PHYSIOLOGICAL FACTORS INFLUENCING THE RIPENING OF KIEFFER PEARS.

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Thesis submitted to the Faculty of the Graduate
School of the University of Maryland
in partial fulfillment of the
requirements for the degree
of Doctor of Philosophy.

1936

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INTRODUCTION

As ordinarily experienced, the Kieffer pear is tough and woody, of poor flavor, and with many sclerenchyma cells to add to its undesirable qualities. Canning, or otherwise cooking the fruit generally does not add greatly to its quality. However, Kieffer pear trees are vigorous, hardy, very productive, and quite resistant to blight and San Jose scale, thus accounting for a large degree of the popularity of this variety in the eastern and southern states. According to Rees (47), Kieffer is the leading variety in all sections of the United States except Washington, Oregon, California, western New York, and the El Paso district of Texas.

In order to determine the factors which might be influential in obtaining optimum dessert and canning quality in the Kieffer pear, experimental work was initiated in 1932. This paper will present some of the results obtained.

REVIEW OF LITERATURE

A brief review of the literature pertaining to the physical and chemical changes occurring in pears during the maturation period on the tree and after harvest, together with factors influencing the quality of pears is given in the following paragraphs.

Several investigators have shown that pears decrease in firmness on the tree as the ripening season progresses. They also have shown that the optimum time of harvesting can be determined fairly accurately by the use of the pressure tester (2)(3)(4)(12)(21)(22)(24)(35)(40)(45). Optimum firmness varies with the variety and at least in the case of Bartlett pears, with the district in which the fruit is grown. Allen (2) and Magness, Diehl and Allen (35) reported that Bartlett pears grown in dry, hot districts tested about 5 pounds firmer at optimum picking maturity than fruit from the cooler growing districts. Allen (1) found that trees on Japanese roots produced firmer fruit than on French roots.

Pentzer et al (45) reported that in the Hudson River Valley during the 1927 season Kieffer pears softened from 18.4 to 14.0 pounds from August 25 to October 8. In all lots picked they reported much shriveling in storage suggesting that as a general practice this variety is picked too early. They state, "It is likely that fruit picked at a firmness of about 13.5 pounds would be better in quality than earlier pickings."

Conversion of the green ground color to yellow is another change that occurs during the ripening season. This criterion also has been suggested as an aid in determining optimum maturity in some varieties of pears (2)(4)(21)(35)(45). However, color at optimum maturity may be influenced by climatic factors. Bartlett pears grown in hot, dry districts with little or no irrigation, develop considerably more yellow color when they reach optimum maturity than pears grown in districts with cooler growing season (2)(35).

Moore (38) has suggested the possibility of electrical resistance as an indication of maturity in pears. Allen (3), however, concluded that this method is "too variable to be considered as a picking index".

Crist and Batjer (9) have made a comprehensive study of the grit cells of pears while on the tree, as well as after harvest. The percentage of lignocellulose (which constituted 77.43 percent of the grit cells) in Kieffer pears reached a maximum on July 17 and then decreased during the period that the fruit remained on the tree. It seems probable that most of this decrease in percentage was due to an increase in the size of the fruit rather than to an actual decrease in the quantity of stone cells per fruit. Allowing the fruit to develop within black cloth bags or wounding the fruit increased the quantity of stone cells.

Pears will continue to show a marked increase in size as long as they remain on the tree (3)(12)(23)(24). Ezell and Diehl (12) started measuring Bartlett pears on August 5, 1930. They noted an increase of 1.95 percent per day. Maximum tonnage was obtained on August 19 when the firmness of the fruit was 16.5 pounds. After this date, loss by dropping was greater than the increase in size of the fruit remaining on the tree.

Murneek (41) has shown that the decreased resistance of pears with increased maturity on the tree is associated with an increase in size of the cortex cells and a slight decrease in thickness of the cortex walls.

Magness (32) has shown that Bartlett pears on the trees increase in sugar content and decrease in the alcohol insoluble, acid hydrolyzable material during the ripening season. Acidity tended to decrease in California fruit, whereas, there was a tendency for the acidity to increase in fruit from Oregon and Washington. Ezell and Diehl (12) working in the Yakima Valley of Washington reported a decrease in the alcohol insoluble solids, reducing sugars, and in the acidity; and an increase in the alcohol soluble materials, cane sugar and total sugars with increased maturity of Bartlett pears on the tree.

Kulisch (28) found that pears from trees bearing a light crop were of larger size and had a higher sugar content than fruit obtained from trees carrying a heavy crop. He suggested that in the case of the fruit growing on trees with a light crop, there was sufficient carbohydrates supplied by the leaves, whereas, in the case of a heavy crop, the leaves were unable to supply sufficient carbohydrates for the fruit and it was even necessary for the fruit to draw on other organs of the tree. Magness, Overly and Luce (36) found that Bartlett, D'Anjou and Winter Nelis pears grown with larger leaf area were not only larger, but were also higher in sugar content, acidity, and on the whole, had a better and more characteristic flavor than fruit grown with a reduced amount of foliage.

A study of the ripening of pears after harvest has been made by several investigators. Pears differ from apples in that they do not soften appreciably at cold storage temperatures and must be ripened at higher temperatures before they can be utilized. The proper method of handling Bosc pears caused considerable concern in Oregon. This variety of pears did not develop satisfactory quality at cold storage temperatures. In order to surmount this difficulty, it was first recommended (39) that the fruit be ripened at higher temperatures upon harvesting and then stored or shipped to eastern markets. Handling of soft, ripened fruit caused considerable difficulty, so it was later found more desirable to place the fruit into storage immediately upon harvesting and to remove the fruit from cold storage a week or so before it was to be consumed (23).

At ordinary cold storage and ripening temperatures, most investigators have found that ripening or softening was most rapid at relatively high temperatures and slowest at temperatures approaching the freezing point of the fruit (3)(29)(30)(33)(34)(35)(43)(45)(46). Magness, Diehl and Allen (35) report one instance where Bartlett pears softened faster at 53°F. than at 70°. However, this was an exception to the rule. Ezell and Diehl (12) report that Bartlett pears ripened slower at 80° to 85° than at 70° to 75°. Shamel (48) observed that Bartlett pears did not ripen properly when stored in a lemon curing room held at high temperature and humidity. He thought that this probably was due to the high humidity. Later, Overholser and Taylor (44)(49) and deVilliers (10) showed that this retardation in ripening was due to the relatively high temperatures of 85° to 90°F.

In all the above mentioned cases, no retardation in the rate of ripening was noted except above 80°F. Kidd, West and Trout (27) and Trout (51) in England reported that 18°C. (64.4°F.) did not result in normal ripening with Doyenne du Comice pears. However, normal ripening took place at 10°C. They reported that at 18°C. the fruit turned yellow and sweetened, but did not soften.

Furlong and Barker (14) have recently reported that Kieffer pears from South Africa ripened satisfactorily at 54°F. and 65° although it required nearly twice as long to reach optimum condition at 54°. The period from optimum to overripe was the same at both temperatures.

Chase (8) reports that ethylene hastens the softening of Bartlett pears and aids in the disappearance of starch. He says, "Stone cells seem not to be affected by the treatment." This is an apparent contradiction to Harvey's (25) statement that ethylene seemed to cause some digestion of stone cells of pears. It is interesting to note in this connection that Crist and Batjer (9) observed no change in lignocellulose, which comprised 77.43 percent of the stone cells, during ripening at 70°F. after 75 days in cold storage. Allen (3) observed that the rate of development of yellow color in Kieffer pears was accelerated by the exposure to ethylene gas at 70°. However, he observed little softening in both treated and untreated lots at this temperature.

Changes in the chemical composition of pears after harvesting have been studied by Magness (32) and Emmett (11). Magness found that Bartlett pears ripened at 70°F. contained the highest percentage of sugar, those ripened at 40° possessed the lowest total sugar content, and those held at 30° for from 6 to 14 weeks and then ripened at room temperature were intermediate in amount of total sugar. Alcohol insoluble, acid hydrolyzable substances decreased after removal from the tree. Emmett (11) in England using Conference pears stored at 12°, 5°, 4°, and 1°C. found that rate of ripening increased with increasing temperatures. Rapid ripening was associated with more rapid conversion of protopectin to soluble pectin, and further breakdown of soluble pectin. Emmett suggested that, in pears, differences in keeping quality are in all probability due mainly to differences in the rate of breakdown of the pectic compounds.

Gore (16) determined the rate of respiration of Kieffer pears for a period of approximately 24 hours. He found that the rate of respiration varied directly with temperature. At 2.9°C. it was 4 milligrams per kilogram hour and at 34.4° it was 50 milligrams. Magness and Ballard (34) using temperatures of 30° to 60°F. reported that the rate of respiration is an accurate means of measuring the ripening process of Bartlett pears. Rate of respiration and rate of ripening were higher at the higher temperatures used. In fruit held continuously at 59°, there was a marked acceleration in the output of carbon dioxide per kilogram hour from the time the fruit was picked until it was soft yellow ripe. They also found that catalase activity increased rapidly at 59°, reached a peak in 5 days and then decreased sharply so that when the fruit was full ripe, the activity was less than the initial rate. At 28° to 33°, catalase activity increased somewhat at first and then decreased slightly.

When pears are held in storage at low temperatures beyond a definite length of time, they do not ripen properly when removed to higher temperatures (26). Gerhardt and Ezell (15) found that this failure to ripen after removal from storage was associated with a rapid decrease in rate of respiration and a marked increase in percentage of acetaldehyde and alcohol.

Harley and Fisher (20) found that acetaldehyde was high in scalded Bartlett pears. A positive correlation existed between severity of scald and concentration of acetaldehyde in the tissue.

With the exception of the work of Crist and Batjer (9) there has been practically no comprehensive work on attempts to improve the quality of Kieffer pears or to study the ripening and storage behavior of this variety, although Allen (3), Pentzer and associates (45), Furlong and Barker (14), and Gore (16) did do a limited amount of work with Kieffer pears.

MATERIAL AND METHODS

In order to make the results obtained on the influence of temperature on the behavior of Kieffer pears as widely applicable as possible, fruit obtained from several states was subjected to various storage temperatures. In addition, fruit harvested at several stages of maturity was also stored at various temperatures.

Tests of firmness with a Magness and Taylor (37) pressure tester using a 5/16 inch plunger were made at intervals of 3 to 7 days during the storage period with all lots of fruit. In 1932 and 1933 samples for analysis of solids, sugars and acidity were also taken at the same time. The interval between the sampling periods varied with the rate of ripening. When ripening was rapid, the intervals were short. Twenty pears constituted a sample wherever possible. In a few cases, as at high temperatures where decay development resulted in a limited quantity of fruit, a sample consisted of 15 specimens. The great uniformity in firmness within any given lot indicated that even a smaller number would have been sufficient.

A representative sample from each lot of fruit was canned when considered ripe. At higher temperatures the fruit did not ripen properly, and in these cases it was canned after it had been allowed to remain in the ripening room as long as possible without loss of the entire lot from decay. In most instances, two or more samples were canned at different times from the fruit held at each temperature. In 1932 fruit from the last picking ripened at 60°F. was canned at 3 to 7 day intervals throughout the ripening period in an effort to ascertain optimum softness for canning. Organoleptic tests on the fresh fruit were made at the same time the canning samples were obtained in all cases.

