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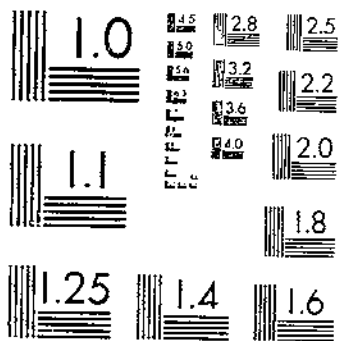
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INVESTIGATIONS ON THE HANDLING OF BARTLETT PEARS FROM PACIFIC COAST

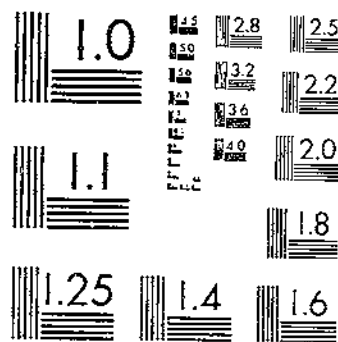
MAGNESS, J. R., DIEHL, H. C., ALLEN, F. W.

1 OF 1

# START



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A



UNITED STATES DEPARTMENT OF AGRICULTURE  
WASHINGTON, D. C.

INVESTIGATIONS ON THE HANDLING  
OF BARTLETT PEARS FROM PACIFIC  
COAST DISTRICTS

By J. R. MAGNESS, *Principal Pomologist*, H. C. DIEHL, *Associate Physiologist*,  
*Office of Horticultural Crops and Diseases, Bureau of Plant Industry*, and  
F. W. ALLEN, *Assistant Pomologist, California Agricultural Experiment  
Station*<sup>1</sup>

CONTENTS

	Page		Page
Introduction.....	1	Relation of climatic conditions to storage quality of the fruit.....	21
Time for picking Bartlett pears.....	2	Relation of shipping conditions to storage quality of the fruit.....	22
Methods of estimating firmness and color.....	3	Discussion of results.....	23
Experimental data.....	4	Recommendations relative to commercial pear handling.....	24
Handling Bartlett pears following harvest.....	10	Summary.....	25
Plan of experimental work.....	11	Literature cited.....	26
Storage conditions.....	12		
Behavior of the pears in storage.....	13		
Ripening at different temperatures.....	15		
Ripening of fruit following removal from cold storage.....	19		

INTRODUCTION

The Bartlett pear is assuming a place of increasing importance in the fruit industry of the Pacific coast. Both fresh shipments and the packing of canned pears have shown a steady growth during the last 10 years. In view of the fact that a large acreage planted to Bartlett pears is not yet in bearing, it is probable that the tonnage of this fruit to be handled, either in the fresh state or canned or dried, will increase materially during the next few years.

Because of the highly perishable nature of this fruit, special care in handling is necessary in order to put it on the market in good condition and at the same time prolong the marketing season sufficiently to take care of the rapidly increasing tonnage.

Bartlett pears on the Pacific coast are grown under a wide diversity of climatic conditions, ranging from those of the cool coastal districts to those of the hot, dry interior valleys. The ripening char-

<sup>1</sup>H. W. Richey and J. C. Shilleter, of the Division of Pomology of the State College of Iowa, assisted in the work in California and made many of the tests herein reported. In the Wenatchee district L. A. Fletcher took a similar part. The cooperation of the fruit and vegetable standardization bureau of the California Department of Agriculture through furnishing transportation and assistance is deeply appreciated. The storage tests at various temperatures were made possible by the cooperation of the Security Warehouse & Cold Storage Co., San Jose, Calif.

acteristics of pears vary considerably under these different growing conditions.

The purpose of the investigations herein reported was to determine as accurately as possible the earliest stage at which Bartlett pears may be picked and still ripen with satisfactory quality, the condition of fruit which when picked develops the best quality, and the latest stage at which fruit may be harvested and still retain satisfactory storage and dessert quality. It was also planned to make a detailed study of the influence of storage temperatures upon the rate of ripening of Bartlett pears, particularly on the effect of temperatures similar to those which prevail in the tops and in the bottoms of loads of fruit in refrigerator cars while in transit. These studies have been made with fruit from different districts of California and from the Wenatchee district of Washington.

### TIME FOR PICKING BARTLETT PEARS

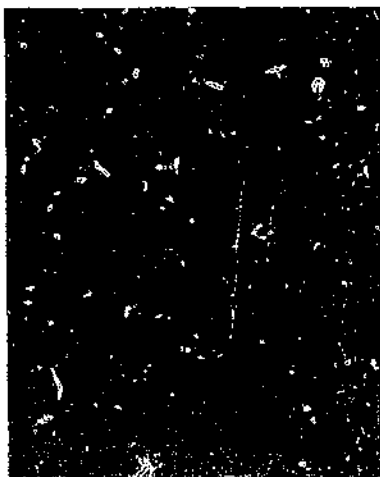
A number of investigations have been conducted to determine the best time for picking Bartlett pears. Lewis, Magness, and Cate (5)<sup>2</sup> studied the increase in size, the disappearance of starch from the fruit, and the specific gravity of the juice in order to determine whether any of these tests were closely associated with the dessert and carrying quality of the fruit. It was found that the fruit increased in size as long as it was hanging on the tree. There was a gradual disappearance of the starch from the fruit, but even fruit which was no longer in the best picking condition retained so much starch that this test was impracticable as a means of determining the best picking date. The specific gravity of the juice did not change sufficiently to be significant. Lewis, Murneek, and Cate (6), Murneek (10), and Hartman (3), continuing the study of Bartlett pears in the Rogue River Valley and other districts of Oregon, found a very close association between the softening of the fruit as measured by a mechanical-pressure test and the stage of ripeness of the pears.

Cruess and Stone (1) followed the changes in size, soluble solids, acids, and starch in Bartlett pears harvested at intervals from early until late in the season. There was not sufficient correlation of the soluble solids, acids, or starch content of the fruit to give a satisfactory measure of the time the fruit was ready to harvest.

All of these investigations indicated that there was a distinct improvement in the dessert quality of Bartlett pears up to a certain point as the fruit matured on the tree. One of the writers (7), in a detailed chemical study of the ripening and storage of Bartlett pears, found that the sugar content, as measured by chemical analysis, increased rather rapidly as long as the fruit remained on the tree. This increase, on the average, ranged from 5 to 10 per cent for each 10-day interval. Titratable acidity at the same time was decreasing in most of the fruit, although this change was very irregular.

All of the investigations showed that neither size, nor sugar content as measured by the specific gravity of the juice, nor starch content was a satisfactory indicator of maturity or of dessert quality in Bartlett pears. The firmness of the flesh appeared to be the most

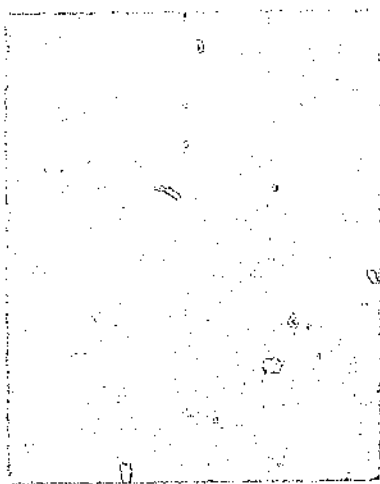
<sup>2</sup> Reference is made by italic numbers in parentheses to "Literature cited," p. 26.



1



2



3

4

COLOR CHART FOR DETERMINING PROPER TIME FOR PICKING BARTLETT PEARS

satisfactory index of pear maturity available. Consequently, it was decided to follow in detail the changes in firmness of the flesh in pears from the principal commercial districts of California and from the Wenatchee district of Washington, and to determine the limits of satisfactory maturity as measured by the pressure-test method. Careful determinations of the color between the lenticels or "dots" were also made and recorded.

#### METHODS OF ESTIMATING FIRMNESS AND COLOR

In this investigation, the work was planned to give general data on the rate of softening of fruit in the different growing sections as well as to determine the dependability of the pressure test as an index of maturity or quality.

At intervals of a week to 10 days, general surveys were made of some of the larger producing sections, and records were obtained of the conditions of the fruit in a number of orchards. These orchards were scattered throughout the different districts and represented an average cross section of the conditions that prevailed in them.

In determining the condition of the fruit then in the orchard, the larger specimens available at the time were used, these being the pears which on the average would be harvested if picking operations were under way on the date of making the test. Ten pears selected from several trees were used for the test in each orchard. The firmness and the ground color of the fruit as well as its size were recorded as accurately as possible.

The firmness of the flesh was determined by means of the United States Department of Agriculture pressure tester, using a plunger point five-sixteenths of an inch in diameter. This tester (9) measures the pressure in pounds required to force such a rounded plunger point into the fruit to the depth of five-sixteenths of an inch. In all of the experiments herein reported the skin was removed from the fruit, and the test was made directly on the flesh. Two or three tests were made on each fruit.

