and 36° F. in the experiments of the Department. The fruit of all varieties has kept longer in the lower temperature and the flesh has retained its commercial qualities longer after removal from the storage house. Bartlett pears were in prime commercial condition

four to five weeks longer, Angouleme two months longer, and Kieffer three months longer in a temperature of 32° F. Plates II and V show the condition of Kieffer pears in March, 1902, in 32° and 36° F., the two lots having received similar treatment in all respects except in storage temperatures. (See also Pl. IV, fig. 2.)

In the higher temperature the fruit ripens more rapidly, which may be an advantage when it is desirable to color the fruit before it leaves storage; but the fruit in that condition is nearer the end of its life history and breaks down more quickly on removal to a warm atmosphere.

There is a much wider variation in the behavior of pears that have been delayed in storage or that are overripe when they enter the storage room at 32° and 36° F. than in pears stored at once in these temperatures. In the higher temperature the fruit that has been improperly handled ripens and deteriorates more quickly. The lower temperature not only keeps the fruit longer when it is stored at once, but it is even more essential in preventing rapid deterioration in fruit that has been improperly handled.

THE INFLUENCE OF THE TYPE OF PACKAGE ON KEEPING QUALITY.

Pears are commercially stored in closed barrels, in ventilated barrels, in tight boxes holding a bushel or less, and in various kinds of ventilated crates. The character of the package exerts an important influence on the ripening of the fruit and on its behavior in other respects, both before it enters the storage house and after it is stored, though this fact is not generally recognized by fruit handlers or by warehousemen. The influence of the package on the ripening processes appears to be related primarily to the ease with which the heat is radiated from its contents. The greater the bulk of fruit within a package and the more the air of the storage room is excluded from it the longer the heat is retained. Quick-ripening fruits, like the Bartlett pear, that enter the storage room in a hot condition in large, closed packages, may continue to ripen considerably before the fruit cools down, and the ripening will be most pronounced in the center of the package, where the heat is retained longest. The influence of the package, therefore, will be most marked in the hottest weather and on fruits that ripen most quickly.

In the experiments of the Department of Agriculture the Bartlett pears were stored in tight and in ventilated barrels, in closed 40-pound boxes, and in slat bushel crates. After three weeks in the storage house the fruit that was stored in barrels soon after picking in a temperature of 32° F. was yellow in the center of the package, while the outside layers were firm and green. Plate VI shows the average condition of the fruit in these two positions one week after storing. After

five weeks in storage the fruit in the center of the barrel was soft and of no commercial value, while the outside layers were still in good condition. The difference was still greater in a temperature of 36° F., and was more marked in both temperatures in fruit that was delayed in reaching the storage house.

In both the closed 40-pound boxes and the slat crates the fruit was even greener in average condition than the outside layers in the barrels, and it was uniformly firm throughout the entire package.

There was apparently no difference between the fruit in the commercial ventilated pear barrel and the common tight pear barrel.

With the Kieffer, which enters the storage room in a cooler condition and which ripens more slowly, a comparison has been made (in 1902) between the closed 40-pound box and the barrel, and while the difference has been less marked the fruit has kept distinctly better in the smaller package. The fruit in barrels was the property of Mr. M. B. Waite, and was under observation by the Department through his courtesy.

There is a wide difference of opinion concerning the value of ventilated in comparison with tight packages for storage purposes. No dogmatic statements can be made that will not be subject to many exceptions. The chief advantage of a ventilated package for storage appears to lie in the greater rapidity with which the fruit cools, and the quickness with which this result is attained depends on the temperature of the fruit, its bulk, the temperature of the room, and the openness of the package. The open-slat bushel crate, often used for storing Bartlett pears, with which rapid cooling is of fundamental importance, may be of much less value in storing later fruits that are cooler and which ripen more slowly, and it may be of even less importance to Bartletts in cool seasons.

The ordinary ventilated pear barrel does not appear to have sufficient ventilation to cool the large bulk of fruit quickly.

The open package has several disadvantages. If the fruit is to remain in storage for any length of time its exposure to the air will be followed by wilting, which, in fruits held until late winter or spring, may cause serious commercial injury. The ventilated package, especially if made of slats, needs to be handled with the utmost care to prevent the discoloration of the fruit due to bruising where it comes in contact with the edges of the slats.

There was little difference in the behavior of the Bartletts in the closed 40-pound boxes and the slat crates at the end of five weeks, and it would appear that a package of this size, even though closed, radiates the heat with sufficient rapidity to quickly check the ripening. Therefore the grower who uses the 40-pound or the bushel pear box for commercial purposes can store the fruit safely in this package, but

if the barrel is used as the selling package, and the weather is hot, it is a better plan to store the fruit in smaller packages, from which it may be repacked in barrels at the end of the storage season. While this practice is followed in several storage houses, it is not to be encouraged, as the rehandling of the fruit is a disadvantage. Rather the use of the pear box should be encouraged as a more desirable package, both for storage and for commercial purposes.