The fruit used in 1932 was grown at Beltsville, Maryland and was picked at approximately ten-day intervals. The first picking was on September 16 and the fifth and last, October 25. The fruit was about two-thirds full size at the first picking. The last picking was made when the pears were dropping badly and was later than pears are ordinarily harvested commercially. The fruit was secured from 30 trees, about one-half a bushel of representative fruit being harvested from each tree at each picking. The trees were carrying a heavy crop so that removal of this amount of fruit probably had little, if any influence on that remaining on the trees. Fruit from each picking was held at 60°F., 70° and 80° for ripening and at 32° for storage. In addition, portions of the fruit of some of the later pickings were held at 40°, 50°, 90° and 100°. A relative humidity of 80 to 90 percent was maintained in all rooms except those at 90° and 100° in which the relative humidity was 75 to 80 percent.

In 1933 Kieffer pears were obtained from several sources to determine whether the locality in which the fruit was grown had any influence on the effect of the various temperatures on the rate of ripening, canning and dessert quality, and content of solids, sugars and acidity. Temperatures ranging from 32°F. to 90° were used on fruit obtained from Beltsville, Maryland; Arlington Farm, Virginia; South Haven, Michigan; and Lockport, New York and temperatures of 50° to 80° were used on fruit obtained from State College, Mississippi. In addition 4 pickings were made with fruit from Arlington Farm, at approximately 12-day intervals beginning August 18 and ending September 21 to determine the influence of maturity on quality and content of solids, sugars and acids. This fruit was ripened at 60°.

For the influence of temperature on the pectic constituents the fruit from Michigan was used. A study of the interrelationship of temperature, rate of softening and composition of internal gases was made on the last picking obtained from Arlington Farm.

In 1934, dessert quality after ripening at 60°F. was determined on 5 pickings of fruit grown at Arlington Farm, Virginia and on 6 pickings of fruit grown at Beltsville, Md. Chemical composition of the first 4 pickings at Arlington Farm was also determined. The first picking at Arlington Farm was made August 30. The last on October 19. The first picking at Beltsville was made on September 4 and the last on November 6. In both cases, the first picking was made several days before the beginning of commercial harvesting of this variety. The last pickings were made when the fruit was dropping badly and was after the end of the commercial harvesting period. The quality and rate of ripening at temperatures of 32° to 80° was determined on the October 1 harvest at Beltsville, the October 8 harvest at Arlington Farm, and fruit grown at College Park, Maryland and Auburn, Alabama. The study of dropping and increase in size during the ripening season was made at Arlington Farm. The influence of ripening and storage on catalase activity, rate of respiration, and on acetaldehyde and alcohol content was studied on Beltsville fruit harvested October 1. Fruit harvested at Beltsville on September 14 also was used for acetaldehyde and alcohol determinations. The influence of leaf area on quality and content of solids, sugars and acids was studied on fruit grown at Beltsville. The influence of ethylene, oiled wraps, and the vapors of various esters was determined on fruit harvested at Beltsville, on September 14 and then held for 26 days at 32° prior to treatment. The influence of varying temperatures, of rapid air circulation, and the influence of temperature on the composition of internal gases was determined on fruit grown at Beltsville and harvested September 14.

All of the fruit used in 1935 was obtained at Beltsville, Maryland. It was harvested on September 25.

For analysis of the content of solids, sugars, and acidity thin longitudinal slices of the edible portion of the fruit were made. The skin was included but the carpels and adjacent tissue were not included. Duplicate 100 gram samples were taken in all cases. The samples were preserved in sufficient 95 percent ethyl alcohol to make the final concentration 80 percent. The alcohol containing the samples was immediately heated to boiling to stop enzymatic action. The samples were extracted the following winter with alcohol in a Soxhlet extraction apparatus and made up to volume. The insoluble residue was dried to constant weight in a vacuum oven at 70°C. The alcohol soluble material was determined by evaporating an aliquot nearly to dryness on a steam bath followed by drying to constant weight in a vacuum oven at 70°C. Total solids was considered as the sum of the two residues. Determination of reducing sugar content was made by the Munson Walker method, the cuprous oxide being determined by the volumetric permanganate method. Total sugars were determined in the same manner after hydrolysis with HCl. Acidity was determined by titrating with N/10 NaOH against phenolphthalein and the results expressed as citric acid.

Samples for determination of pectic constituents were preserved in alcohol and also by freezing for comparison.

The samples preserved by alcohol were ground in a food chopper and preserved in alcohol as described above. For determination of soluble pectin, the storage alcohol was filtered off with suction and the residue extracted by grinding first with N/10 ammonium citrate and then with water. Two extractions with ammonium citrate and two with water were made. The total extraction time was approximately 15 minutes. The liquid remaining in the residue was then squeezed out through muslin and the residue returned to alcohol. The filtrate and extracting liquid then were boiled and centrifuged. The supernatant liquid was filtered off and the small amount of residue added to the other residue in alcohol. The filtrate was made up to volume and an aliquot was made up to 300 ml. with water. Soluble pectin was determined essentially by the method described by Carre and Haynes (7). One hundred ml. of N/10 NaOH was added to the solution. After standing overnight 50 ml. N acetic acid was added and after standing for 5 minutes, 50 ml. M $CaCl_2$ was added and the solution allowed to stand for 1 hour. It then was boiled and filtered hot through a fluted filter. The gel after washing with hot water until free of chlorides was dried in tared beakers at 70-75°C. Results are expressed as calcium pectate. Extraction with ammonium citrate also extracted any pectic acid and pectates that were present (5). Since these materials are probably degradation products of soluble pectin, it was thought advisable to include any that may have been present, with soluble pectin. Preliminary tests showed pectic acid was not present except in very ripe pears and then only in very slight amounts. The insoluble residue after drying and grinding was hydrolyzed in a manner similar to that described by Nightingale, Addoms and Blake (42). The ground sample was extracted by refluxing with N/30 HCl for thirty minutes after which the mixture was filtered and washed with hot N/30 HCl. The filtrate was cooled and neutralized immediately with N/10 NaOH. The residue was then refluxed with N/30 HCl for an additional 30 minutes. This procedure was repeated after each 30 minute hydrolysis until the total time of hydrolysis was 2 hours. All filtrates were combined and pectin determined as calcium pectate as described above for soluble pectin.

The samples preserved by freezing were ground as described above, placed in stoppered bottles, frozen and stored at 15°F. They were thawed overnight at 40°, the liquid squeezed out and the residue washed twice with 50 ml. N/10 ammonium citrate and once with 50 ml. of water. The solution was then boiled, centrifuged and filtered. The soluble pectin was determined on the filtrate, and insoluble pectin on the residue in the same manner as described above.

Acetaldehyde was determined essentially by the method suggested by Thomas (50) and modified by Harley and Fisher (20). A 200 gram sample was rapidly weighed and cut up into small pieces and immediately placed in a liter round bottom pyrex flask and distilled by steam distillation. The steam which was generated in a 2 liter round bottom flask passed through a bent glass tube to the bottom of the flask containing the sample of fruit. Rapid circulation of cold water was maintained in the condensor. The delivery tube of the condensor, which passed through the stopper of a filtering flask, was connected with a glass tube which dipped below a solution consisting of 20 ml. of cold N/10 sodium bisulfite and 50 ml. of cold water. The filtering flask was cooled with finely divided ice. The outlet of this filtering flask was connected by a bent tube to a small erlenmeyer flask, also cooled with ice. This second flask was used as a precautionary measure to retain any aldehyde which might escape from the first flask. According to Thomas (50) acetaldehyde rarely escapes to the second flask and then only in traces. The steam distillation was continued for 2 hours, during which time approximately a liter of distillate was collected. The amount of aldehyde which distilled was determined by titrating the sodium bisulfite in the receiving flasks with iodine using a starch solution as indicator. Blanks were run in all cases and the iodine and sodium bisulfite solutions standardized daily. By storing the reagents at 32°F., their deterioration was greatly minimized.

Ethyl alcohol was determined essentially by Fidler's (13) modification of the method suggested by Thomas (50). A 200 gram sample was steam distilled as described above except that 50 ml. of cold water only, was used in the receiving flask. The distillate was transferred to a distilling flask and 20 grams of powdered potassium dichromate was added. Fifty ml. of concentrated sulfuric acid was then added very slowly by means of a dropping funnel. After allowing the mixture to stand for 1 hour at room temperature, the acetic acid formed by the oxidation of alcohol was distilled off with frequent additions of water to the distilling flask. Titration with N/10 NaOH using phenolphthalein as an indicator gave the content of acetic acid from which the alcohol content was calculated.

Catalase activity was determined in an apparatus essentially like that described by Harding (18). A cylinder of tissue was taken transversely through the fruit by means of a cork borer. After removing and discarding the skin and core tissue, a 5 gram sample was rapidly weighed and mixed with an equal weight of calcium carbonate and a few drops of distilled water. The sample was then ground in a mortar until a creamy consistency was obtained. The suspension was brought up to a volume of 100 ml. and catalase activity of a 5 ml. aliquot was determined by placing it in one arm of the catalase tube and 5 ml. of hydrogen peroxide in the other. After allowing the solutions to reach the temperature of the water bath (70°F.), the samples were shaken and the oxygen evolved was measured.

The internal gases were extracted by a modification of the method suggested by Magness (31). The modification consisted primarily in the use of a much larger extraction cylinder (500 ml.) which permitted the analysis of about 250 ml. of fruit tissue. The period of extraction was standardized at 5 minutes. The gas thus extracted was analyzed in an Orsat gas analysis apparatus in which the standard 100 ml. gas burette was replaced with a 25 ml. burette, instead of the Bonnier-Mangin apparatus. This method of extracting and analyzing gas was found not only to be more rapid than the method suggested by Magness but also gave more reliable results in this work.

The procedure and apparatus for the determination of respiration was exactly that described by Haller and Rose (17).

PRESENTATION AND DISCUSSION OF RESULTS

Storage Temperature Relations and Effects of Several Storage Temperatures

Changes in Firmness. The rate of softening at various temperatures of the fifth picking of Kieffer pears harvested at Beltsville in 1932 are given in table 1 and illustrated in figure 1. The results obtained with Kieffer pears grown in New York and Beltsville, Maryland in 1933 are illustrated in figures 2 and 3 respectively. These results on the relative effects of temperature on the rate of softening are typical of those obtained on all of the fruit used in this investigation. The figures show smooth curves rather than points, but the actual points would in all cases have been very near to, and in a great many cases exactly on, the curves.

Table 1 -- Changes in Firmness of Kieffer Pears at Various Temperatures. (Beltsville, Maryland -- Harvested October 25, 1932.)