The average ground color on the pears used for pressure testing was recorded by comparing the fruit color with the chart shown in Plate 1. Round holes about three-fourths of an inch in diameter were cut in the center of each color section. The pears were then placed behind the color chart, and the color between the lenticels was recorded in terms of the chart colors. For example, color 1 would correspond to No. 1 in the color chart;  $1\frac{1}{2}$  would be half way between No. 1 and No. 2; color 2 to 2+ would represent colors similar to No. 2, or slightly more yellow.

In addition to the pressure-test and color determinations careful notes were made of the browning of the lenticels or dots due to the formation of cork. One of the writers (9) had found this to be a fairly good indication of the approach of picking maturity. The ease of separation of the fruit from the spur and the finish of the fruit were also noted. The term "finish" refers to the rounding out of the fruit and to the characteristic smoothness and waxiness taken on by the skin as the fruit matures.

Besides the fruit used for pressure testing, several pears from each orchard were taken at the time of each survey and held for 12 days

at a temperature of about 52° F. This represents approximately the average temperature in the top layers of a refrigerator car in transit east loaded with fruit not precooled. The fruit was then removed from 52° and held at about 75° until ripe and overripe. The quality of the different lots as well as the tendency to shrivel and the way the fruit held after becoming ripe were recorded. In the Wenatchee district from 20 to 30 pears were taken at each picking and were held at 75°. Notes were taken at intervals as to the character of the ripened product, and the time required to ripen and ultimately to break down was determined.

During the 1925 season surveys were made in California in the Sacramento River district, in Santa Clara County, and in Placer

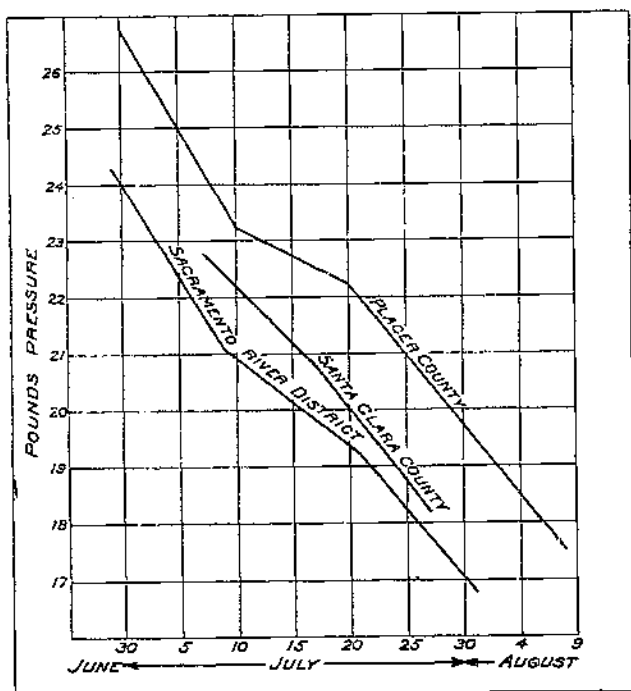


FIGURE 1.—Softening of Bartlett pears, California, 1925

County. In 1926 surveys were repeated in these three districts and also were made in the Vacaville district and the Fairfield-Suisun district (in Napa and Sonoma Counties) of California and in the Wenatchee district of Washington. In addition one or more surveys were made in the Placerville district, in the upper Sacramento River district about Marysville, and in Lake County, Calif., as well as in the Rogue River Valley, Oreg. Tests in the Wenatchee, Wash., district were continued through 1927.

#### EXPERIMENTAL DATA

In Figure 1 the softening of Bartlett pears during the 1925 season in certain of these districts is shown. It is apparent that on the average the fruit softens 2 to 3 pounds during each 10 days. Fruit from



the Sacramento River district was earlier than that from any other section studied, as indicated by the softness of the flesh, whereas that from Placer County averaged about 10 days later in reaching the same stage of softness. Average figures in districts such as Placer County or Wenatchee are significant only as a basis of comparison. The wide range of topography in these districts results in considerable variation in maturity even in closely adjacent districts.

In Figure 2 is shown the softening rate of Bartlett pears from the different districts studied in 1926. Each point on the curves in both Figures 1 and 2 represents the average of the pressure in the district on the date given, based on an average of 5 to 10 orchards.

In a comparison of Figure 1 and Figure 2 it is apparent that the season of 1926 was approximately 15 days earlier than the season of

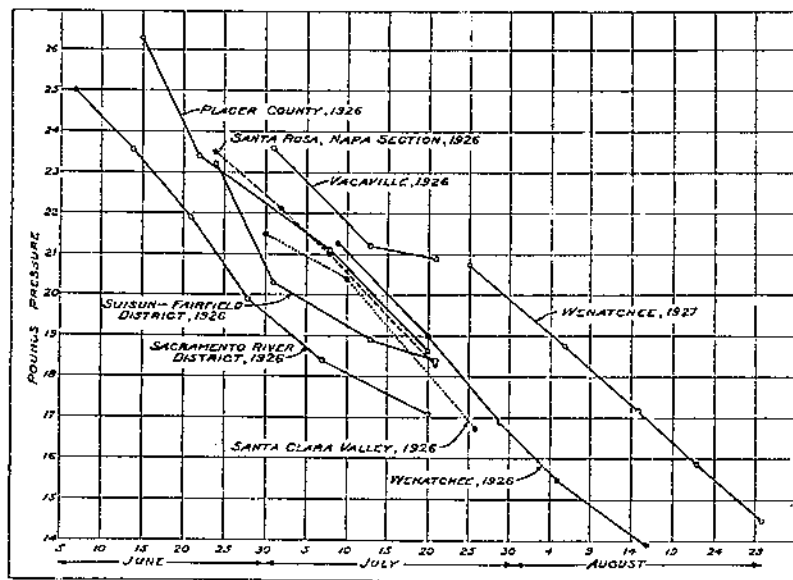


FIGURE 2.—Softening of Bartlett pears from the different districts studied in 1926

1925. Fruit in the Sacramento River district reached a pressure test of 20 pounds about July 15, 1925, whereas in 1926 this same condition was reached on June 28. Similarly, Placer County fruit reached a test of 20 pounds on July 28, 1925, and a like condition on July 13, 1926. This outstanding difference between the two seasons was apparently due almost entirely to the fact that the blooming season in 1926 was two or three weeks earlier than in 1925, owing to the warm spring temperatures. No outstanding difference in climatic conditions followed the blooming period during the two seasons. A blooming season in the Wenatchee district approximately two weeks later in 1926 was also followed by the fruit being two weeks later in ripening.

In general in 1926 the rate of softening during the period under test was 2 to 3 pounds for each 10-day period. The average rate of softening seemed to be very similar in the different sections with the

exception of Vacaville, where softening appeared to be slower than in the other districts.

The relative maturity of fruit in the different districts, as indicated by pressure-test data in Figure 2, is particularly interesting. The fruit from the Sacramento River district (representing the earliest maturity) and that from the Wenatchee district in north-central Washington (representing a late section) was only about 20 days apart in condition. This shows that there is only a relatively small spread in the harvesting season due to variation in time of maturity. It is true that there is a spread of somewhat more than 20 days between peak shipments from Sacramento Valley points and peak shipments from the late-shipping districts, but this is due to the fact that in these later districts the fruit is normally harvested in a more mature condition.

Table 1 shows the location of the orchards and the detailed pressure tests made in each during the 1926 season in the Sacramento River district. It will be noted that not until June 21, when the average fruit of the district showed a pressure test of 21.9 pounds and when fruit from all of the orchards averaged less than 23 pounds, was fruit obtained that ripened with fair quality. A week earlier, when the fruit from this district was testing 23.5, the flavor was poor and insipid. Although this latter fruit softened with only slight shriveling, it was found that within two days after the fruit was eating ripe it was breaking down and was entirely past market condition. Fruit harvested later, testing 22 pounds and less, was of fair to good flavor when ripe, with an attractive yellow color, and it held in satisfactory market condition for a longer period after becoming ripe.

TABLE 1.—Softening of Bartlett pears from the Sacramento River district, California, 1926

Date	Pressure test (pounds) from orchard—								Color of fruit	Condition of ripened fruit
	Isleton		Walnut Grove	Steamboat Slough		Courtland	Hood	Average		
	No. 1	No. 2		No. 1	No. 2					
June 7	24.7	24.5	25.2	25.6	25.5	24.3		25.0		Shriveled, quality flat, very poor.
14	23.2	23.6	24.1	23.8	22.9	23.0	24.0	23.5	1½	
21	21.8	22.4	22.4	22.6	21.0	21.4	21.4	21.9	1½ to 2	Very little shriveling, good clear yellow color; flavor fair to good, mostly fair; held well after ripening.
28	20.2	20.5	19.8	20.4	19.7	19.8	19.1	19.9	do.	No shriveling, attractive yellow color; flavor fair to good.
July 7	18.1	18.2	19.3	18.5		17.8	18.3	18.4	2 to 2+	Good yellow color; good flavor, aromatic.
20	16.6	18.1	18.5	10.4		16.7	16.5	17.1	2 to 3, mostly 2½.	Quality good to very good; held well after ripening.

Table 2 shows the detailed figures for the surveys made in Placer County. This is a warmer district, at a higher elevation, and the

water supply is short in certain orchards. There was considerable variation in the different orchards because the topography of the district is rolling, with various exposures and elevations.