The fruit-package question, as it relates to the storage house, may be summed up by stating that fruits like the Bartlett pear and others that ripen quickly and in hot weather may be expected to give best results when stored in small packages. If the storage season does not extend beyond early winter, an open package may be of additional value, though not necessary if the package is small. But fruits like the winter apples and late pears, which ripen in the fall in cool weather and remain in storage for a long period, should be stored in closed packages to prevent wilting. In such cases the disadvantages of a large package, like a barrel, are not likely to be serious.

THE INFLUENCE OF A WRAPPER ON KEEPING QUALITY.

The life of a fruit in cold storage is prolonged by the use of a fruit wrapper, and the advantage of the wrapper is more marked as the season progresses. In Plate VII is shown the average quantity of Kieffer pears in unprinted news paper and in parchment wrappers in comparison with the quantity of commercial unwrapped pears in boxes in January. Nearly 50 per cent of the unwrapped fruit had decayed at that time. Early in the season the influence of the wrapper is not so important, but if the fruit is to be stored until late spring the wrapper keeps the fruit firmer and brighter. It prevents the spread of fungus spores from one fruit to another and thereby reduces the amount of decay. It checks the accumulation of mold on the stem and calyx in long-term storage fruits, and in light-colored fruits it prevents bruising and the discoloration that usually follows.

Careful comparisons have been made of the efficiency of tissue, parchment, unprinted news paper, and waxed papers, and but little practical difference has been observed, except that a large amount of mold has developed on the parchment wrappers in a temperature of 36° F. A double wrapper has proved more efficient for long keeping than a single one, and a satisfactory combination consists of an absorbent, unprinted news paper next to the fruit, with a more impervious paraffin wrapper outside.

The chief advantage of the wrapper for the Bartlett pear, which is usually stored for a short time only, lies in the mechanical protection to the fruit rather than in its efficiency in prolonging its season. Its use for this purpose is advisable if the fruit is of superior grade and

designed for a first-class trade. For the late varieties the wrapper presents the same advantages, and has an additional value in increasing the commercial life of the fruit. It is especially efficient, if the package is not tight, in lessening the wilting.

THE INFLUENCE OF COLD STORAGE ON THE FLAVOR AND AROMA OF THE FRUIT.

There is a general impression that cold storage injures the delicate aroma and characteristic flavors of fruits. In this publication the most general statements only can be made concerning it, as the subject is of a most complicated nature, not well understood, and involving a consideration of the biological and chemical processes within the fruit and of their relation to the changes in or to the development of the aromatic oils, ethers, acids, or other products which give the fruit its individuality of flavor.

It is not true that all cold-storage fruits are poor in quality. On the contrary, if the storage house is properly managed the most delicate aromas and flavors of many fruits are developed and retained for a long time. The quality of the late fall and winter apples ripened in the cold-storage house is equal to that of the same varieties ripened out of storage, and the late pears usually surpass in quality the same varieties ripened in common storage.

The summer fruits, like the peach, the Bartlett pear, and the early apples, lose their quality very easily, and in an improperly managed storage house may have their flavors wholly destroyed. Even in a room in which the air is kept pure the flavor of the peach seems to be lost after two weeks or more, while the fruit is still firm, much as the violet and some other flowers exhale most of their aromatic properties before the flowers begin to wilt.

It is probable that much of the loss in quality may be attributed to overmaturity, brought about by holding the fruit in storage beyond its maximum time; but it should be remembered that the same change takes place in fruits that are not ripened in cold storage, the aroma and fine flavor often disappearing before the fruit begins to deteriorate materially in texture or appearance.

On the other hand, it is certain that the quality of stored fruits may be injuriously affected by improper handling or by the faulty management of the storage rooms. Respiration goes on rapidly when the fruit is warm. If placed in an improperly ventilated storage room, in which odors are arising from other products stored in the same compartment or in the same cycle of refrigeration, the warm fruit may absorb these gases and become tainted by them, while the same fruit, if cool when it enters the storage room, will breathe much less actively, and there will be less danger of injury to the quality, even

though the air is not perfectly sweet. The atmosphere of the rooms, in which citrus fruits or vegetables of various kinds—such as cabbage, onions, and celery—are stored, is often charged with the odors arising from these products, if the ventilation is not thorough. In small houses, in which a single room can not be used for each product, fruits are often stored together during the summer months, and at this period the storage air is in greater danger of vitiation, since it is more difficult to provide proper ventilation.

The summer fruits, therefore, being generally hot when placed in the storage room, are in condition to absorb the odors which are likely to affect the rooms during the warm season, and as the biological and chemical processes are normally more active in the case of such fruit than in fruits maturing later, the flavors deteriorate more quickly, even in well-ventilated rooms. The fruits that are picked in cool weather and enter the storage rooms in a cooler and less active condition are not in the same danger of contamination.

From the practical standpoint it may be pointed out that summer fruits should be stored in rooms in which the air is sweet and pure. They should not be stored with products which exhale strong aromas, and the danger of contamination is lessened if the fruit can be cooled down in a pure room before it is placed with other products in the permanent compartment provided for it. For the same reason the winter fruits should be stored in rooms in which the air is kept pure, and preferably in compartments assigned to a single fruit.