Days in Storage	Temperature °F.							
	32	40	50	60	70	80	90	100
	Pounds Pressure							
0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
4			11.3	11.0	11.3	11.8	11.8	
7	11.8	11.9	10.9	8.5	10.2	11.4	11.4	11.7
10			9.9	5.2	8.7	11.1	11.4	
13	11.6	11.6	8.6	4.1	7.4	10.0	11.0	12.9
16			8.0	3.7	6.9	11.4	11.8	13.0
20	10.8	11.1	6.5	3.4	7.1	10.6	11.2	13.0
27		10.2	3.9	2.5		9.6	11.3	13.1
35	10.4	8.2	3.1					
60	10.6	4.5						

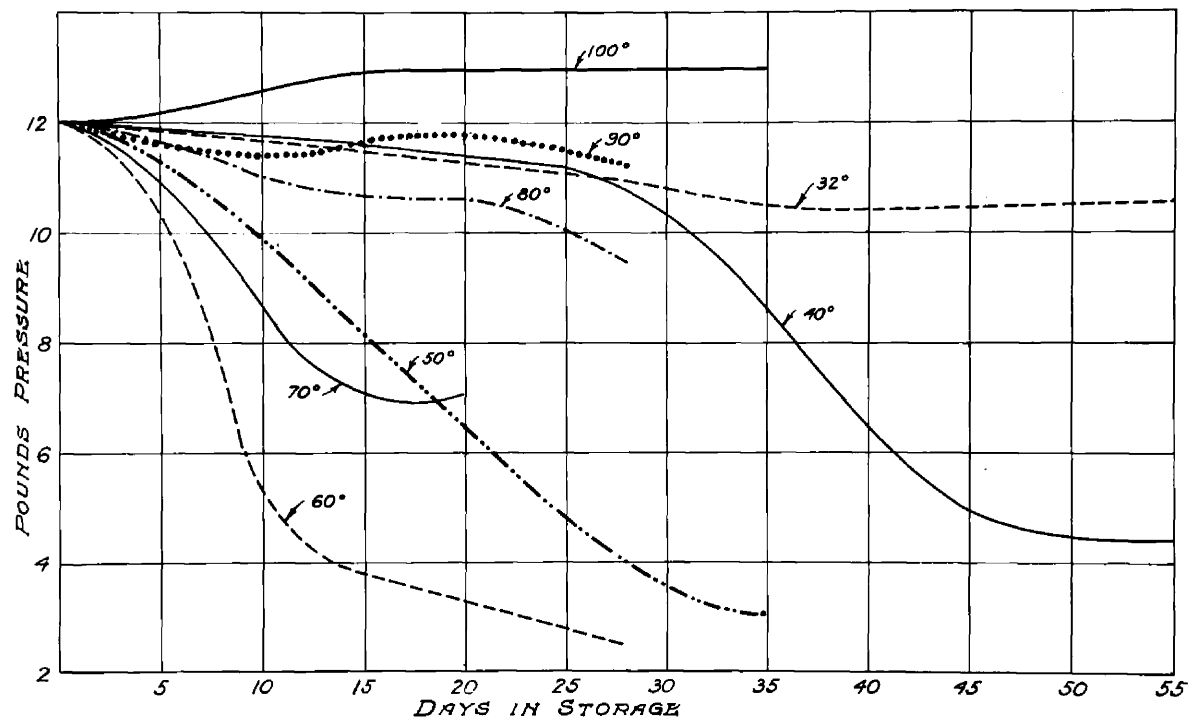

Figure 1.--Change in firmness of Kieffer pears in storage at various temperatures (°F.) (Beltsville, Maryland, October 25, 1932).

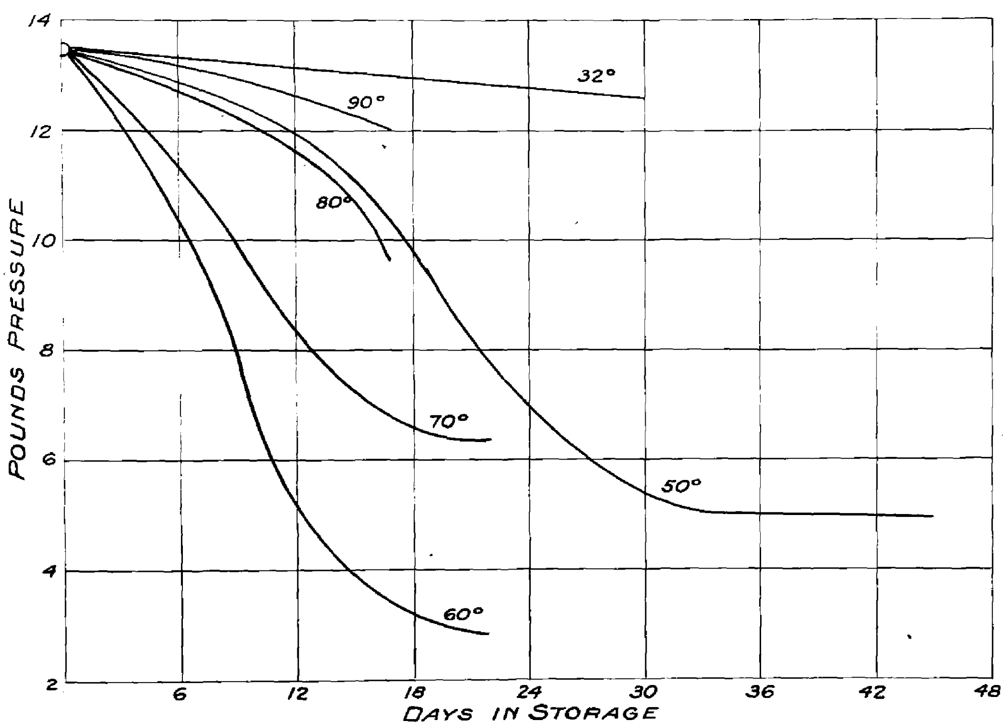

Figure 2.--Changes in firmness of Kieffer pears (New York 1933) as influenced by temperature in storage (°F.).

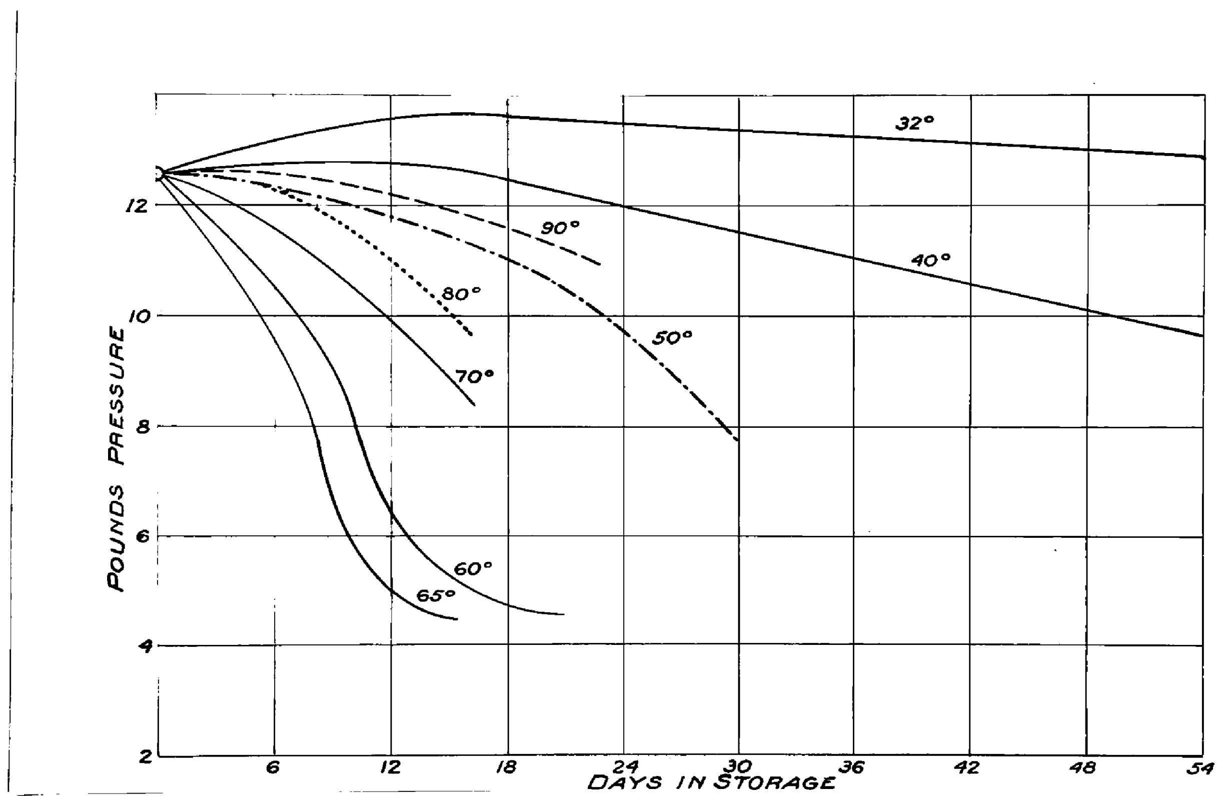

Figure 3.--Changes in firmness of Kieffer pears (Beltsville 1933) as influenced by temperature in storage (°F.).

The firmness of the several lots of pears used in these experiments, after ripening at different temperatures is given in table 2. Figures 4, 5 and 6 illustrate the firmness at various temperatures of 3 of these lots of pears. These figures show that after 16 to 20 days, only fruit ripened at 60°F. or 65° had softened to around 3 or 4 pounds at which firmness the fruit was at optimum dessert or canning quality. The data upon which these figures are based was obtained from the smoothed curves shown in figures 1, 2 and 3, thus accounting for occasional apparent slight discrepancies between table 2, and figures 4, 5 and 6.

It is evident that the most rapid softening occurred at 60° or 65°F. The rate of softening decreased with higher or lower temperatures. The decreased rate of softening with lower temperatures was to be expected in view of the generally accepted fact that deciduous fruits ripen most slowly at temperatures near their freezing point and ripen more rapidly with increasing temperatures until a certain maximum is reached. This maximum temperature is evidently lower in the case of pears than in other fruits. Overholser and Taylor (44) reported that high temperatures do not retard ripening of apples until a temperature is reached where protoplasmic contents of the cells are disorganized. Ezell and Diehl (12) noted that a temperature of 80° to 85°F. retarded ripening of Bartlett pears as compared to 70° to 75°. In these experiments with Kieffer pears, a temperature even of 70° caused a retardation in ripening when compared to 60° or 65°. At 80° the fruit never did ripen enough to be edible. It has been reported in Great Britain that 18°C. (64.4°F.) did not result in proper ripening of Doyenne du Comice pears, although normal ripening occurred at 10°C. (50°F.). There has apparently been no retardation in ripening of this variety reported in the United States at this temperature. In fact, Hartman (24) found that Comice pears ripened faster at 65°F. than any of the other 6 varieties which he used.

Table 2 -- Firmness of Various Lots of Kieffer Pears before and after Storage at Different Temperatures. (°F.)