TABLE 2.—Softening of Bartlett pears from Placer County, Calif., 1926

Date	Pressure test (pounds) from orchard—						Color of fruit	Condition of ripened fruit	
	Loomis	Monte Rio		Penryn	Newcastle				Average
		No. 1	No. 2		No. 1	No. 2			
June 15	27.3	25.3	27.4	26.2	27.3	24.5	26.3	Mostly 1½ to 2	Shriveled, poor quality, astringent. Slight shriveling, good appearance, quality fair.
22	25.0	23.3	23.9	22.8	23.5	22.0	23.4		
July 8	22.9	30.0	20.3	20.4	21.7	20.6	21.0	2 to 2+	No shriveling, full yellow, quality good to very good. Full yellow, quality very good.
20	20.4	18.8	19.2	19.0	19.4	17.2	18.7	2 to 2½	

In this district on June 22, with an average pressure test of 23.4 pounds, the fruit was of fair quality and showed very slight shriveling. On July 8, with a pressure test of 21 pounds, the quality was very good. In the Sacramento River district equal quality was not obtained until the fruit was testing under 20 pounds.

Tables 3, 4, and 5 give in detail the data for fruit from the Vacaville district, a relatively hot, dry section; for the Suisun district, located only a few miles from Vacaville, but nearer to San Francisco Bay and with a cooler growing season; and for Santa Clara Valley, which is also near San Francisco Bay, with summers somewhat cooler than in the Suisun district.

TABLE 3.—Ripening of Bartlett pears from the Vacaville district, California, 1926

Date	Pressure test (pounds) from orchard—					Color of fruit	Condition of ripened fruit
	No. 1	No. 2	No. 3	No. 4	Average		
July 1	23.2	23.7	23.0	24.5	23.6	2 to 2+	Full clear yellow, quality good to very good, no shriveling. Full clear color, quality very good. Full yellow, clear color, quality fair to good, somewhat dry and insipid.
13	20.4	22.7	20.5	21.2	21.2	2 to 2½	
21	20.2	21.3	19.6	20.7	20.4	2½ to 3	

TABLE 4.—Softening of Bartlett pears from the Suisun district, California, 1926

Date	Pressure test (pounds) from orchard—					Color of fruit	Condition of ripened fruit
	No. 1	No. 2	No. 3	No. 4	Average		
June 24	22.3	22.8	23.8	23.2	23.0	1½ to 2	Quality fair, little shriveling, rather flat and insipid.
July 1	26.1	21.3	20.7	18.7	20.2	2 to 2-	
13	18.2	19.8	20.2	18.2	19.1	1½ to 2	Clear yellow color, no shriveling, quality good. Good clear color, good to very good flavor, held well after ripening. Quality mostly good, color good clear yellow.
21	16.7	19.5	18.3	18.2	18.2	Mostly 2½	

TABLE 5.—Softening of Bartlett pears from Santa Clara Valley, Calif., 1926

Date	Pressure test (pounds) from orchard—				Color of fruit	Condition of ripened fruit
	No. 1	No. 2	No. 3	Average		
June 20	21.3	21.5	20.9	21.2	1 to 1½	Yellow, no shriveling; juicy, but flat in flavor, quality fair.
July 3	21.5	21.5	21.5	21.5	1 to 1½	Flat in flavor, quality fair.
July 5	20.6	19.5	23.0	21.0	1½ to 2, mostly 1½	Yellow, clear color, no shriveling, quality fair to good.
10	19.7	19.8	19.75	19.75	1½	Full yellow, quality good, best quality of any fruit tested from district.
25	16.7	-----	-----	16.7	2	Quality fair, somewhat mealy

Tables 1 to 5 also give a record of the color of the fruit from the several districts at the different dates, the colors being estimated as heretofore described and recorded according to the color number on the color chart shown in Plate 1 with which they compare most closely.

Tables 6 and 7 present records on fruit from the Wenatchee district of Washington for the seasons of 1926 and 1927, respectively. Samples were taken from orchards in the vicinity of Rock Island, one of the earliest and warmest sections, from orchards in the neighborhood of Wenatchee proper, and some from near Peshastin, the coolest portion of the district.

TABLE 6.—Softening of Bartlett pears from Wenatchee Valley, Wash., 1926

Date	Pressure test (pounds) from orchard—									Color of fruit	Condition of ripened fruit
	Rock Island			Wenatchee			Peshastin		Average		
	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2			
July 9	22.8	19.7	20.1	20.7	21.2	23.6	24.4	-----	21.3	1 to 1½	Poor to fair, shriveled.
23	20.0	17.7	18.6	18.7	18.5	18.3	19.0	20.3	19.0	1½ to 2	Fair to good.
29	17.6	15.2	16.6	17.0	16.7	16.9	17.5	17.7	16.9	2 to 2½	Good to very good.
Aug. 5	15.7	14.5	14.8	15.3	15.8	15.6	16.1	16.6	15.5	2 to 2½	Fair to good.
16	-----	13.7	14.5	14.5	13.5	-----	13.3	-----	13.9	2½	Fair to good, mostly fair.

TABLE 7.—Softening of Bartlett pears from Wenatchee Valley, Wash., 1927

Date	Pressure test (pounds) from orchard—									Color of fruit	Condition of ripened fruit
	Rock Island			Wenatchee			Peshastin		Average		
	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2			
July 25	21.9	20.4	20.8	20.7	20.5	19.5	21.7	-----	20.8	1	Wilted, poor.
Aug. 6	19.0	18.2	18.1	19.3	17.6	17.1	19.7	21.2	18.8	1½	Fair to good.
15	18.2	16.9	16.0	17.0	16.3	16.7	17.5	18.0	17.2	2	Do.
22	-----	16.0	14.5	-----	15.7	16.0	16.2	16.9	15.9	2 to 2½	Good to very good.
30	-----	14.5	13.6	-----	14.2	15.8	14.1	15.6	14.5	2½ to 3	Fair to good.

Tables 1 to 7 show a very interesting variation in the tendency of the fruit to yellow and to soften in different districts and under different growing conditions. In the cool districts with ample

moisture supply the pears tend to be somewhat softer and greener in color, whereas in the hotter districts, particularly where there is water shortage, the fruit tends to be yellower while still distinctly firm. For example, the fruit from the dry orchards in the Vacaville district showed a color of 2 to 2+ on July 1, with an average pressure test of 23.6 pounds; in the Santa Clara Valley, on the other hand, with a cooler season and ample soil moisture, fruit did not reach a similar color stage until July 26, when it was past its best picking conditions and had a pressure test of 16.7 pounds. Fruit from the Sacramento River district did not reach a color stage of 2 to 2+ until July 7, when the average pressure test was 18.4 pounds. Fruit from the Wenatchee Valley did not reach a color stage corresponding to 2 until it tested well under 20 pounds. Fruit from Placer County reached this color stage while testing 21 to 23 pounds.

The general observation that the fruit yellows while still firm, in the hotter, drier districts, was further substantiated by some tests made in Lake County as well as in the Napa and Sebastopol districts. Fruit from Lake County, particularly where grown with a shortage of water, showed a distinctly yellow tint while still very firm, but the pears from the vicinity of Napa and Sebastopol, grown under cool climatic conditions, remained green in color even when becoming fairly soft.

Tables 1 to 7, giving pressure tests, color, and the ripening quality of the fruit, indicate that no single test is entirely satisfactory for determining when Bartlett pears from all of the different districts are sufficiently mature to be of good quality when ripened. In the Vacaville section, fruit testing about 23 pounds ripened with very good quality, whereas fruit from the Sacramento River district showing about equal firmness was poor to only fair in quality. In the Santa Clara Valley and the Wenatchee district pears testing 23 pounds have been almost invariably of poor quality.

Similarly, the color of the fruit is not an entirely satisfactory indication of its maturity. Fruit from the cool coastal valleys remains green, with relatively little yellowing until past its best commercial condition.

In order to govern satisfactorily the harvesting date of Bartlett pears under different growing conditions, picking regulations should be based on two alternative tests for the time that harvesting may commence. In the growing districts with warm temperatures the pressure test is probably the most satisfactory index. Fruit from these districts will generally ripen with fair quality if harvested when the average pressure test on 10 or more pears is under 23 pounds. For the best quality, fruit from these districts should test under 20 pounds when harvested.

In very hot districts, and particularly where the fruit is grown with a shortage of water, the fruit tissue appears to be tougher and harder. Some fruit may show a yellow tint in the skin while its pressure test is above 23 pounds. After such fruit has developed a slight yellowing in the color between the lenticels or dots, it has been found to ripen without shriveling and with fair to good quality. If fruit is not harvested until it shows a pressure test under 23 pounds, or until the color corresponds to No. 2 in Plate 1, it will generally ripen with fair quality.

In the coolest districts fruit grown with ample soil moisture will generally be of poor quality if harvested when testing above 20 pounds pressure. The pressure test is a valuable aid in determining the proper time of picking in any district, but the optimum picking pressure for the fruit will vary somewhat under different growing conditions.