The experiments furnish no evidence that the quality deteriorates more rapidly as the temperature is lowered. On the contrary, all of the experience so far indicates that the delicate flavors of the pear, apple, and peach are retained longer in a temperature that approaches the freezing point than in any higher temperature.

THE BEHAVIOR OF THE FRUIT WHEN REMOVED FROM STORAGE.

There is a general impression that cold-storage fruit deteriorates quickly after removal from the warehouse. This opinion is based on the experience of the fruit handler and the consumer, and in many cases is well founded, but this rule is not applicable to all fruits in all seasons. The rapidity of deterioration depends principally on the nature of the fruit, on its degree of maturity when it leaves the warehouse, and on the temperature into which it is taken. A Bartlett pear, which normally ripens quickly, will ripen and break down in a few days after removal. If ripe or overmature when removed, it will decay much more quickly, and in either condition its deterioration will be hastened if the weather is unusually hot and humid. In the practical management of this variety it is fundamentally important that it be taken from storage while it is still firm and that it be kept

as cool as possible after withdrawal. It is probably true that all fruits from storage that are handled in hot weather will deteriorate quickly, but it appears to be equally true that similar fruits that have not been in storage break down with nearly the same rapidity if they are equally ripe. The late pears, which ripen more slowly, if withdrawn in cool weather will remain firm for weeks when held in a cool room after withdrawal. If overripe they break down much sooner, and a hot room hastens decay in either case. The same principles hold equally true with apples. The winter varieties, if firm, may be taken to a cool room and will remain in good condition for weeks or months and retain their most delicate qualities, but in the spring, when the fruit is more mature and the weather warmer, they naturally break down more rapidly.

In commercial practice fruits of all kinds are often left in the storage house until they are overripe. The dealer holds the fruit for a rise in price, and removes it, not because the price is more satisfactory, but because a longer storage would result in serious deterioration. If considerable of the fruit is decayed when withdrawn, the evidence is conclusive that it has been stored too long. Fruit in this condition normally decays in a short time, but the root of the trouble lies not in the storage treatment, but rather in not having offered it for sale while it was still firm. In the purchase of cold-storage fruit, if the consumer will exercise good judgment in the selection of sound stock that is neither fully mature nor overripe, he will have little cause to complain of its rapid deterioration.

SUMMARY.

A cold-storage warehouse is expected to furnish a uniform temperature in all parts of the storage compartments throughout the season, and to be managed in other respects so that an unusual loss in the quality, color, or texture of the fruit may not reasonably be attributed to improper handling or neglect.

An unusual loss in storage fruit may be caused by improper maturity, by delaying the storage after picking, by storing in an improper temperature, or by the use of an unsuitable package. The keeping quality is influenced by the various conditions in which the fruit is grown.

Pears should be picked before they are mature, either for storage or for other purposes. The fruit should attain nearly full size, and the stem should cleave easily from the tree when picked.

The fruit should be stored at the earliest possible time after picking. A delay in storage may cause the fruit to ripen or to decay in the storage house. The effect of the delay is most serious in hot weather and with varieties that ripen quickly. (See Pls. II, III, and IV, fig. 1.)

The fruit should be stored in a temperature of about 32° F., unless the dealer desires to ripen the fruit slowly in storage, when a temperature of 36° or 40° F., or even higher, may be advisable. The fruit keeps longest and retains its color and flavor better in the low temperature. It also stands up longer when removed. (See Pls. II, IV, fig. 2, and V.)

The fruit should be stored in a package from which the heat will be quickly radiated. This is especially necessary in hot weather and with quick-ripening varieties like the Bartlett pear. For the late pears that are harvested and stored in cool weather it is not so important. Bartletts may ripen in the center of a barrel before the fruit is cooled down. A box holding not more than 50 pounds is a desirable storage package, and it is not necessary to have it ventilated. The chief value of a ventilated package lies in the rapidity with which the contents are cooled, but long exposure to the air of the storage room causes the fruit to wilt. (See Pl. VI.)

Ventilation is essential for large packages, especially if the fruit is hot when stored and ripens quickly.

A wrapper prolongs the life of the fruit. It protects it from bruising, lessens the wilting and decay, and keeps it bright in color. A double wrapper is more efficient than a single one, and a good combination consists of absorptive unprinted news paper next to the fruit, with a more impervious paraffin wrapper outside. (See Pl. VII,)

The quality of a pear normally deteriorates as it passes maturity, whether the fruit is in storage or not, or it is never fully developed if the fruit is ripened on the tree. The quality of the quick-ripening summer varieties deteriorates more rapidly than that of the later kinds. Much of the loss in quality in the storage of pears may be attributed to their overripeness. The quality is also injured by impure air in the storage rooms, and the warm summer pears will absorb more of the odors than the late winter varieties. The fruit will absorb less if cool when it enters the storage room. The air of the storage room should be kept sweet by proper ventilation.