Source	Date of Storage	Days in Storage	Firmness at Start	32	40	50	60	65	70	80	90	100
Beltsville	9/16/32	22	14.5	13.5			2.8		4.2	10.4		
do	9/24/32	18	12.7				4.1		5.2	9.3		
do	10/4/32	20	13.0	12.9	13.1	4.5	3.1		5.5	9.9	13.4	
do	10/13/32	18	12.2	11.5	11.9	5.7	2.8		6.7	9.6	13.0	
do	10/25/32	16	12.0			8.0	3.7		6.9	11.4	11.8	13.0
do	10/25/32	20	12.0	10.8	11.1	6.5	3.4		7.1	10.6	11.2	13.0
New York	10/9/33	17	13.5	13.0		9.9	3.2		6.8	9.7	12.0	
Beltsville	9/25/33	16	12.6	13.7	12.6	12.2	5.3	4.5	8.5	9.7	11.0	
Michigan	10/7/33	17	13.0	12.2	12.7	8.9	3.2		6.4	8.6	10.6	
Mississippi	9/15/33	17	12.7			11.1	3.1		3.2	7.8		
Arlington	9/21/33	19	14.4	13.8	13.8	14.8	8.0	7.3	10.9	15.2	18.0	
do	10/8/34	18	12.1				6.3		7.8	9.5		
College Park	10/1/34	23	15.0				5.1		8.2	9.9		
Beltsville	10/1/34	23	12.0	10.5		7.1	5.2		7.1	9.4		
Alabama	9/11/34	14	11.1				2.9		4.6	9.8		

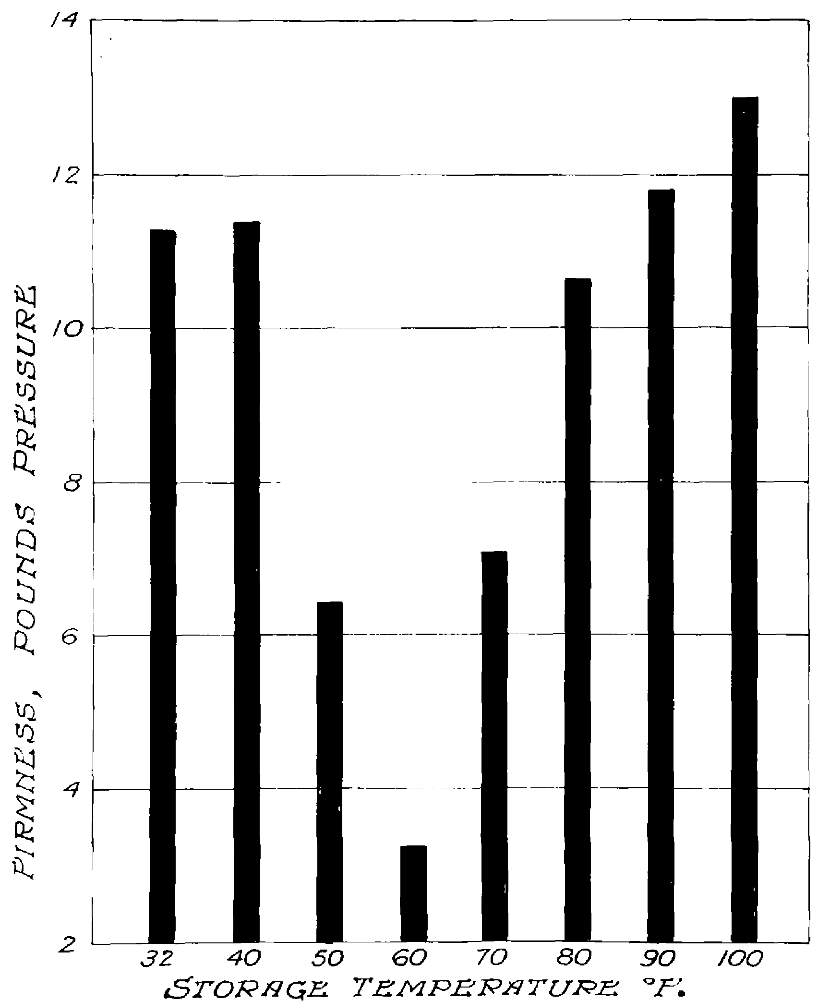

Figure 4.--Firmness of Kieffer pears after 20 days storage at various temperatures (°F.) (Beltsville, Maryland, October 25, 1932).

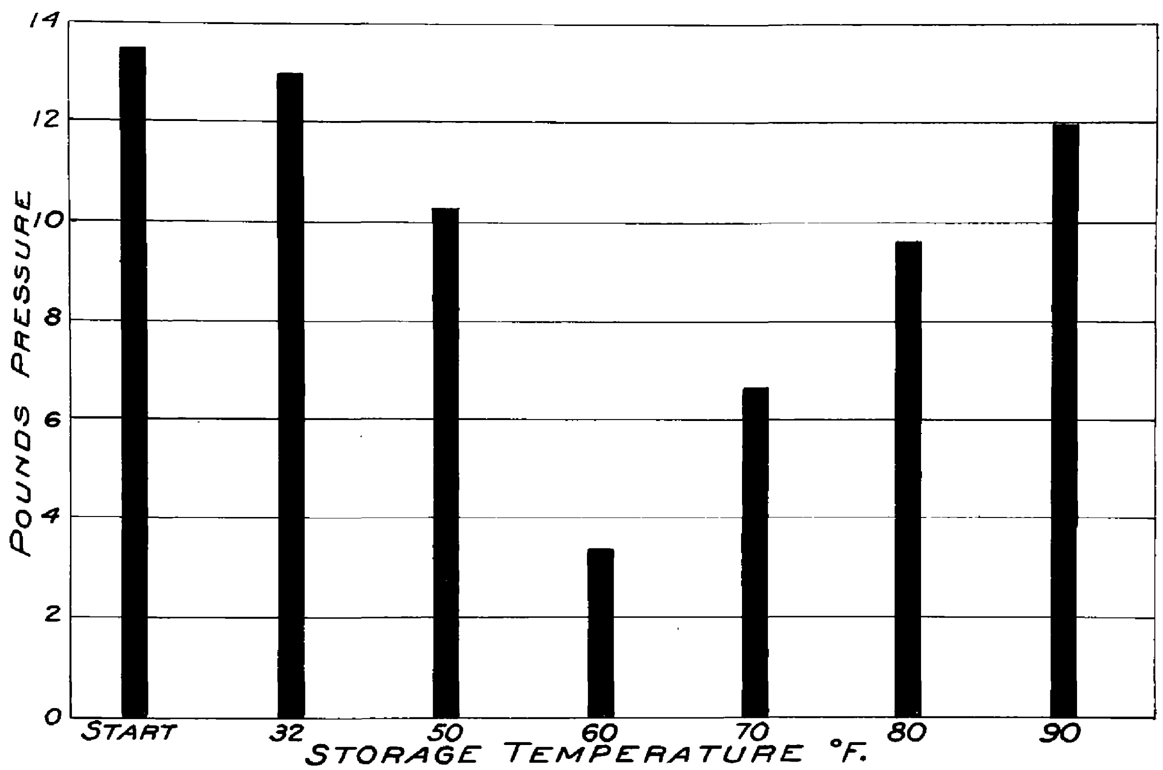

Figure 5.--Firmness of Kieffer pears (New York 1933) after 17 days storage at various temperatures.

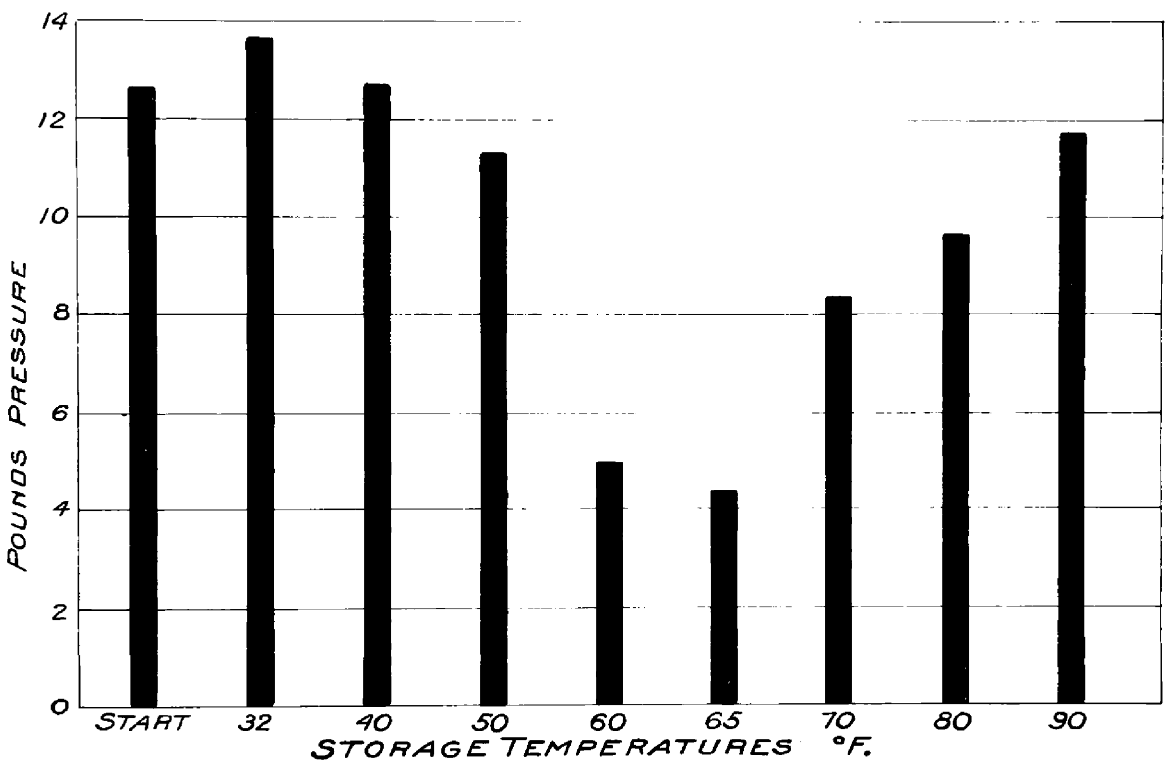

Figure 6.--Firmness of Kieffer pears (Beltsville 1933) after 16 days storage at various temperatures.

<u>Dessert Quality.</u> The dessert quality of the various lots of pears after ripening was judged in both the fresh and canned state by several interested parties. The quality attained by Kieffer pears seemd to be largely determined by the temperature at which they were ripened. When ripened at 60°F. to a pressure test of 3 to 4 pounds, the fruit was of considerably better quality in both texture and flavor than is usually attained with this variety. Pears ripened at 65° were of practically the same quality as those ripened at 60°. Kieffer pears ripened at 70° were about equal in quality to that ordinarily expected of this variety and were always markedly inferior in texture and flavor to fruit ripened at 60°. Although 80° was most effective in changing the green color of the fruit to yellow, pears ripened at this temperature were so tough and woody that they were practically inedible. Fruit ripened at 90° or 100° was even worse. Kieffer pears held at 50° often failed to ripen properly, frequently breaking down before becoming sufficiently soft. When the fruit ripened at 50° without breaking down it was nearly equal in quality to 60° fruit. At 40° there was little softening for 30 or 40 days. There was some softening after this period but the fruit never attained full quality. At this temperature, decay and breakdown set in before the fruit became fully ripe. Apparently 55° and 65° are the lower and upper limits of ripening temperature for securing optimum quality of Kieffer pears. A temperature of 70° resulted in a mediocre product and a temperature of 50° often failed to result in proper ripening.