In addition to the pressure test and color, the corking of the lenticels and general finish of the fruit are valuable as indices of picking maturity. The lenticels of the immature pear are white; as cork cells develop they become dark brown in color and shallow in appearance. The development of this dark-brown color in the lenticels is a good indication that the fruit will ripen without shriveling. The development of a characteristic smoothness or waxiness in the skin and the rounding out of the fruit are also valuable guides in determining the optimum picking conditions.

### HANDLING BARTLETT PEARS FOLLOWING HARVEST

A wide variation in the type of handling is necessary to meet different market conditions with Bartlett pears from the various districts of the Pacific coast. In the earlier shipping districts the fruit intended for immediate consumption on the fresh market is shipped east generally without precooling. Usually it is desirable that the fruit arrive on the market in such a condition that it will quickly reach the eating-ripe stage. Fruit from these early districts is not held in cold storage either at the shipping point or at eastern terminals to any appreciable extent.

Fruit in these districts is normally packed and loaded in the cars within 24 hours of the time of picking. Transit time to eastern seaboard points under present shipping conditions is 12 to 14 days, during which period temperature conditions to which the fruit is exposed are variable. The fruit loaded in the bottom of the car will be carried at a temperature averaging approximately 40° F., whereas the fruit loaded at 70° to 90° in the top layer of the car will gradually cool to temperatures ranging from 45° to 50° at the time of unloading. The temperatures for the 12-day trip in the top layers of pears in a modern refrigerator car will usually average from 52° to 54°.

It is frequently desirable to postpone the time of consumption of Bartlett pears from the later shipping districts as much as possible; consequently, the fruit is held in cold storage either at the shipping point or at destination. Such fruit may be pre-cooled prior to shipping or may be loaded warm into iced cars.

If the fruit is loaded directly from the orchard, temperature conditions in transit will be approximately those mentioned above; if it is pre-cooled, temperatures in transit will be very much lower. The term "pre-cooled" is applied to fruit placed in cold-storage rooms equipped for heavy refrigeration and held there until the temperature of the fruit in the centers of the boxes is below 40°. With packed pears this usually can be accomplished in 36 to 48 hours. The fruit is then loaded into the cars. Temperatures in the bottom of a carload of such fruit will generally average between 38° and 40°, whereas temperatures in the top of the car will average about 45° for the period of transit.

When cold-storage space is available at the shipping point, as in most of the districts in the Pacific Northwest, the fruit is frequently held as long as two months before loading. The temperature in storage is generally held at about 30° F., so that the fruit is thoroughly chilled when loaded. Under these conditions the temperature in transit is generally slightly below that in the precooled cars heretofore mentioned. The temperature is lower partly because the fruit is cooled prior to loading and partly because the later shipment is made in somewhat cooler weather.

In addition to the Bartlett pears for eastern shipment, handled by these methods, large quantities of pears for canning are handled through cold storage. This fruit is placed in storage and held for one, two, or in some cases even three months, and is then removed from cold storage and allowed to ripen. Under these conditions the storage temperature can usually be maintained at whatever point seems most desirable.

One of the writers (9) has recommended that for the longest periods of storage Bartlett pears should be held at a low temperature, preferably around 30° F. Overholser and Latimer (11) reported that much longer storage is possible for pears held at 32° than for similar fruit held at 36°. Under commercial shipping conditions, however, it is impracticable to maintain these temperatures while the fruit is in transit. In order to determine the storage life of Bartlett pears handled under different commercial conditions, a detailed study of the effect of different storage temperatures upon the rate of ripening and breakdown of the fruit was undertaken.

One of the writers (9) also pointed out the relationship between climatic conditions under which the fruit is grown and its reputation for holding up during handling and storage. Consequently, in this investigation it was planned to conduct tests with fruit from districts where fruit has the reputation of being of poor shipping quality and from districts producing fruit of good shipping quality and texture. The relationship of the stage of maturity at the time of harvest to storage and handling quality of the fruit was also determined.

#### PLAN OF EXPERIMENTAL WORK

Fruit for storage tests was procured from three of the principal pear-producing districts of California, which included the Santa Clara Valley, the Sacramento River district, and the Sierra Nevada foothill district in Placer County.

The fruit from the Santa Clara Valley was obtained within a few miles of San Jose. The soil in the orchard was moderately heavy, and the trees were producing a very heavy crop of fruit. This district is located about 30 miles from the Pacific Ocean near San Francisco Bay and has a cooler growing season than do the other districts studied. Nights during the summer are generally cool and sometimes foggy.

The Sacramento River district is an area lying along the river below Sacramento. The soil is a rich, deep loam lying only a few feet above the river. This district is characterized by a moderately warm growing season, intermediate between that at San Jose and that in the foothills. Fruit was obtained from near Courtland.

Fruit representative of the Sierra Nevada foothill district was obtained near Newcastle, Placer County. This district is characterized by relatively warm days and nights. The elevation is about 1,500 feet at the point where the fruit was procured. The mean summer temperatures for these districts and for Wenatchee, Wash., during 1926 are shown in Table 8.

TABLE 8.—Mean monthly temperatures in districts from which storage fruit was obtained, 1926

District	Weather Bureau station	Mean temperature (° F.)			
		May	June	July	August
Santa Clara Valley.....	San Jose.....	61.0	66.2	66.8	.....
Sacramento Valley.....	Sacramento.....	66.4	73.4	77.0	.....
Sierra Nevada foothills.....	Auburn.....	65.2	78.2	80.8	.....
Wenatchee, Wash.....		58.3	70.2	75.5	70.2

The mean temperature in June and July in the Sacramento district was 7° to 10° F. above that at San Jose. The temperature at Courtland was probably slightly below that at Sacramento, since Courtland is considerably nearer San Francisco Bay. The temperature at Auburn averaged about 4° above that at Sacramento for June and July. Thus the average temperature in the foothills district was more than 10° above that in the Santa Clara Valley. The temperatures at Wenatchee, Wash., during June and July were intermediate between those in the Santa Clara and Sacramento Valleys.

Three pickings of fruit were obtained from orchards in each district of California. Fruit chosen for the first picking represented early commercial-harvest conditions and consisted of the larger sizes available on the trees. The second picking from each orchard was made at the height of the commercial season, and the third was made near the close of the commercial season.

In addition to these lots of fruit, one lot picked in midseason from Lake County, Calif., was also studied. Lots of fruit from other orchards of these districts were held as checks, but are not reported upon in detail.

The pears selected as representative of the Wenatchee district were taken from a number of orchards distributed from Rock Island, in the lower, hotter, drier section of the district, to Peshastin, which represents a higher and slightly more humid area.

The orchards are located in the Columbia and Wenatchee Valley floors at elevations of 600 to 1,100 feet, the higher altitudes being in the cooler localities of the district. Orchards were selected that had various soil conditions such as are typical of the Wenatchee district. Pickings were made throughout the growing seasons of 1926 and 1927 at about 10-day intervals.

#### STORAGE CONDITIONS

In the experiments in California all the fruit except that from Lake County arrived at the storage plant within 24 hours of the time of picking. For storage tests under varying conditions it was separated into five lots and stored at the following temperatures: Lot 1,



30° to 31° F.; lot 2, 36°; lot 3, 43°; lot 4, 53°; lot 5 fluctuated from 60° to 70°, averaging about 65°.

Lot 3 represents the average temperature in transit in the lower part of cars loaded with warm fruit, or in the center and upper part of cars filled with fruit that was cooled before being loaded. The temperature in the top layer of a car loaded with precooled fruit will usually average slightly higher.

Lot 4 approximates the average temperature in the tops of cars in which the fruit is shipped without precooling.

After 12 days some of the fruit held at 43° F. and some of that held at 53° was removed to a room having a temperature of 31°, in order to simulate storage of precooled and nonprecooled fruit at the eastern terminals.

At the time it was harvested and placed in storage, samples of this fruit were pressure tested in the manner heretofore described, and the size and color of the fruit were recorded. Pressure tests were taken at intervals of 3 days on the samples held at 53° and 65° F. and at intervals of 6 days on the samples held at 43°.

Every 15 days tests of samples held at 36° and 31° were made.

At intervals of 15 days samples of fruit from the 36° and 31° F. lots were withdrawn from storage and held at temperatures of about 60° to determine whether they would ripen satisfactorily. In some cases samples of this fruit were also exposed to a temperature of 43° for 12 days to determine whether or not it would prove suitable for eastern shipment.

These detailed storage tests were carried on during the seasons of 1925 and 1926 with fruit from the California districts. Results in the two seasons were so closely comparable that both series are not reported in detail.

In the Wenatchee district the pears were stored within 24 hours of the time they were picked. Part of the fruit was held at 60° to 65° F., and the remainder was placed in cold storage ranging from 30° to 32°. At intervals of one month, fruit from cold storage was withdrawn and allowed to ripen at about 65°. Because of the lack of facilities it was not possible to handle this fruit at the intermediate temperatures of 36°, 43°, and 53°, as was done with the California fruit.