The rapidity with which the fruit breaks down after removal depends on the nature of the variety, the degree of maturity when withdrawn, and the temperature into which it is taken. Summer varieties break down normally more quickly than later kinds. The more mature the fruit when withdrawn the quicker deterioration begins, and a high temperature hastens deterioration. If taken from the storage house in a firm condition to a cool temperature, the fruit will stand up as long as other pears in a similar degree of maturity that have not been in storage.

It pays to store the best grades of fruit only. Fruit that is imperfect or bruised, or that has been handled badly in any respect, does not keep well.

INFLUENCE OF COLD STORAGE ON THE PEACH INDUSTRY.

Cold storage has not materially influenced the development of the American peach business, and it is not likely to do so to any extent in the future. In the early days of peach growing the industry was localized in sections like the Chesapeake Peninsula, New Jersey, and Michigan. The use of the fruit in considerable quantities was then limited to a few near-by markets and to a short time in July, August, and September. Now peach growing is rapidly extending to all parts of the country where the climatic conditions and the facilities for transportation are favorable. The refrigerator-car service has brought the peach belts and the distant markets close together, and whenever the crop is general the New York or the Chicago trade may be supplied almost continuously from May till late October with fruit from Florida, Texas, Georgia, the Chesapeake Peninsula, New Jersey, the Ozark Mountain region, Michigan, New England, California, West Virginia, western Maryland, and other peach-growing sections.

The chief value of cold storage to the peach industry will probably lie in the temporary storage of the fruit during an overstocked market, when, however, there is a reasonable prospect of a better market within two or three weeks. It might be useful also in filling the gaps between the crops of different regions, especially when there are local failures which prevent a continuous supply. It is not now profitable to store the fruit for any length of time, nor under any circumstances unless the condition of the fruit and the storage conditions are most favorable. The life processes in the peach and the weather conditions in which it is handled make it even more critical as a storage product than the delicate Bartlett pear. In normal ripening it passes from maturity to decay in a few hours in hot, humid weather. The aroma and flavor are most delicate in character and are easily injured or lost, and the influence of any mismanagement of the fruit in the orchard, in transit, or in the storage house is quickly detected by the consumer.

PRACTICAL DIFFICULTIES IN PEACH STORAGE.

Under the most favorable conditions known at present, peach storage is a hazardous business. Before the fruit is taken from the storage house the flesh often turns brown in color, while the skin remains bright and normal. If the flesh is natural in color and texture it frequently discolors within a day or two after removal. There is a rapid deterioration in the quality of stored peaches when the fruit is held for any length of time, the delicate aroma and flavor giving way to an insipid or even bitter taste. Sometimes the flesh dries out, or under other conditions it may become "pasty." Dealers in storage peaches frequently sell them in a bright, firm condition, and shortly afterwards the purchasers complain of the dark and worthless quality of

the flesh. It has often been noticed that fruit in the various packages in the same room does not keep equally well, some of it ripening and even softening while the fruit in other packages is still firm. In fact, the difficulties are so numerous that few houses attempt to store the fruit.

It has been the aim in the cold-storage investigations of the Department of Agriculture to determine, as far as possible, the cause of the peach-storage troubles and to indicate the conditions under which the business may be more successfully developed.

OUTLINE OF EXPERIMENTS IN PEACH STORAGE.

The investigations have been conducted in the cold-storage department of the Reading Terminal Market in Philadelphia, Pa., with Elberta peaches from the Hale Orchard Company, Fort Valley, Ga., and in the warehouse of the Hartford Cold Storage Company, Hartford, Conn., with Elberta and several other varieties grown by J. H. Hale at South Glastonbury, Conn.

In Georgia the fruit was packed in the Georgia peach carriers, left unwrapped, and divided into two lots, one representing fruit that was nearly full grown, well colored, and hard; the other, highly colored fruit, closely approaching but not yet mellow. Three duplicate shipments were forwarded at different times in the two bottom layers of refrigerator cars, and in each shipment part of the fruit was placed in the car within three or four hours after it was picked, and an equal quantity delayed in a packing shed from ten to fifteen hours during the day before it was loaded. Equal quantities of each series were stored in temperatures of 32°, 36°, and 40° F. The transfer from the refrigerator car to the storage house was made by wagon at night, the interval between the car and storage varying from two to five hours.

In Connecticut the fruit represented two degrees of maturity, similar to the Georgia shipments, except that the most mature fruit was mellow when stored. This fruit was grown at an elevation of 450 feet on trees six years old. It was medium in size, firm, highly colored, and of excellent shipping quality. Equal quantities were wrapped in California fruit paper and left unwrapped, and packed in the Connecticut half-bushel basket, in Georgia carriers, and in flat, 20-pound boxes, holding two layers of fruit. The peaches were forwarded by trolley to the storage house, which was reached in two hours after the fruit left the packing shed. Duplicate lots of all the series were stored in temperatures of 32°, 36°, and 40° F.

GENERAL STATEMENT OF RESULTS.