The relationship of temperature to the quality attained by Kieffer pears was similar in both fresh and canned fruit. Prolonged cooking not only failed to materially soften fruit which had failed to soften properly at ripening-room temperatures which were too high, but also imparted an undesirable pink discoloration to the fruit. The results on quality of the canned fruit obtained with the third picking in 1932 are given in table 3. Quality ratings were made on a scale of 1 to 10. A rating of 1 represents the best or highest quality and 10 the poorest. Consequently, a grade of 1 to 3 upon any character indicates that the material was satisfactory to very good in respect to that character, while a rating of 5 to 10 indicates that it was mediocre to very poor. It is evident that 60°F. resulted in a product markedly superior to that produced at higher temperatures. The results given in table 3 on the comparative effects of temperature on quality of the canned fruit are typical of those obtained with all lots of Kieffer pears used in these experiments.

Of the last picking in 1932, the fruit which was ripened at 60°F. was canned at intervals during the ripening period. The results which are given in table 4 show that maximum quality was reached when the fruit had softened to 3.4 pounds although it was very good at all stages as soft or softer than 4.1 pounds.

Table 3 -- Influence of Ripening Temperature on the Canning Quality of Kieffer Pears. (Picked October 4, 1932, Beltsville)

Temperature of Ripening Room	Days in Ripening Room	Firmness when Canned Pounds Pressure	Quality Rating Color	Quality Rating Texture	Quality Rating Flavor
50	20	4.5	1 1/2	1	1 1/2
60	20	3.1	1 1/4	1	1
70	20	5.5	2	5	3
80	20	9.9	3	6	6
90	20	13.4	5	10	7

Table 4 -- Influence of Length of Ripening Period at 60°F. on Quality of Canned Kieffer Pears. (Picked October 25, 1932, Beltsville)

Days Ripening at 60°F.	Firmness when Canned Pounds Pressure	Quality Rating Color	Quality Rating Texture	Quality Rating Flavor
0	12.0	1	9	9
7	8.5	1	8	5
10	5.1	1	3	3
13	4.1	1	2	2
16	3.7	2	1	1
20	3.4	1 1/4	1	1
27	2.5	1	1	2

Table 5 -- Influence of Ripening Temperature on Decay Development and on Firmness in Kieffer Pears Picked October 25, 1932.

	Days in Ripening Room																			
	7					13					20					27				
Temperature °F.	Percent of Decay B	Percent of Decay M	Percent of Decay S	Sound %	Firmness lbs.	Percent of Decay B	Percent of Decay M	Percent of Decay S	Sound %	Firmness lbs.	Percent of Decay B	Percent of Decay M	Percent of Decay S	Sound %	Firmness lbs.	Percent of Decay B	Percent of Decay M	Percent of Decay S	Sound %	Firmness lbs.
50	0	1.2	2.4	96.4	10.9	0	0	7.1	89.3	8.6	0	2.4	10.7	76.2	6.5	2.4	0	8.3	65.5	3.9
60	0	1.2	7.0	91.8	8.5	0	3.5	5.8	82.5	4.1	5.8	12.8	11.6	52.3	3.4					
70	2.4	1.2	11.9	84.5	10.2	10.7	7.1	8.3	58.4	7.4	39.3	13.1	1.2	4.8	7.1					
80	10.3	8.0	11.5	70.2	11.4	18.4	8.0	9.2	34.6	10.0	17.2	8.0	6.9	2.5	10.6					
90	8.3	9.5	14.7	67.5	11.4	6.0	6.0	13.1	42.4	11.0	0	4.8	4.8	32.8	11.2					
100	0.0	2.5	5.1	92.4	11.7	0	3.8	0	88.6	12.9	1.3	1.3	6.3	79.7	13.0					

B--Badly decayed.
M--Moderately decayed.
S--Slightly decayed.
Note--All decayed fruit was discarded at each inspection but figures given are based on original number of pears.

Table 6 -- Influence of Ripening Temperature on Decay Development in Kieffer Pears (Lockport, N. Y. - 1933) after 17 Days in Ripening Room.

Temperature (°F.)	Firmness (Pounds Pressure)	Percent Decay (Mostly Rhizopus)
60	3.2	1.3
70	6.8	6.6
80	9.7	10.3

Development of Decay. The effect of ripening temperature on decay in a lot of Kieffers which developed considerable decay is given in table 5. It is evident that 70°F. and 80° are especially conducive to decay. Although 60° produced more decay than 50°, the fruit held at the former temperature ripened faster. At a given stage of ripeness about equal amounts of decay developed at the two temperatures. Most of the decay which developed at temperatures of 50° and above was Rhizopus rot. The influence of ripening temperature to decay in a lot of Kieffers which showed relatively slight invasion by decay organisms is given in table 6.

Loss of Weight. The loss in weight of the third picking of Kieffer pears obtained at Beltsville, Maryland in 1932 as influenced by temperature are given in table 7. As would be expected, loss in

Table 7 -- Loss of Weight of Kieffer Pears in Storage as Influenced by Temperature. (Beltsville, October 4, 1932)

Storage Temperature	Percentage Loss in 20 Days
32	1.35
50	2.11
60	2.62
70	3.05
80	4.46
90	7.48

weight is closely associated with temperature. Most of this loss is evidently due to loss in water, as the loss in carbon through respiration amounted to from 1/10 to 1/40 of these values.

Stone Cells and Grittiness. During the organoleptic tests on both the fresh and canned material, many observers commented on the fact that the stone cells were less objectionable in the Kieffer pears ripened at 60°F. and suggested the possibility of this temperature causing a diminution in the quantity of stone cells. Crist and Batjer (9) reported that this did not happen during ripening at 70°. To obtain evidence on this point several lots of pears were subdivided into several portions, each of which was ripened at a different temperature, covering a similar range for each lot. After holding the fruit at these various temperatures until that at 60° had ripened, the fruit was sectioned transversely into slices approximately 1/8 of an inch thick. These sections were kept for 3 hours in a solution of phloroglucin acidified by hydrochloric acid. A photograph of typical specimens is shown in figure 7. In all cases, there was no apparent difference in quantity of stone cells among lots held at the various temperatures. Although the fruit ripened at 60° was much softer than that at the other temperatures, it had just as many stone cells.

Apparently the stone cells in the Kieffer pear are especially objectionable when the flesh is tough. When the flesh is melting, the stone cells seem to be less objectionable even though they are present in as large a quantity. Although Kieffer pears have more stone cells than most other commercial varieties, the presence of the stone cells per se are not the cause of the poor quality generally attributed to this variety. For example, in Michigan Technical Bulletin No. 113, figure 2A illustrates a Bosc pear, which is usually regarded to be a variety of good quality, with apparently nearly as many stone cells as

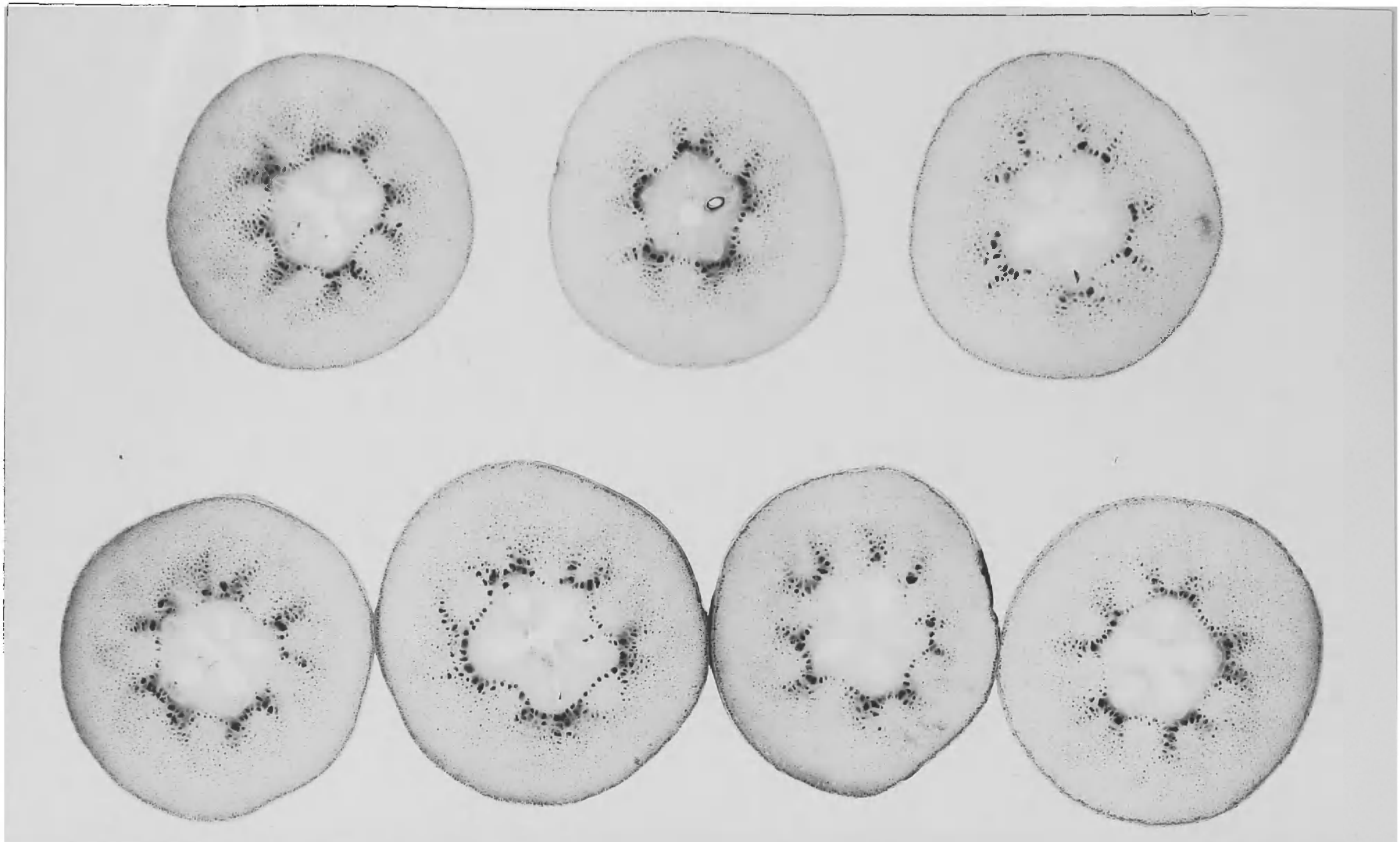

Figure 7.--Stone cells of Kieffer pears after 17 days storage at various temperatures (Michigan, 1933).
Top row, left to right--32°, 40°, 50°. Bottom row, left to right--60°, 70°, 80°, 90°F.

are found in the Kieffer. All varieties of pears contain some stone cells. Figure 8 shows that even the Seckel pear which generally is considered the acme of perfection as regards quality in pears contains some stone cells.