#### BEHAVIOR OF THE PEARS IN STORAGE

The results obtained with the different lots of fruit from California during the 1926 season are shown in detail in Figures 3 to 11, where the rate of softening of the fruit is shown graphically and the

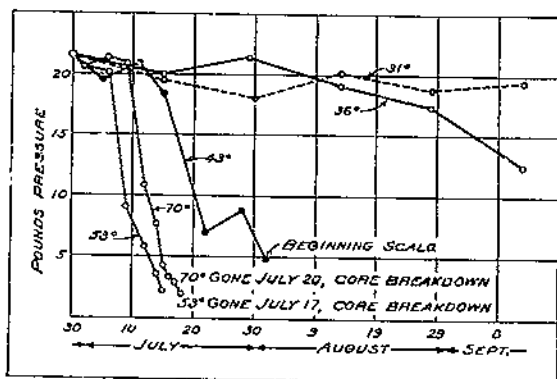


FIGURE 3.—Softening of Bartlett pears, Santa Clara Valley, early pick, 1926

type of breakdown is recorded. The behavior of fruit following withdrawal from storage at 36° and 31° F. is recorded in Tables 9 and 10.

The storage life of Bartlett pears may be limited by various factors (2, 3, 4). These include the following: (1) Overripeness. The tissue passes through a prime eating condition and gradually softens until it becomes mushy and overripe. (2) Core breakdown. The core region becomes discolored and broken down, while the outside of the fruit may be hard or in prime eating condition and show no discoloration. (3) Storage scald. The skin becomes blackened

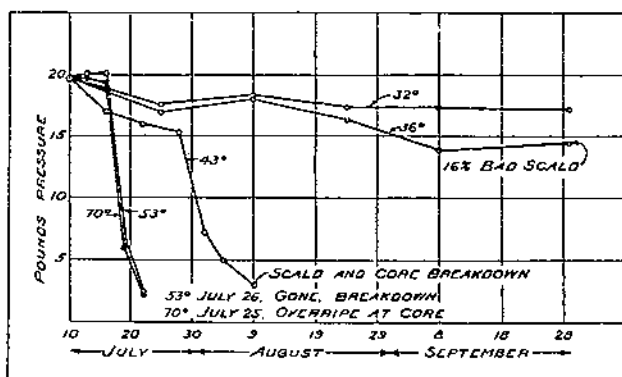


FIGURE 4.—Softening of Bartlett pears, Santa Clara Valley, mid-season pick, 1926

while the fruit is still firm. When storage scald occurs the fruit is of no value commercially, as it develops very bad flavor and fails to soften or ripen further.

TABLE 9.—Ripening of Bartlett pears in 1926 following removal from cold storage at 36° F.

Location and time of picking	Pressure test when picked	Time in storage	Pressure test after storage	Time required—		Cause of discard
				To ripen	Until discarded	
Santa Clara Valley:	Lbs.	Days	Lbs.	Days	Days	
Early.....	21.5	35	19.0	5	3	Core breakdown.
	21.5	45	20.0	5	2	Do.
	21.5	60	17.0	6	0	Do.
Midseason.....	19.7	30	18.0	5	4	Do.
	19.7	45	16.5	4	2	Do.
	19.7	60	13.5			Did not ripen, scald and core breakdown.
Late.....	16.6	30	14.8	5	2	Core breakdown.
	16.6	45	13.3	6	2	Do.
	16.6	60	13.0			Did not ripen, scald and core breakdown.
Sacramento Valley:	19.8	35	20.0	5	4	Surface discoloring and core breakdown.
Early.....		60	14.8	4	2	Do.
Midseason.....	19.4	30		7	7	Do.
	18.2	30	18.0	0	5	Do.
Late.....	18.2	45	15.7	5	3	Do.
	18.2	62	13.7	5	2	Do.
Placer County:	19.0	30	15.7	4	5	Do.
Midseason.....	19.0	45	14.0	5	3	Do.

TABLE 10.—Ripening of Bartlett pears in 1926 following storage at 31° F.

Location and time of picking	Pressure test when picked		Time in storage at 31° F.	Pressure test when removed		Time required		Cause of discard
	Pounds	Days		Pounds	Days	To ripen at 65° F.	Until discarded	
<b>Santa Clara Valley:</b>								
Early	21.5	0			15	5		Core breakdown and discoloring. Do. Scald, core breakdown. Core breakdown.
	21.5	45	20.0	6	4	4		
	21.5	75	19.5	7	3	3		
Midseason	19.7	0			12	4		Do. Do. Do. Do.
	19.7	30	18.3	5	4	4		
	19.7	60	17.3	6	4	4		
	19.7	80	17.2	5	2	2		
Late	16.6	0			9	2		Do. Do.
	16.6	30	15.3	7	3	3		
16.6	65	15.4	6	3	3		Do.	
<b>Sacramento Valley:</b>								
Early	19.8	0			12	7		Overripe, no discoloring. Overripe, surface discoloring. Overripe.
	19.8	30	20.7	6	5	5		
	19.8	75	20.3	7	5	5		
Midseason	19.3	0			11	6		Do. Do. Do.
	19.3	30	17.7	6	6	6		
	19.3	60	16.2	6	6	6		
Late	18.0	0			9	5		Do. Do.
	18.0	30	18.3	7	5	5		
18.0	60	15.3	7	5	5		Do.	
<b>Placer County:</b>								
Early	23.0	0			12	8		Do. Do. Overripe, no core breakdown. Overripe.
	23.0	45	19.6	6	6	6		
	23.0	60	18.0	6	7	7		
Midseason	19.0	0			9	7		Do. Do.
	19.0	30	17.7	8	6	6		
19.0	60	16.8	5	5	5		Do.	
<b>Wenatchee Valley, Wash.:</b>								
First picking	21.3	32	16.4	8	5	5		Core breakdown. Scald, core breakdown.
	21.3	66	18.0	4	4	4		
	21.3	116	12.0	4	1	1		
Second picking	19.0	32	15.3	7	5	5		Do. Do.
	19.0	66	16.2	5	3	3		
	19.0	116	13.1	3	2	2		
Third picking	16.9	32	14.2	7	5	5		Do. Do. Do.
	16.9	70	15.1	5	3	3		
	16.9	103	12.4	3	2	2		
Fourth picking	15.5	35	12.9	5	3	3		Do. Do.
	15.5	65	13.6	6	3	3		
Fifth picking	15.5	95	12.3	3	2	2		Do. Do.
	13.9	35	11.5	4	2	2		
13.9	63	11.5	4	1	1		Do.	

RIPENING AT DIFFERENT TEMPERATURES

Pears of all pickings from all districts ripened fairly satisfactorily at 65° and 53° F. It was rather surprising that there was generally only a slight difference in time of ripening at these two temperatures. A pressure test of 3 pounds represents full eating-ripe condition for Bartlett pears. The average time required to reach this degree of ripeness in the nine lots of fruit stored at 65°, as shown in Figures 3 to 11, was 11 days and at 53° was slightly under 15 days.

Considering all the lots of fruit, including both early and late pickings, the average pressure test at the end of 12 days at 53° F. was 5 pounds, which represents a firm-ripe stage, the average condition in which fruit that was not precooled would reach destination if shipped in the tops of cars. Generally, fruit picked in midseason or late-season condition was firm to full-eating ripe at the end of 12 days at 53°. This was true of fruit from all districts and indicates that the top layer of such fruit shipped from Pacific coast points without

precooling will generally arrive at eastern markets in firm-ripe to ripe condition.

RIPENING FRUIT AT 43° F.

The behavior of Bartlett pears when held continuously at 43° F., as shown in Figures 3 to 11, is particularly interesting. In general,

relatively little softening occurred during the first 10 to 15 days, after which time the fruit softened rather rapidly. In some cases it reached a pressure test of about 5 pounds, which represents a firm eating-ripe condition, and in other cases the pressure test dropped to about 3 pounds.

In a number of cases,

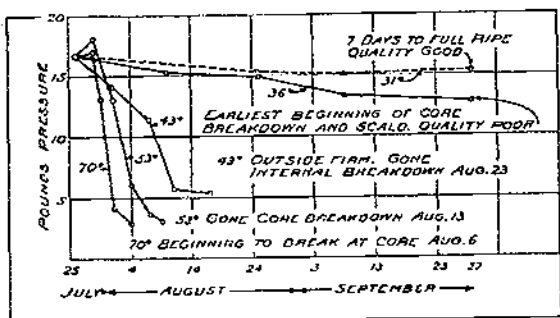


FIGURE 5.—Softening of Bartlett pears, Santa Clara Valley, late pick, 1928

particularly with early-season and late-season pickings of Santa Clara Valley fruit, the pressure test at 43° did not drop under 5 pounds. The fruit remained in this firm-ripe stage until scald developed.

In practically every instance at a temperature at 43° F. the storage life of the fruit was ended by the development of storage scald, whereas at the higher temperatures the fruit either became overripe or developed core breakdown. At 43° the surface usually blackened, while the core and flesh tissue was still in firm-ripe condition. This was

true regardless of the time of picking or the section from which the fruit was taken, except in the late-picked fruit from the Santa Clara Valley, in which core breakdown developed prior to the appearance of storage scald.