The general outcome of the experiments, both with the Georgia and the Connecticut fruit, is similar and may be summed up as follows:

The fruit that was highly colored and firm when it entered the storage house kept in prime commercial condition for two to three weeks

in a temperature of 32° F. The quality was retained and the fruit stood up two or three days after removal from the storage house, the length of its durability depending on the condition of the weather when it was removed. After three weeks in storage the quality of the fruit deteriorated, though the peaches continued firm and bright in appearance for a month, and retained the normal color of the flesh two or three days after removal. If the fruit was mellow when it entered the storage house it deteriorated more quickly, both while in storage and after withdrawal. If unripe it shriveled considerably.

In a temperature of 40° F. the ripening processes progressed rapidly, and the flesh began to turn brown in color after a week or ten days in storage. The fruit also deteriorated much more quickly after removal, as it was already nearer the end of its life history. It began to lose in quality at the end of a week.

In a temperature of 36° F. the fruit ripened more rapidly than in 32°, and more slowly than in 40° F. It reached its profitable commercial limit in ten days to two weeks, when the quality began to deteriorate, and after this period the flesh began to discolor. (See Pl. I, frontispiece.

The fruit kept well in all of the packages in a temperature of 32° F. for about two weeks, after which that in the open baskets and in the Georgia carriers began to show wilting. In the 20-pound boxes, in which the circulation of air is restricted, the fruit remained firm throughout the storage season.

It is necessary that the fruit be packed firmly to prevent bruising in transit, but if the peaches pressed against each other unduly it was found that the compressed parts of the flesh discolored after a week in storage. A wrapper proved a great protection against this trouble, especially in the baskets of the Georgia peach carrier, and in all of the packages the wrapped fruit retained its firmness and brightness for a longer time than that left without wrappers.

The fruit should be removed from storage while it is still firm and bright. The peach normally deteriorates quickly after it reaches maturity, and the rapidity of deterioration is influenced by the nature of the variety, by the degree of ripeness when removed, and by the temperature into which it is taken. A quick ripening sort, like Champion, is more active biologically and chemically than the Elberta variety, and the warmer the temperature in which either is placed the sooner decomposition is accomplished. It is advisable therefore to remove the fruit while firm and keep it in the coolest possible temperature.

The peaches in the top of a refrigerator car that has been several days in transit in hot weather are sometimes overripe and need to be sold as soon as the market is reached, while at the same time the fruit in the bottom layers may still be firm. The rapidity with which the

fruit cools down in the car depends on the care with which the car is iced, and on the temperature at which the fruit enters the car. Fruit that is loaded in the middle of a hot day and that has been picked in a heated condition may be 20 or more degrees warmer than fruit picked and loaded in the cool of the morning. Such warm fruit ripens much more rapidly, consumes more ice in cooling down, and takes longer to reach a low temperature. When the temperature in the top of the car is higher than that of the lower part the ripening of the upper layers of fruit will be hastened. If the fruit is destined for cold storage, these upper layers, if more mature, should be piled separately, and sold as soon as their condition warrants it. Under these conditions if the fruit from this position is mixed in with the rest of the load it may begin to deteriorate before the remainder of the fruit shows mellowing.

The general principles outlined in former pages for the handling of the Bartlett pear apply to the storage of the peach, except that the latter fruit is more delicate and the ripening processes are even more rapid. Every condition, therefore, surrounding the peach in the orchard, in transit, in the storage house, and at withdrawal must be most favorable. The fruit must be well-grown and well-colored but firm when picked. The packing must be done with care to prevent bruising. If the fruit is to be transported in refrigerator cars, it should be loaded soon after picking, and preferably before it loses the cool night temperature. The peaches should be transferred from the cars to the storage house, or from the orchard to the storage house if the latter is near the orchard, in the quickest possible time. The air of the storage room should be kept sweet and pure. The fruit should always be removed to the coolest possible temperature, usually at the end of two weeks, while it is still firm, and it should be placed in the consumer's hands at once.

If the fruit is overripe when picked, or becomes mellow from unfavorable handling before it enters the storage house, it is already in a critical condition and may be expected to deteriorate quickly.

If the conditions outlined are observed in the handling of the peach, it is possible to store it temporarily with favorable results.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. (Frontispiece.) Average condition of Georgia Elberta peaches two weeks in storage after forty-eight hours' withdrawal to a warm room. The upper specimen represents the average condition of fruit stored in a temperature of 36° F. The lower specimen represents the average condition of the fruit stored in 32° F. The lower temperature gave better results in every respect. (Natural size.)

PLATE II. Average condition of Maryland Kieffer pears, March, 1902. This fruit was picked from young trees on October 21, 1901, and was stored the following day in a temperature of 32° F. Under these conditions the fruit kept well until late in the spring. (Reduced one-fifth.)

PLATE III. Average condition of Maryland Kieffer pears on January 15, 1902. This fruit was picked from young trees October 21, 1901, and stored in a firm condition ten days later in a temperature of 32° F. The delay in the storage caused the fruit to decay from the core outward. (Reduced one-fifth.)