In the preparation of Kieffer pears for canning, it has been found desirable to core the fruit somewhat deeper than in the case of Bartletts. This removes a large percentage of the stone cells which are concentrated around the carpels in the former variety.

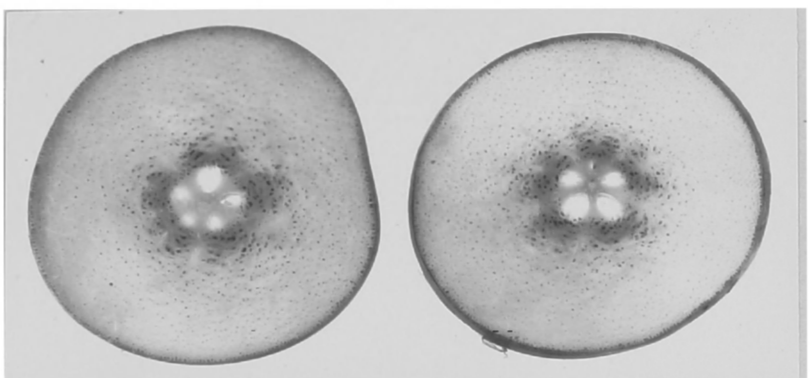

Figure 8.--Stone cells in Seckel pears.

Solids, Sugars and Acidity. The influence of storage temperature on the content of alcohol soluble solids, alcohol insoluble solids, total solids, reducing sugars, total sugars and acidity is given in tables 8, 9 and 10. These results, which are typical of many others which were obtained, show that although the different ripening temperatures do have a profound influence on the quality of the fruit as noted, differences in quality are not reflected in the analysis of the above mentioned constituents which usually are determined in the evaluation of quality in pears. At the higher temperatures (80° and above) there was generally a slight increase in percentage of sugars and solids due to a more rapid loss in weight at these higher temperatures. (See table 7). These temperatures resulted in the poorest quality, however. Iodine tests showed that starch was not present in Kieffer pears except in the very early pickings when a slight amount was present.

Table 8 -- Influence of Storage Temperature on Content of Solids, Sugars and Acids in Kieffer Pears. (Beltsville, October 25, 1932)

Storage Temperature °F.	Days	Firmness when Sampled. Pounds Pressure	Percentage on Fresh Weight Basis					
			Alcohol Soluble Solids	Alcohol Insoluble Solids	Total Solids	Reducing Sugars	Total Sugars	Acid (as Citric)
--	0	12.0	12.92	3.23	16.15	6.58	6.90	.208
40	20	11.1	12.60	3.38	15.98	6.81	7.05	.229
50	20	6.5	11.92	3.29	15.21	6.65	6.69	.218
60	20	3.4	11.56	3.23	14.79	6.60	6.74	.205
70	20	7.1	11.14	3.50	14.64	6.41	6.63	.180
80	20	10.6	12.26	3.50	15.76	7.04	7.15	.202
90	20	11.2	13.04	3.72	16.76	7.24	7.25	.225
100	20	13.0	15.16	3.86	19.02	7.79	7.79	.175

Table 9 -- Influence of Storage Temperature on Content of Solids, Sugars and Acids in Kieffer Pears. (Mississippi. 1933)

Storage Temperature °F.	Days	Firmness when Sampled. Pounds Pressure	Percentage on Fresh Weight Basis					
			Alcohol Soluble Solids	Alcohol Insoluble Solids	Total Solids	Reducing Sugars	Total Sugars	Acid (as Citric)
--	0	12.7	13.68	3.30	16.98	7.78	8.30	.262
60	17	3.1	13.46	3.19	16.65	7.81	8.14	.262
70	17	3.2	13.64	3.36	17.00	7.78	8.06	.242
80	17	7.8	14.26	3.36	17.62	8.24	8.38	.282

Table 10 -- Influence of Storage Temperature on Content of Solids, Sugars and Acids in Kieffer Pears. (Beltsville, September 25, 1933)

Storage Temperature °F.	Days	Firmness when Sampled. Pounds Pressure	Percentage on Fresh Weight Basis					
			Alcohol Soluble Solids	Alcohol Insoluble Solids	Total Solids	Reducing Sugars	Total Sugars	Acid (as Citric)
--	0	12.6	11.40	3.59	14.99	6.25	6.46	.316
32	16	13.7	11.18	4.15	15.33	6.33	6.51	.323
40	16	12.6	11.38	3.50	14.88	6.56	7.12	.296
50	16	12.2	11.40	3.39	14.79	6.75	7.17	.289
60	16	5.3	10.94	3.31	15.25	6.70	7.22	.302
70	16	8.5	11.40	3.30	14.70	6.95	7.36	.296
80	16	9.7	11.76	3.66	15.42	7.09	7.36	.299
90	16	11.0	11.08	3.52	14.60	6.52	6.86	.272

Pectic Changes. The influence of temperature on the pectic constituents of Kieffer pears is given in table 11. The conversion of protopectin to soluble pectin was definitely correlated with the degree of softening. It will be noted that a progressive decrease in percentage of protopectin, and an increase in the percentage of soluble pectin and the ratio of soluble pectin to total pectin occurred with every increase in temperature up to 60°F. At temperatures above 60°, the reverse was true; the percentage of protopectin increased, while the percentage of soluble pectin and the ratio of soluble pectin to total pectin decreased with each increase in temperature.

Although the two methods of preserving samples show slight differences in analysis, both show the same relative effect. Freezing results in a slightly greater range in the soluble/total pectin ratios among various temperatures.

Table 11 -- Influence of Storage Temperature on Pectic Constituents of Kieffer Pears Ripened 17 Days at Various Temperatures. (Michigan, 1933)

Storage Temperature °F.	Firmness when Sampled. Pounds Pressure	Sample Preserved by: Freezing: Soluble Pectin	Proto-pectin	Total Pectin	Soluble/Total Pectin	Alcohol: Soluble Pectin	Proto-pectin	Total Pectin	Soluble/Total Pectin
		Percentage on Fresh Weight Basis							
32	12.2	.155	.478	.633	24.5	.204	.564	.768	26.6
50	8.9	.425	.338	.763	55.7	.364	.492	.856	42.5
60	3.2	.495	.279	.774	64.0	.467	.314	.781	59.8
70	6.4	.365	.310	.675	54.0	.342	.356	.698	49.0
80	8.6	.340	.391	.731	46.5	.308	.508	.816	37.7
90	10.6	.194	.626	.820	23.7	.170	.510	.680	25.0

Content of Acetaldehyde and Alcohol. It has been shown by Gerhardt and Ezell (15) that failure of Comice pears to ripen after prolonged storage was associated with an accumulation of acetaldehyde and alcohol in the pear tissue. From *a priori* reasoning it was thought that the failure of Kieffer pears to ripen at high temperatures also might be due to, or associated with an accumulation of these constituents. As shown in tables 12 and 13 it is evident that the retardation in ripening at temperatures of 70° and 80° cannot be accounted for by accumulation of alcohol or acetaldehyde in the tissue. The values reported in table 12 and 13 are below the threshold values as reported by Gerhardt and Ezell (15) that are associated with failure of Comice pears to ripen after storage. The values for acetaldehyde reported in these tables are also below the values reported by Harley (19) and Harley and Fisher (20) to be associated with scald and breakdown in Bartlett pears.

Table 12 -- Influence of Storage Temperature on Accumulation of Acetaldehyde in Kieffer Pear Tissue. (Beltsville, September 15, 1934)

Days in Storage	60°F.		70°F.		80°F.	
	Firmness Pounds Pressure	Milligrams Acetaldehyde per 100 Grams Pear Tissue	Firmness Pounds Pressure	Milligrams Acetaldehyde per 100 Grams Pear Tissue	Firmness Pounds Pressure	Milligrams Acetaldehyde per 100 Grams Pear Tissue
0	14.2	0	14.2	0	14.2	0
14	6.2	1.2	5.6	1.6	10.2	1.7
18	5.1	1.1	6.2	1.3	9.8	1.1

Table 13 -- Influence of Storage Temperature on Accumulation of Alcohol and Acetaldehyde in Kieffer Pear Tissue (Beltsville, October 1, 1935 -- Held at 32°F. for 35 Days before Ripening) Alcohol and Acetaldehyde in Milligrams per 100 Grams Pear Tissue.

Days in Storage	60°F.			70°F.			80°F.		
	Firmness	Alcohol	Acetaldehyde	Firmness	Alcohol	Acetaldehyde	Firmness	Alcohol	Acetaldehyde
0	10.4	0	.2	10.4	0	.2	10.4	0	.2
7	6.0	15.8	.6	6.0	14.3	.6	8.9	11.5	.4
15	3.2	28.5	2.1	4.7	45.5	2.6	7.7	27.6	1.9

<u>Composition of Internal Gases.</u> Studies were made on the internal gases of Kieffer pears as it was thought that the retardation in the rate of softening of the fruit at temperatures of 70°F. or above might be the result of a particularly high content of CO_2 within the tissues of the fruit ripened at these temperatures. The results of the analyses of internal gases as given in figure 9 and table 14 indicate that the accumulation of a somewhat higher CO_2 content within the fruit ripened at temperatures of 70° or above is only a minor factor in the retardation of the rate of softening at these temperatures. The analyses of internal gases shown in figure 9 and table 14 are the averages of three determinations made at 5 day intervals. Figure 9 shows that although the percentage of CO_2 increases and the percentage of O_2 decreases as the storage temperatures increase to 80°, there is no sharp change in the CO_2 content from 60° to 70° as might be expected if CO_2 were an important factor in causing a decreased rate of softening at the higher temperature. It can be seen in table 14 that the fruit held at 60° in an external atmosphere of 5.3 percent CO_2 softened more than similar fruit held in ordinary air at 80° despite the fact that the former fruit had a much higher percentage of CO_2 and a lower percentage of O_2 within its tissues. The high accumulation of CO_2 in this case did, however, have some effect in retarding the rate of softening, as can be seen when the firmness of this fruit is compared to that ripened at 60° in ordinary atmosphere.