There was relatively little difference in the length of time that fruit from different pickings and from various sections

could be held at 43° F. In practically all cases the fruit became unmarketable at the end of 30 to 35 days. This condition was caused primarily by the development of storage scald, as previously stated.

The results indicate that 43° to 45° F. is approximately the lowest temperature at which Bartlett pears will ripen. Some of the lots failed to soften to a good eating-ripe condition at this temperature,

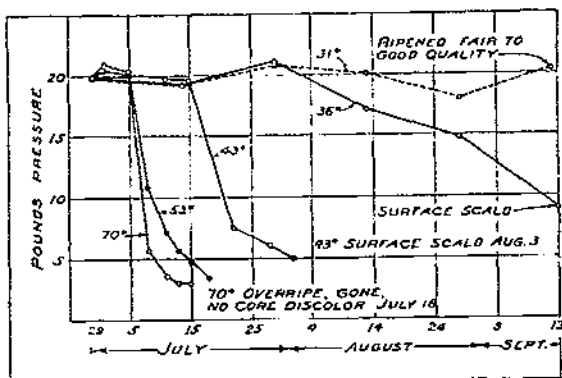


FIGURE 6.—Softening of Bartlett pears, Sacramento River district, early pick, 1926

whereas other lots ripened fairly satisfactorily. Fruit ripened at this temperature was in all cases inferior in quality to that ripened at temperatures above  $50^{\circ}$ . At temperatures lower than  $43^{\circ}$  Bartlett pears apparently will not ripen with satisfactory quality, but will develop either scald or breakdown or both while the flesh is still firm or hard.

At all the higher temperatures, including  $65^{\circ}$ ,  $53^{\circ}$ , and  $43^{\circ}$  F., there was a considerable interval after picking before softening began. At  $65^{\circ}$  and  $53^{\circ}$  this interval in most cases was at least 6 days, while at  $43^{\circ}$ , as previously stated, relatively little softening occurred until 12 to 18 days after harvest. This does not indicate that ripening changes do not occur during that time, for any delay in placing the fruit in storage results in a shortening of the possible storage period. The changes that take place during the first few days after picking, however, apparently do not affect the firmness of the flesh as measured by the pressure test.

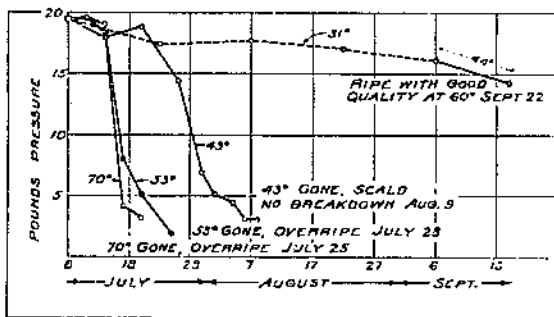


FIGURE 7.—Softening of Bartlett pears, Sacramento River district, midseason pick, 1926

a shortening of the possible storage period. The changes that take place during the first few days after picking, however, apparently do not affect the firmness of the flesh as measured by the pressure test.

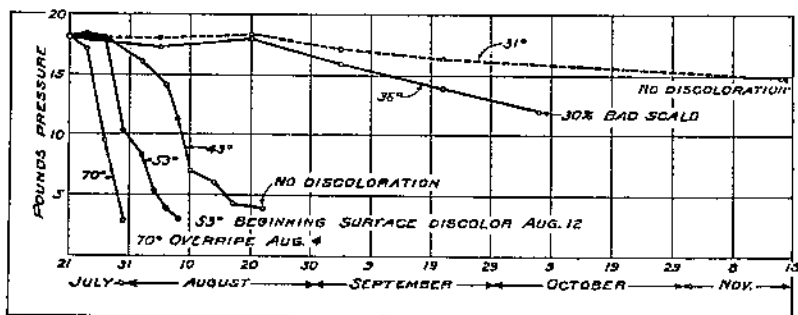


FIGURE 8.—Softening of Bartlett pears, Sacramento River district, late pick, 1926

Softening and color change apparently occur at the same time at the higher temperatures. At  $65^{\circ}$  and  $53^{\circ}$  F., the fruit was eating ripe by the time it became yellow. At lower temperatures this was not true.

#### RIPENING FRUIT AT $36^{\circ}$ F.

Bartlett pears of the different lots held continuously at  $36^{\circ}$  F., showed a moderately slow softening rate. Usually the pressure test at the end of two months was not more than 5 pounds lower than the pressure test at time of picking.

At the end of 60 days in storage at  $36^{\circ}$  the fruit of practically all lots was full yellow in color although still firm in texture. Fruit of

all but two of the lots (one each of midseason and late picking of Santa Clara Valley pears) held up for 60 days at 36° without the development of storage scald. In 70 to 80 days at this temperature the fruit began to blacken on the surface and to show scald. This represents an interval slightly more than twice as long as was required for the fruit to develop scald when held at 43°.

RIPENING FRUIT AT 31° F.

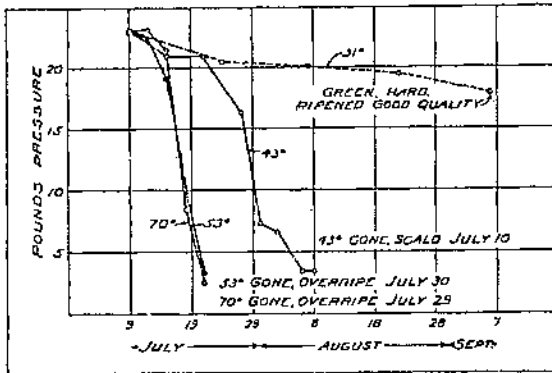


FIGURE 9.—Softening of Bartlett pears, Placer County, early pick, 1926

In most instances the fruit from the different districts of California in storage at 31° F. was not held until the end of the possible storage season. The fruit from Placer County picked in midseason was held 140 days without developing discoloration in storage. The late-picked fruit from the Sacramento River district was held 120 days without discoloration

in storage. On the other hand, fruit from Lake County which stood two to three days at high temperatures before moving into cold storage showed a beginning of scald development at the end of 100 days at 31°. The few lots of fruit held for a long season at 31° indicate that the possible storage period at this temperature is almost twice as long as at 36°. The storage period at each temperature is determined by storage scald, and the interval before scald developed when the fruit was held at 31° was very much longer than when it was held at 36°.

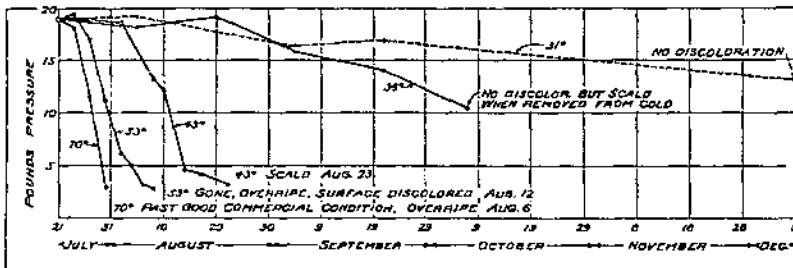


FIGURE 10.—Softening of Bartlett pears, Placer County, midseason pick, 1926

In the experiments in the Wenatchee district of Washington the pears were held in storage at 32° F. for 100 to 120 days without developing storage scald. However, this fruit did develop scald following removal from storage and in some cases failed to ripen with satisfactory quality.

These results would indicate that Bartlett pears harvested in proper condition and placed immediately in storage at 31° F., may be held as long as three months in storage and after removal to higher temperatures will ripen without developing storage scald. If the storage of the fruit is delayed even two or three days following picking, or if cooling in the warehouse is slow, this period will be greatly shortened. At temperatures above 31° the period will also be shortened. It is not recommended commercially that such long storage be practiced unless the complete history of the fruit is known, since there is a large element of risk in prolonging the storage season. As will be mentioned later, fruit held for a long period in cold storage has a relatively short life at high temperatures following its removal from cold storage, and its dessert quality is poorer than that of fruit held for shorter periods.

#### RIPENING OF FRUIT FOLLOWING REMOVAL FROM COLD STORAGE

In Tables 9 and 10 is summarized the behavior of fruit following its removal from storage at 36° and 31° F. after different intervals of time in storage.

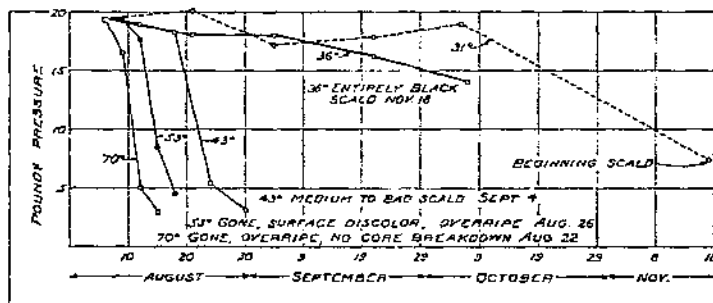


FIGURE 11.—Softening of Bartlett pears, Lake County, midseason pick, 1926

Fruit was removed from storage at 15-day intervals. Not all the data for removals are recorded in the tables, but sufficient data are given to indicate the general trend. The column showing days "to ripen" represents the time following removal from cold storage that the fruit was held at 60° F. before it reached a satisfactory eating-ripe condition. The column showing days "Until discarded" represents the interval between the time the fruit reached satisfactory eating condition and the time when it had passed marketable condition because of core breakdown, scald, or overripeness.