PLATE IV. Fig. 1 shows the influence of immediate and delayed storage on Maryland Kieffer pears. The fruit in the box at the right represents the average condition of pears picked October 21, 1901, stored October 22, and withdrawn March 3, 1902. Storage temperature 32° F. The fruit was wrapped in parchment paper. It was in prime commercial condition when withdrawn from storage. The fruit in the box at the left represents the average condition of pears picked from the same trees at the same time. It was stored in the same temperature ten days later and withdrawn March 3, 1902. All of the fruit had decayed. Fig. 2 shows the influence of 36° and 32° F. storage temperature on the keeping of Kieffer pears. The fruit in both packages was picked October 21, 1901, and stored October 22, 1901. The package at the left represents the average condition of the fruit when withdrawn March 3, 1902, from a temperature of 36° F. All of the pears were soft and discolored, and some of them decayed. The fruit in the package at the right, kept in a temperature of 32° F., was bright yellow, firm, and in prime commercial condition.

PLATE V. Average condition of Maryland Kieffer pears March 3, 1902. Picked October 21, 1901; stored October 22, 1901. Temperature 36° F. In this temperature the fruit did not keep well after December 1. (Reduced one-fifth.)

PLATE VI. The upper figure shows the average condition of western New York Bartlett pears in the center of a barrel one week after being placed in storage. In this position the fruit cools more slowly than that near the staves or ends and it therefore ripens considerably before the temperature is reduced. The lower figure shows the average condition of the pears one week after storing at top and bottom and next to the staves of the same barrel. In these positions the fruit cools quickly and the ripening processes are retarded. For quick ripening fruits that are handled in hot weather small packages are preferable. (Natural size.)

PLATE VII. Illustration of the influence of wrappers on the keeping of the Kieffer pear. This fruit was picked October 21, 1901, stored October 22, 1901, in a temperature of 32° F., and withdrawn January 20, 1902. Nearly 50 per cent of the unwrapped fruit was decayed, while there was no loss in the fruit wrapped in news paper or in parchment paper (lowest figure).

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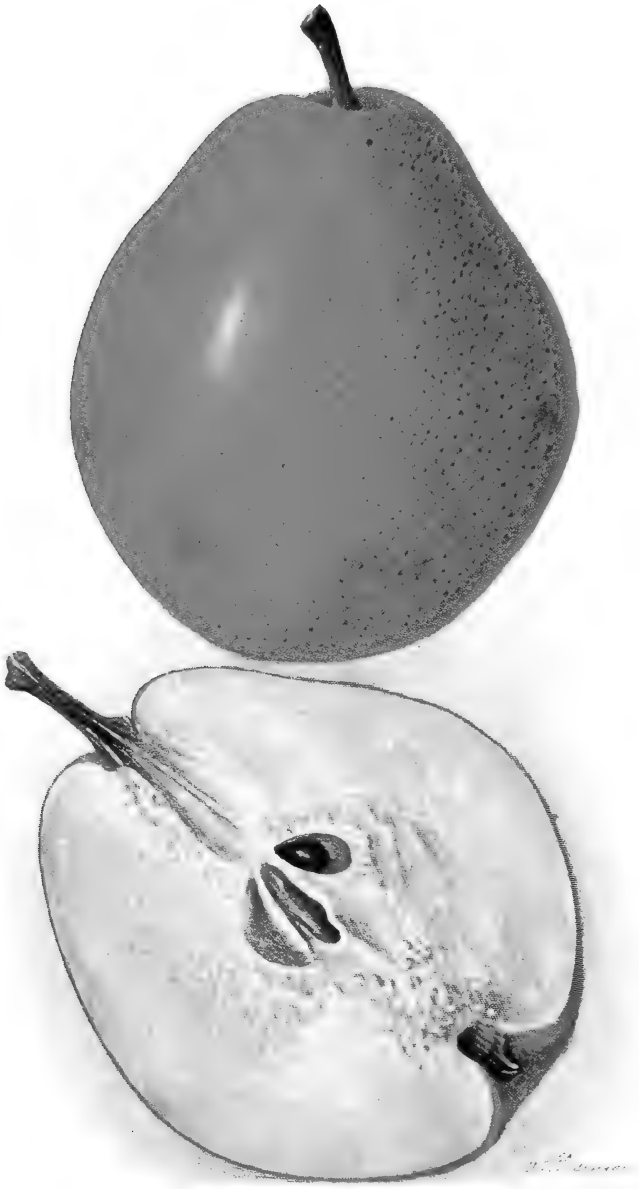
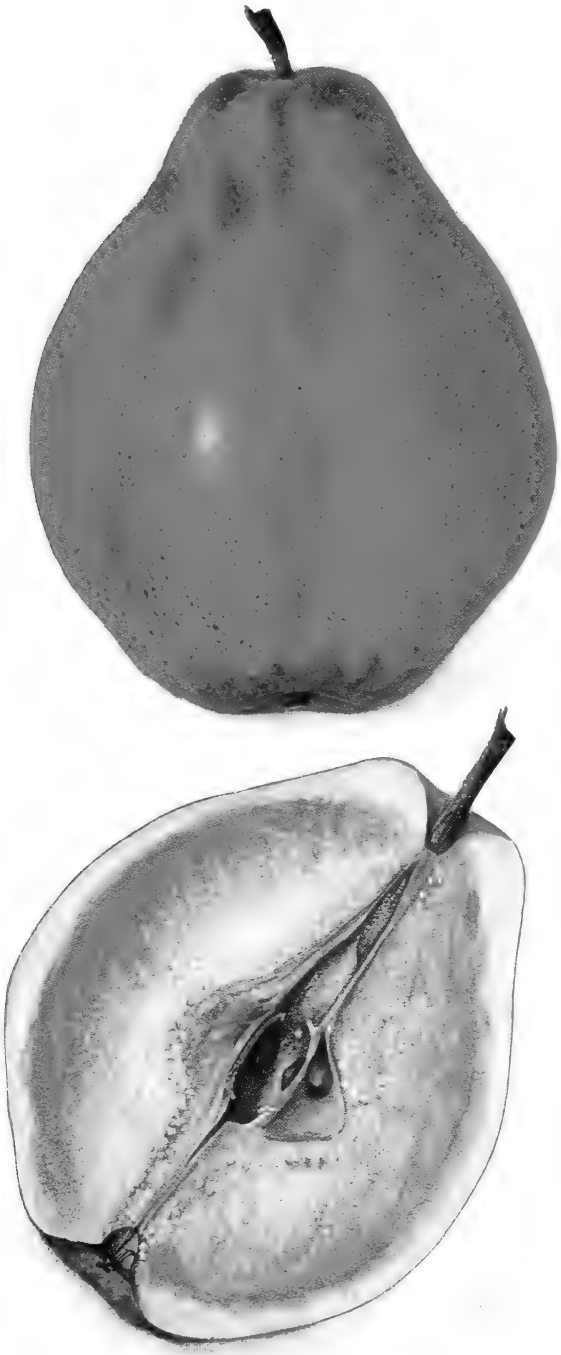