Low oxygen content within the fruit at 80°F. was apparently not responsible for the retardation in the rate of ripening at this

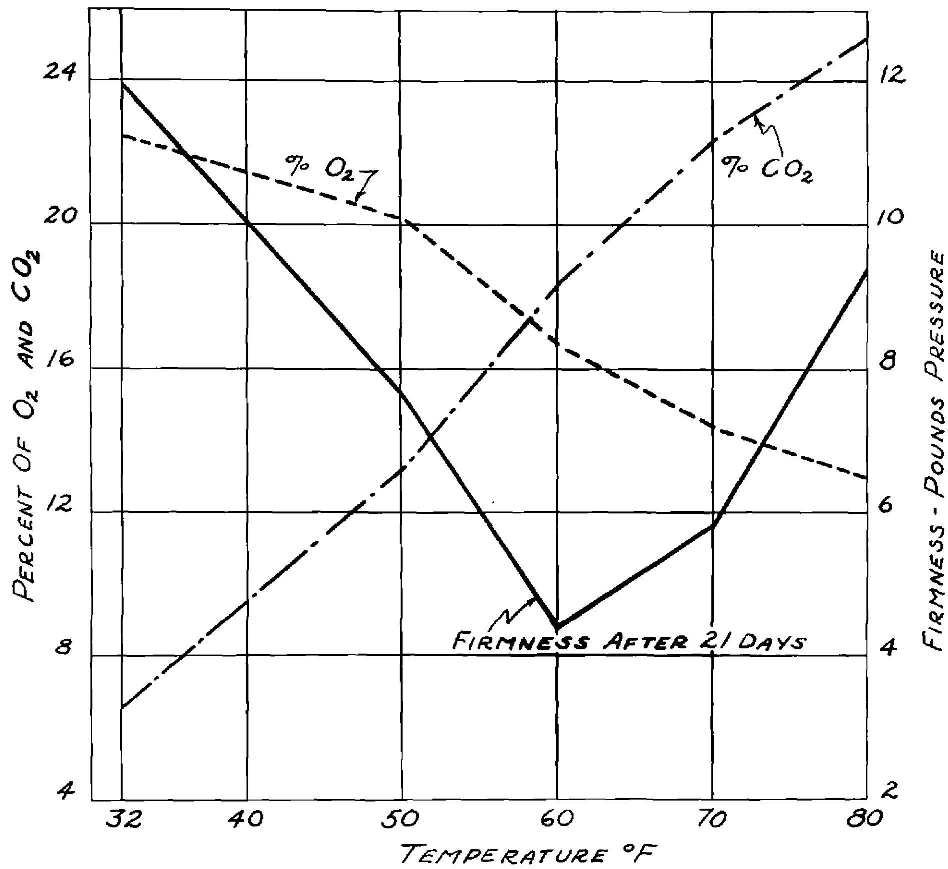

Figure 9.--Interrelationship of ripening temperature change of firmness and composition of internal gases of Kieffer pears (Beltsville, Maryland, 1934).

temperature. In fruit which had 44.1 percent O_2 in its internal gases, there was even less softening than in the normal fruit at 80°.

Table 14 -- Interrelationship of Storage Temperature and External Atmosphere to Composition of Internal Gases and Degree of Softening of Kieffer Pears. (Beltsville, Harvested September 14, 1934).

Storage Temperature °F.	External Atmosphere	Average Composition of Internal Gases during Storage: Percent CO_2	Average Composition of Internal Gases during Storage: Percent O_2	Firmness after 21 Days
32	Ordinary	6.7	23.4	11.9
50	do	13.3	20.3	7.7
60	do	18.6	16.7	4.4
60	High CO_2 (5.3% CO_2 15.1% O_2)	36.0	11.9	8.0
70	Ordinary	22.5	14.4	5.8
80	do	25.2	13.0	9.4
80	High O_2 (82% O_2 0.3% CO_2)	27.7	44.1	10.8

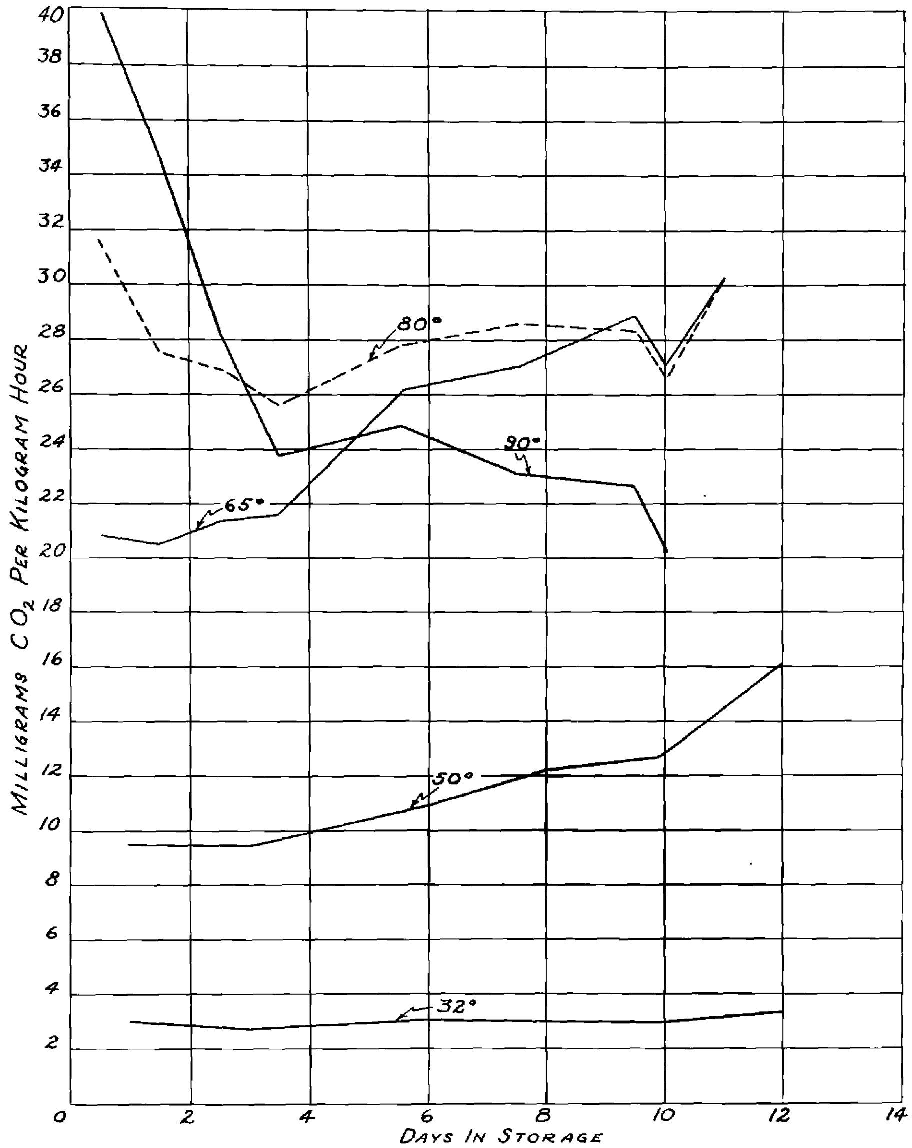

Figure 10.--Respiration of Kieffer pears as influenced by temperature -- 1935.

<u>Rate of Respiration.</u> The rate of respiration of Kieffer pears as influenced by storage temperature is given in table 15 and figure 10. In 1934, the respiration runs were started 2 days after harvesting in order to allow the fruit to come to the temperature of the room and to allow equilibrium to become established in the respiration chamber. In 1935, only 1 day elapsed between the time of harvest and the beginning of the respiration determinations.

In 1934 (table 15) it can be noted that there was some increase in respiration at 80°F. and 50° during the storage period. At 70° there was a greater increase and at 60° a still greater increase. As a result, the respiratory rate at the end of the period at 80° was no greater than at 70° and only slightly greater than at 60° although at the beginning the rate at 80° was nearly twice that at 60° and over 1/4 greater than at 70°. The rates of softening under these conditions can be found in table 17. The increase in rate of respiration was directly associated with rate of softening at the various temperatures. At 60°, 70° and 80° the ratio of the firmness at the end of the period to that at the beginning was practically equal to the reciprocal of the ratio of the respiratory rate at the end to that at the beginning. Magness and Ballard (34) observed an even greater increase in rate of respiration in Bartlett pears with ripening.

In 1935 (figure 10), the rate of respiration at 90° decreased to approximately 50 percent of its original value. There was a slight increase at 80°, a marked increase at 65°, a slight increase at 50° and practically no change at 32°. Although the rate at 65° was only about 2/3 that at 80° and 1/2 that at 90° at the beginning, at the end of

Table 15 -- Respiration of Kieffer Pears as Influenced by Storage Temperature. (Beltsville, October 1, 1934) Respiration Given in Milligrams CO_2 per Kilogram Hour.

Run No.	Length of Run Days	Storage Temperature °F. 32	50	60	70	80
1	2	2.31	7.26	10.82	15.37	19.58
2	4	2.04	7.17	11.62	16.92	20.15
3	4	2.05	8.41	12.71	19.88	19.89
4	2	2.08	8.23	14.97	21.35	20.03
5	3		9.03 (2 days)	18.97	23.77	23.79
6	4			22.51	27.34	28.67
7	2			24.13	27.49	27.23
Ratios:-						
$\frac{\text{Rate Run 7}}{\text{Rate Run 1}}$				2.23	1.79	1.39
$\frac{\text{Rate Run 1}}{\text{Rate Run 7}}$				.448	.559	.719
$\frac{\text{Firmness End}}{\text{Firmness Beginning}}$				.436	.594	.788

the period the rate at 65° had equalled that at 80° and was appreciably greater than at 90°. The rate of change in firmness at various temperatures for the fruit used in 1935 is given in table 16. It is evident that increase in rate of respiration is closely associated with rate of decrease in firmness.

Table 16 -- Firmness of Kieffer Pears during Ripening at Various Temperatures. (Beltsville, 1935)

Storage Temperature °F.	Firmness after -- days 0	6	9	14
	Pounds Pressure			
32	14.6			14.7
50	14.6		9.6	6.4
65	14.6	7.0	5.8	4.6
80	14.6		10.4	9.6
90	14.6			14.0

Catalase Activity. This phase of the work was undertaken to determine if the marked influence of temperature, especially temperatures of 70° and 80°F. on ripening was reflected in the catalase activity. The results obtained are given in table 17 and 18. In practically every case, catalase activity was higher at 60°, at which temperature softening was most rapid, than at higher or lower temperatures. The greatest activity reached in both lots of fruit was at 60°. At 80° where softening was retarded, catalase activity decreased with time after the first few days. At 70°, the results with respect to both catalase and firmness were intermediate between those at 60° and at 80°. Catalase activity was apparently associated to some extent with rate of softening and increase in rate of respiration (table 15). The decrease in rate of catalase activity towards the end of the ripening period in the Kieffer pears was similar to the decrease in Bartlett pears reported by Magness and Ballard (34).

Table 17 -- Catalase Activity and Firmness of Kieffer Pears as Influenced by Storage Temperature. (Beltsville, October 1, 1934) Catalase Activity Expressed as CC. O_2 Liberated in 10 Minutes.

Days in Storage	Storage Temperature °F.									
	32		50		60		70		80	
	Firmness	Catalase	Firmness	Catalase	Firmness	Catalase	Firmness	Catalase	Firmness	Catalase
0	12.0	11.1	12.0	11.1	12.0	11.1	12.0	11.1	12.0	11.1
4	12.1	11.1	11.7	13.3	9.9	12.7	10.3	13.4	9.9	13.8
9	10.9	11.65	11.5	9.35	10.3	14.5	10.6	12.3	12.2	11.05
16	--	10.8	7.6	13.0	5.6	16.2	7.6	13.4	9.1	10.8
23	10.5	13.2	7.1	13.1	5.2	14.1	7.1	12.4	9.4	8.65

Table 18 -- Catalase Activity and Firmness of Kieffer Pears as Influenced by Storage Temperature.

(Beltsville, October 1, 1934 -- Held at 32°F. for 35 Days Prior to Ripening).

Catalase Activity Expressed as CC. O_2 Liberated in 10 Minutes.