The results of the tests at 36° F. are recorded in Table 9. It is apparent that on an average the fruit from the Santa Clara Valley broke down much earlier after becoming ripe than did fruit from the Sacramento Valley and from Placer County. At the end of 30 days at 36° fruit from the Santa Clara Valley held up from 2 to 4 days after becoming ripe; that from the Sacramento Valley held up 4 to 7 days, while that from Placer County held up 5 days. This indicates that there is a very much shorter season for handling the fruit from the cooler sections both on the fresh market and through

canneries. There was not an appreciable difference in the time required for the fruit from the different districts to ripen following its removal from storage, but there was a distinct difference in the tendency of the fruit to break down after reaching an eating-ripe or canning-ripe condition.

In general, the longer the fruit was held in storage the shorter the interval during which it remained in good condition after reaching an eating or canning ripe stage. Fruit from the Santa Clara Valley held 45 days at 36° F. remained in satisfactory condition only 2 days after ripening, whereas fruit held 60 days in cold storage generally failed to ripen following removal to a higher temperature. The pears from Sacramento Valley and Placer County remained in satisfactory condition for 3 days after removal at the end of 45 days and ripened with satisfactory quality after 60 days in cold storage.

These results indicate clearly that at a temperature of 36° F. the possible commercial storage period for Bartlett pears is limited to about 45 days.

The behavior following removal from 31° F. is summarized in Table 10. Again it is apparent that the fruit from the cooler growing districts, including the Santa Clara Valley and the Wenatchee district of Washington, did not hold quite so long after it reached an eating-ripe condition as did fruit from the Sacramento district and from Placer County. Fruit from the Santa Clara and Wenatchee Valley districts held 1 to 5 days, whereas that from the Sacramento Valley held 5 to 7 days and that from Placer County 5 to 8 days.

Fruit from the hotter growing districts, including the Sacramento Valley and Placer County, broke down very largely through becoming overripe and discolored on the surface, whereas that from the cooler growing districts tended to develop core breakdown while the surface remained sound in appearance. This resulted in the fruit from the cooler growing districts being somewhat difficult to handle satisfactorily, since the fruit may no longer be in good commercial condition even though appearing sound on the outside.

Fruit from the California districts held 60 to 80 days at 31° F. and then removed to 60° for ripening ripened with good quality and remained in the ripe stage for several days before showing breakdown. Fruit stored at 31° for 60 days was as satisfactory as fruit stored at 36° for 30 days. Although the extreme storage limit at 31° was not determined by these tests, the results indicate that the fruit can be held safely under commercial conditions for periods up to 75 days and generally can be held as long as three months. Fruit held 100 days or longer in the Wenatchee district generally tended to scald following removal from storage and was not satisfactory for handling commercially.

On the average, the longer the fruit was held in cold storage the poorer its dessert quality when ripened. Fruit held 30 days was of better quality than that held 60 days, and the latter was superior in quality to that held 90 days. As is herein shown, the color of the fruit in cold storage is the best indication of the probable development of storage scald yet observed.



## RELATION OF CLIMATIC CONDITIONS TO STORAGE QUALITY OF THE FRUIT

One of the writers (9) has previously pointed out the relationship that exists between climatic conditions in the growing district and the commercial reputation of Bartlett pears so far as storage and shipping quality are concerned. It was stated that the fruit from the cooler growing districts has a reputation for being poorer in shipping and storage qualities. The more detailed study here reported indicates this this fruit is inferior in storage and handling qualities, primarily through having a shorter period during which it is in satisfactory dessert or canning condition, and because it tends to break down at the core while yet firm on the outside. The possible storage-holding period at 31° F. was only slightly shorter for fruit from the cooler growing districts. There was, however, a distinct difference in the tendency of the fruit to break down after it reached the firm-ripe condition. Fruit from the warmer districts had a relatively long period during which it was in satisfactory dessert condition, and it tended to pass good commercial condition primarily by becoming overripe and showing discoloration on the surface.

This relationship holds both when the fruit is ripened immediately and when it is held in cold storage. Table 10 gives data for fruit ripened immediately following picking at a temperature of 65° F., which show that Santa Clara Valley fruit held from 2 to 5 days after reaching eating-ripe condition. Sacramento Valley fruit under similar conditions held 5 to 7 days, whereas Placer County fruit held 5 to 8 days. Observations made on Wenatchee pears indicate that they behave somewhat like those obtained from the Sacramento Valley.

One of the writers (9) in discussing storage scald in Bartlett pears reported that the more immature the fruit at the time of harvesting, the greater its tendency to develop storage scald. These observations were based on fruit picked at intervals and held in storage at temperatures of about 40° F. The amount of scald developed in the different lots was checked on certain dates, and the greater amount of scald was found in the earlier picked fruit.

These conclusions were only partially borne out in the studies here reported. Both early-picked and late-picked pears tended to scald somewhat sooner than pears picked in midseason. Apparently, a fairly definite time is required for scald development at the different temperatures. In fruit stored at 43° F. this was from 30 to 35 days; for that stored at 36° it was from 70 to 80 days. For fruit stored at 31° the time was not definitely determined but apparently was from 125 to 150 days.

The time required to develop storage scald is fairly definite, and this indicates that Bartlett pears harvested in midseason or late in the season can be held satisfactorily until a later date than can early-harvested fruit. The end of the storage season can normally come in approximately a certain time following the picking date. This period is slightly longer for fruit picked in midseason than for either early-picked or late-picked fruit.

## RELATION OF SHIPPING CONDITIONS TO STORAGE QUALITY OF THE FRUIT

Bartlett pears produced on the Pacific coast and intended for fresh consumption must generally be shipped to eastern markets. Shipment may occur immediately following harvest in precooled or nonprecooled carloads, or it may occur at the end of a storage season. The temperatures in transit in the lower half of a car loaded warm will range from 40 to 45°. A temperature of about 43° also represents about the average prevailing in the upper half of a car of fruit thoroughly cooled before shipping, although the temperature in the top layer of fruit in such cars will usually average slightly higher. The average time required to ship to eastern markets is about 12 days. Consequently, the effect of holding fruit for that length of time at 43°, both immediately after harvest and after a period of two months in cold storage, was determined for certain lots of fruit.

Results obtained with lots of fruit held for 12 days at 43° F. and then transferred to 31° storage are reported in Table 11. After periods of 30 to 50 days at 31° this fruit was withdrawn from cold storage and allowed to ripen at 60°.

As will be noted in Table 11, fruit picked in midseason from three different districts and held for 50 days at 31° F. following 12 days at 43° ripened with satisfactory quality and without loss upon removal to higher temperatures. Late-picked Santa Clara Valley fruit after 32 days in storage at 31° ripened satisfactorily but broke down very quickly after reaching an eating-ripe condition. These results indicate that if Bartlett pears picked in midseason can be immediately precooled and shipped east, a storage season of 1½ months following arrival in the East is fairly safe.

TABLE 11.—Record of fruit held for 12 days at 43° F., then at 31° F.

Location and time of picking	Time held at—		Time required—		Cause of discard
	43° F.	31° F.	To ripen at 60° F.	Until discarded	
	Days	Days	Days	Days	
Placer County: Midseason.....	12	50	5	4	Overripe.
Sacramento Valley: Late picking.....	12	50	3	4	Core breakdown.
Santa Clara Valley:					
Midseason.....	12	50	4	4	Do.
Late picking.....	12	32	4	1	Do.
Lake County: Midseason.....	12	34	3	5	Overripe.

Samples of fruit were also held in storage for 12 days at 53° F., the average temperature in the top layer of an iced car loaded with warm fruit. This fruit was generally firm eating ripe at the end of the 12-day period and not suitable for further storage holding. Although it was possible to hold such fruit for two to three weeks in cold storage, it deteriorated so rapidly following removal from cold storage that the practice would prove unsatisfactory under commercial conditions. The results obtained in the investigation indicate that it is hazardous to attempt to place Bartlett pears in cold storage following a 12-day shipment in the top layers of cars

initially loaded with warm fruit. Boxes loaded in the lower portions of such cars should be satisfactory for storage up to 1½ months, provided the storage temperature is held at 31 to 32°.

Similar satisfactory results were obtained from storing the fruit for two months at 31° F. and then holding for 12 days at 43°, as reported in Table 12. The fruit handled in this way ripened with good quality and held up satisfactorily for a moderate period of retail marketing.

TABLE 12.—Record of Bartlett pears held for varying periods at 31° F. and then held for 12 days at 43° F.

Location and time of picking	Days held at—		Condition of fruit at end of storage period
	31° F.	43° F.	
Santa Clara, midseason.....	60	12	Ripened with fair quality.
Sacramento, midseason.....	60	12	Ripened at 60° F., good quality, held 4 days.
Placer County, midseason.....	62	12	Ripened with good quality.