KIEFFER PEAR, MARCH, 1902. (FRUIT PICKED OCTOBER 21, 1901, AND PLACED IN STORAGE THE FOLLOWING DAY AT A TEMPERATURE OF 32° F.) REDUCED ONE-FIFTH.



KIEFFER PEAR, JANUARY, 1902. (FRUIT PICKED OCTOBER 21, 1901, AND PLACED IN STORAGE TEN DAYS LATER AT A TEMPERATURE OF 32° F.) REDUCED ONE-FIFTH.

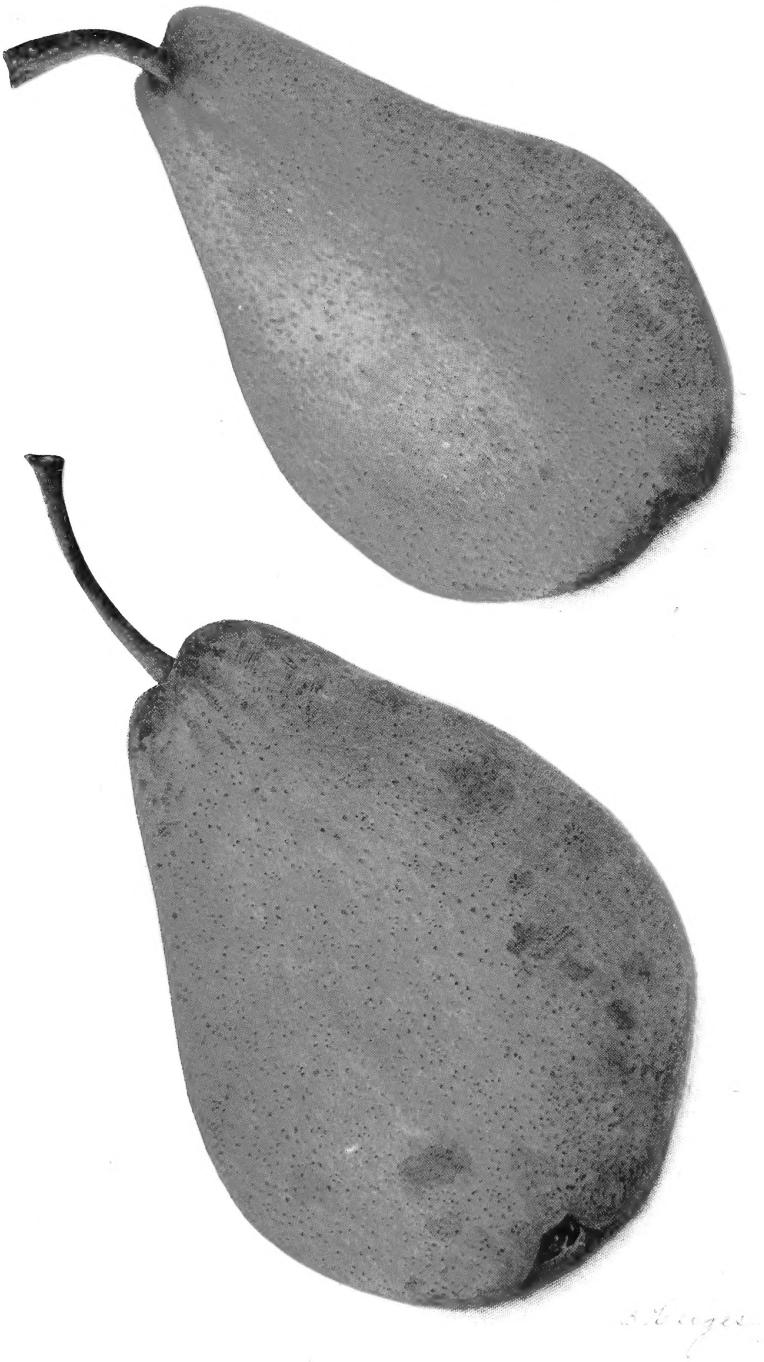
FIG. 1.—WRAPPED KIEFFER PEARS, REMOVED FROM COLD STORAGE (32° F.) ON MARCH 3, 1902.

Fruit in both boxes picked October 21, 1901, that on the right being placed in storage on the following day, while that on the left was not stored for ten days.

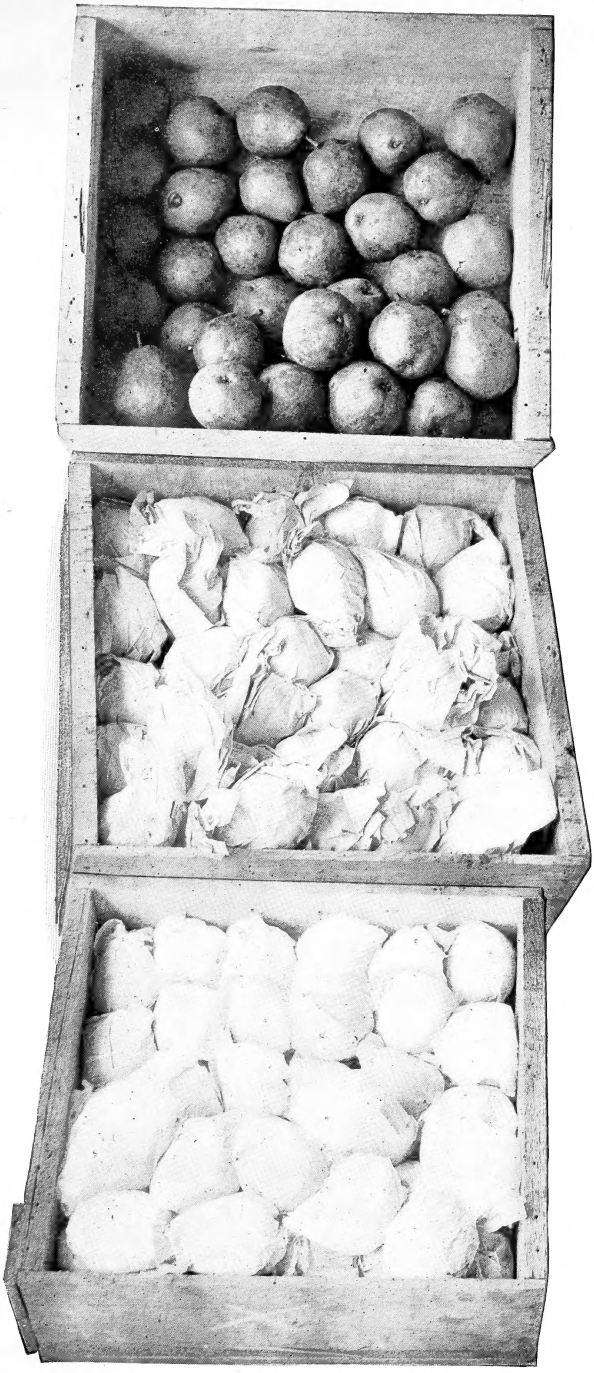
FIG. 2.—WRAPPED KIEFFER PEARS, REMOVED FROM COLD STORAGE (36° AND 32° F.) ON MARCH 3, 1902.

Fruit in both boxes picked October 21, 1901, and stored on the following day, that on the right at a temperature of 32° and that on the left at 36° F.

KIEFFER PEARS, MARCH, 1902. (FRUIT PICKED OCTOBER 21, 1901, AND STORED ON THE FOLLOWING DAY AT A TEMPERATURE OF 36° F.) REDUCED ONE-FIFTH.



BARTLETT PEARS, ONE WEEK AFTER BEING PLACED IN COLD STORAGE. (THE UPPER FIGURE SHOWS THE AVERAGE CONDITION OF THE FRUIT IN CENTER OF BARREL; THE LOWER FIGURE THAT NEAR THE OUTSIDE OF THE BARREL.) NATURAL SIZE



KIEFFER PEARS, REMOVED FROM COLD STORAGE ON JANUARY 20, 1902.

Fruit picked October 21, 1901, and placed in storage on the following day. Nearly 50 per cent of the unwrapped fruit decayed, while that in parchment wrappers (lowest figure) and in unprinted newspaper kept in perfect condition.