These results indicate that Bartlett pears picked in midseason and stored at once at 30° to 31° F. can be held for two months in storage and can then be shipped east and marketed without loss. This possible storage season will be correspondingly shorter if higher storage temperatures are used.

#### DISCUSSION OF RESULTS

The results of this investigation have emphasized the very close relationship between the temperatures under which Bartlett pears are handled in storage and the behavior of the fruit. The possible storage period can be predicted with fair accuracy if the temperature under which the fruit is held and the growing conditions are known. Fruit from all districts at temperatures above 45° F. ripened satisfactorily without scald, although in some cases core breakdown developed. Bartlett pears held continuously in storage at temperatures under 45° generally scalded before reaching full eating-ripe condition. This was always the case with fruit held continuously at 36° and at 31°.

A close relationship existed between the prevailing temperatures in the different producing districts and the tendency of the fruit to break down at the core prior to becoming overripe or scalding on the surface. Fruit from the warmer districts generally held in marketable condition after reaching the eating-ripe stage much longer than fruit from the cooler growing districts. Core breakdown rarely occurred in fruit from the hotter districts before the general collapse of the fruit, whereas it developed in almost all cases in fruit from the cooler districts while the outside of the fruit appeared sound.

Hartman (3) found that pears produced under the cool growing conditions of western Oregon tended to develop breakdown if they became overmature on the trees, but that relatively little of this injury occurred if the fruit was harvested moderately early. In the studies herein reported there was not nearly so close a relationship between stage of maturity and breakdown as Hartman found under

Oregon conditions. In general, the more mature fruit tended to develop the breakdown earlier, but core breakdown occurred while the surface appeared to be in good dessert condition in all pickings of fruit from the Santa Clara Valley, particularly when handled under low temperatures for a portion of the time.

There was some relationship between the amount of core breakdown and the storage temperatures. The least tendency to develop breakdown occurred in fruit held at 60° to 70° F. from the time of picking until it was ripe. The greatest amount of breakdown developed in fruit held for a considerable period at 36° to 50° and then moved to 65° temperature for ripening. Fruit held at 31° for one or two months and then transferred to 60° storage for ripening developed less breakdown than fruit held at intermediate temperatures, but more breakdown occurred than in fruit held continuously at 60° to 70°.

Fruit of all pickings and from all districts developed storage scald when held too long at low temperatures. Harley and Fisher (2) have recently reported a very close association between the development of storage scald in pears and the presence of acetaldehyde in the fruit tissue. They found a similar relationship between the presence of acetaldehyde and core breakdown in pears. In the work herein reported it was apparent that there was a very close relationship between the growing conditions and the development of core breakdown, but there was no similar relationship between the growing conditions and the development of pear scald. In general, core breakdown seemed to occur to the greatest extent in fruit containing the least proportion of acid. Bartlett pears from the cool growing districts generally contain less acid than those from the warmer districts, and the holding of fruit at intermediate temperatures ranging from 36° to 50° F. results in a more rapid decrease in acidity than holding the fruit at higher temperatures or at extremely low temperatures, unless the storage is greatly prolonged.

#### RECOMMENDATIONS RELATIVE TO COMMERCIAL PEAR HANDLING

The results obtained in this investigation emphasize the necessity of handling Bartlett pears under the coolest possible storage conditions if satisfactory results are to be obtained. The limit of the storage period at 43° F. was about 30 days; at 36° it was about 60 days, whereas at 31° the fruit could be held as long as 100 days in most cases. Even for holding for relatively short periods, placing the fruit at a low temperature to check ripening processes to the greatest degree possible gave fruit that held well after ripening and proved most satisfactory for the retail market or for canning. Bartlett pears should be stored at temperatures not higher than 30° to 31° F. if the best results are to be obtained.

In general, the longer Bartlett pears are held in cold storage the poorer the dessert quality of the ripened product. Fruit held for 30 days at 31° F. ripened with quality almost equal to that of fruit ripened immediately after harvest. Fruit held 60 days was somewhat poorer than that held for 30 days, whereas fruit held for 90 days or longer in cold storage was generally of only fair quality when ripened.

The best ripening temperatures for Bartlett pears either immediately after picking or following a period in cold storage seems to be from 60° to 70° F. Fruit ripened at temperatures below 60° or above 70° F. was inferior to that ripened at 60° to 70° F.

At cold-storage temperatures the fruit becomes yellow in storage, but does not soften or reach satisfactory eating condition. It was repeatedly observed in these tests that Bartlett pears rarely scalded in storage so long as they were still distinctly green in color. The development of an almost full yellow color in Bartlett pears in cold storage is a danger signal. They should be removed while showing a slight green color and allowed to ripen at higher temperatures, if loss from storage scald is to be avoided.

In handling fruit from the cooler growing districts, shippers and canners should realize that the fruit will have a relatively shorter period after removal from cold storage before breakdown occurs than will fruit from warmer districts. The cooler the growing season in a district the earlier the fruit will normally show breakdown. If the pears are to be canned the operation should be completed as soon as possible after the fruit is sufficiently ripe, if loss from core breakdown is to be avoided. Such fruit shipped to eastern markets will have to be handled rapidly if it is to be consumed without loss.

If carloads of Bartlett pears are thoroughly cooled prior to loading, they can be safely stored at eastern terminals for periods of a month to 45 days, provided the fruit is sent promptly to the pre-cooling plant and the cooling is accomplished rapidly and thoroughly. Similarly, fruit can be held at the shipping point at a temperature of 31° F. for periods up to two months and still be shipped to eastern markets without loss, provided it is placed in suitable cold storage within 24 hours of the time of picking. Bartlett pears shipped in cars loaded with warm fruit will vary greatly in condition, depending upon whether they are loaded in the top or the bottom of the car. Fruit from the top layers of the car will usually be suitable for only a very short storage season, if any at all, whereas that from the lower half of the car will generally be suitable for holding up to 45 days in storage at 30° to 31°.

#### SUMMARY

Studies have been conducted on the change in firmness of flesh, color, and other physical properties of Bartlett pears as they mature on the trees.

Bartlett pears from warm districts, particularly when grown under water shortage, are firm in flesh but have a distinctly yellow color when in satisfactory picking condition.

Fruit from cooler growing districts, with sufficient soil moisture, is greener in color and softer of flesh, as measured by the pressure test, when in satisfactory picking condition.

Fruit from the cooler growing districts will not ripen with even fair quality when testing above 23 pounds average under the conditions described in this bulletin. Fruit of high quality is obtained when harvested at a pressure test under 20 pounds, that having a pressure test of 17 to 19 pounds generally giving the best quality.

Bartlett pears showing a distinctly yellow cast corresponding to No. 2 of Plate 1 generally will ripen with good quality. This con-

dition may be reached in the dry, hot districts with fruit testing above 23 pounds.

The ripening rate for Bartlett pears at 65° F. is only slightly faster than at 53° F. The storage life at 43° is about double that at 53°. At 36° the possible storage period is about double that at 43°, but at 31° the storage life is almost double that at 36°.

Bartlett pears generally will not ripen satisfactorily at temperatures of 43° F. or lower. Storage scald develops before the fruit reaches prime eating condition at these temperatures.

Storage scald developed in 30 to 35 days at 43° F., in 70 to 80 days at 36°, and generally did not develop up to 120 days at 31°. Fruit held beyond 60 days at 36° usually scalded instead of ripening upon removal to higher temperatures. Fruit held continuously at 31° from the time of picking ripened with satisfactory quality after storage periods up to 100 days. The dessert quality of Bartlett pears becomes poorer the longer the fruit is held in storage.

Bartlett pears in cold storage at 36° or 31° F. become yellow with relatively little softening. In these tests fruit practically always became yellow before scald developed. Regardless of the firmness of Bartlett pears, they should be removed from cold storage before they reach a full yellow condition, as storage scald soon develops after the fruit becomes yellow.

Bartlett pears held 12 days at 53° F., corresponding to a transit period from the Pacific coast to eastern seaboard points, in the top layer of a car of fruit loaded warm, usually arrived in firm-ripe condition and were not suitable for cold-storage holding.

Similar fruit held at 43° F., corresponding to the lower half of cars of pears loaded warm or the upper portion of cars of fruit thoroughly cooled before loading, was hard green at the end of 12 days and could be held at 31° for one and one-half months and still ripen satisfactorily.

Fruit held as long as two months from date of picking at 31° F. was held 12 days at 43°, representing transit time and temperature, and ripened with good quality.

Fruit from the cooler growing districts became eating ripe in a slightly shorter period than fruit from hotter growing districts. Fruit from cooler districts after reaching eating-ripe condition kept for a distinctly shorter time than did fruit from the hotter districts, and it tended to break down at the core while still firm on the outside.

There was no apparent relationship between climatic conditions in the producing regions and the tendency of the fruit to scald.

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<i>Bureau of Plant Industry</i> .....	WILLIAM A. TAYLOR, <i>Chief.</i>
<i>Office of Horticultural Crops and Diseases</i> .....	EUGENE C. AUCHTER, <i>Principal Horticulturist, in Charge.</i>



**END**