Days after Removal from 32°F.	Storage Temperature °F. 50		60		70		80	
	Firmness	Catalase	Firmness	Catalase	Firmness	Catalase	Firmness	Catalase
0	10.4	9.85	10.4	9.85	10.4	9.85	10.4	9.85
7	9.7	6.6	6.0	13.75	6.0	12.7	8.9	12.3
15	6.3	9.8	3.2	9.4	4.7	8.4	7.7	7.15

Influence of Varying Storage Temperatures.

Since 60°F. resulted in much more rapid softening than either 50° and 70°, it was thought desirable to determine the effect of subjecting Kieffer pears to alternating temperatures of 70° and 50°. The fruit was shifted from one temperature to the other every 24 hours. The results which are given in table 19 show that the alternating temperatures did not produce as rapid softening as 60°. This indicates that in commercial practice, a uniform temperature of 60° would be preferable to one fluctuating between 50° and 70° even though the average temperature in the latter instance were 60°F.

Table 19 -- Influence of Alternating Temperatures.

(Beltsville, September 14, 1933)

Firmness at Start	14.2 Pounds
" after 21 Days at 70°	5.8 "
" " " " " 50°	7.7 "
" " " " " 70°-50° Alternating	6.1 "
" " " " " 60°	4.4 "

Another study considered the effect of subjecting Kieffer pears to 80°F. prior to ripening at 60° as shown in table 20 and illustrated in figure 11. A 3 or 7 day exposure to 80° accelerated ripening when the fruit subsequently was transferred to 60°. However, the flavor of this fruit which was transferred to 60° after 3 or 7 days at 80° was not quite equal to that which had been held at 60° continuously. Exposure to 80° for 14 or 21 days before removed to

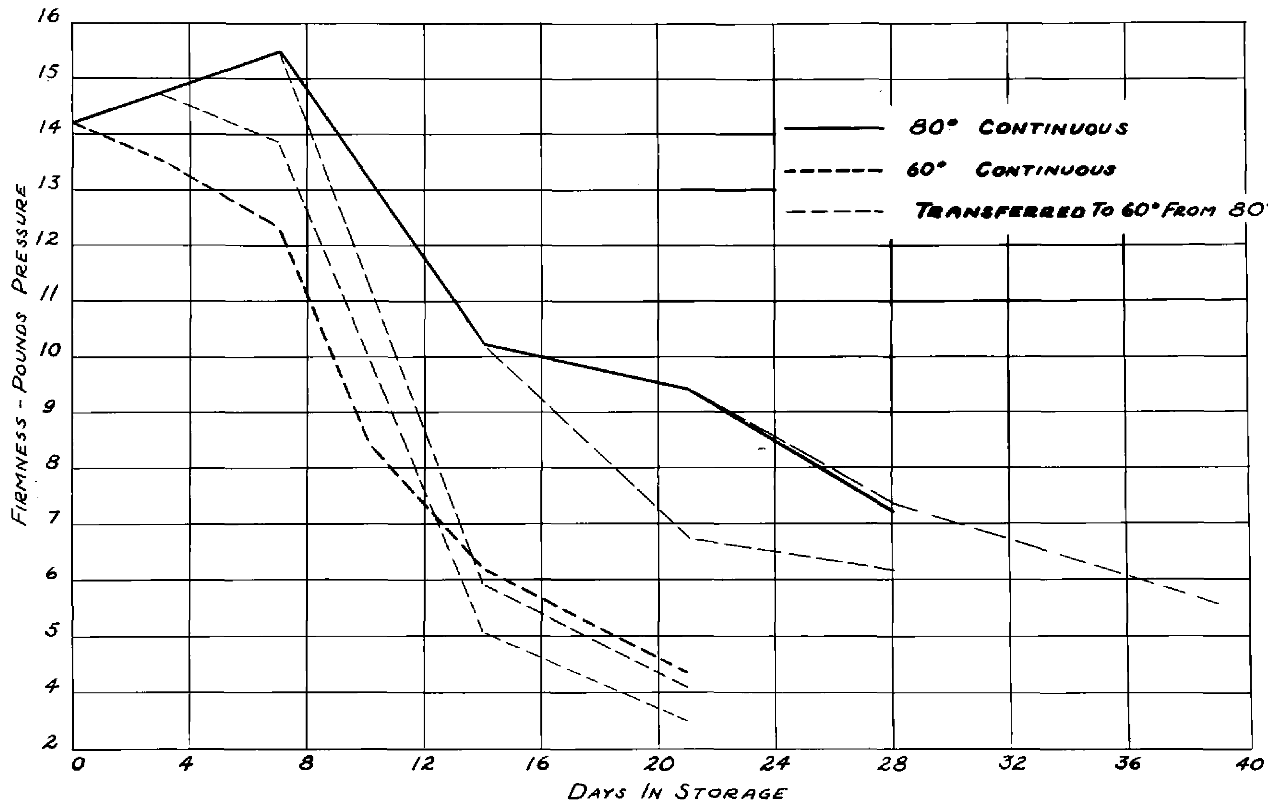

Figure 11.--Influence on Kieffer pears of exposure to 80°F. on subsequent softening at 60° (Beltsville, Maryland, September 14, 1934).

60° did not result in as rapid softening as in fruit not subjected to this prolonged treatment at 80°. Apparently, the injurious effect of 80° previously noted, persisted after the fruit was transferred to 60° under these conditions.

These results indicate that pears can be held as long as 7 days at temperatures as high as 80° and still get satisfactory ripening when removed to 60°, although there might be a slight loss in flavor by such treatment. Holding at 80° for 14 days or longer would not permit proper ripening when the fruit was removed to 60°.

Further combination of varying temperatures involved the behavior of Kieffer pears at 80°F. after exposure to 60° as given in table 21 and illustrated in figure 12. This experiment was undertaken to determine whether pears which had started to soften at 60° would continue to soften properly when removed to a higher temperature such as 80°. It is evident from the data presented that removal to 80° after exposure to 60° resulted in a marked retardation in the rate of softening.

Table 20 -- Influence on Kieffer Pears of Exposure to 80°F. on Subsequent Softening at 60°. (Beltsville, September 14, 1934)

Total Number of Days in Ripening Room	80° Continuous	60° Continuous	Days at 80° before Transferring to 60°			
			3	7	14	21
			Firmness Pounds Pressure			
0	14.2	14.2				
3	14.7	13.5				
7	15.5	12.3	13.9			
10		8.5				
14	10.2	6.2	5.1	6.0		
18		5.1				
21	9.4	4.4	3.5	4.1	6.8	
28	7.2				6.2	7.4
39						5.6

Table 21 -- Influence on Kieffer Pears of Exposure to 60°F. on Subsequent Softening at 80°. (Beltsville, September 14, 1934)

Total Number of Days in Ripening Room	60° Continuous	80° Continuous	Days at 60° before Transferring to 80°			
			3	7	10	14
			Firmness Pounds Pressure			
0	14.2	14.2				
3	13.5	14.7				
7	12.3	15.5	14.1			
10	8.5					
14	6.2	10.2	10.0	8.5	6.9	
18	5.1					
21	4.4	9.4	8.9	8.9	7.9	7.1
28		7.2		7.0	6.6	4.9

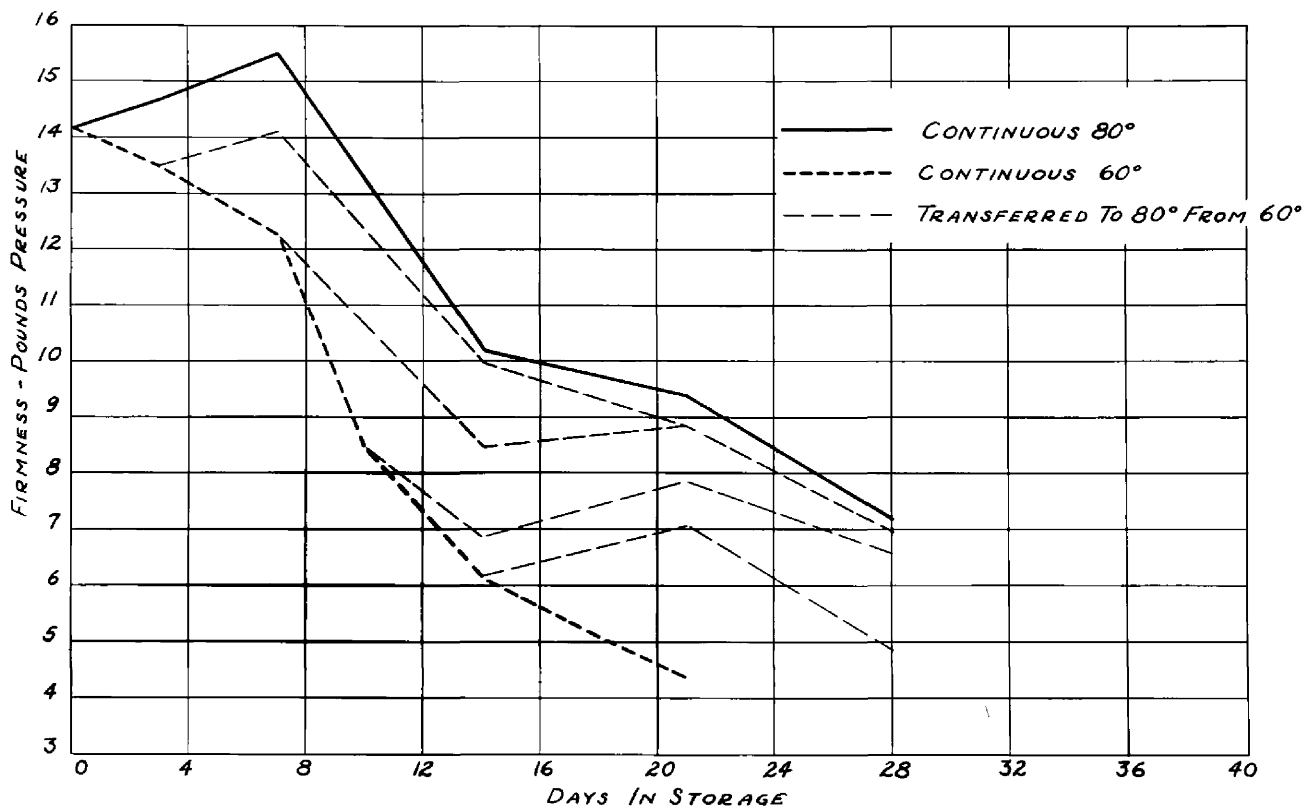

Figure 12.--Influence on Kieffer pears of exposure to 60°F. on subsequent softening at 80° (Beltsville, Maryland, September 14, 1934).

Influence of Length of Storage at 32°F.

A large quantity of fruit from each picking in 1932 was placed in storage at 32°F. at the time of harvesting. After 30, 60, 120 and 180 days storage, representative samples were transferred to 60° for ripening. In addition, samples were transferred to 50°, 70° and 80° after the 30 and 60 day storage periods. After 30 and 60 days at 32°, the fruit ripened much more slowly and with much inferior quality at 70° and 80° than at 60°, just as was the case when the fruit was ripened at these temperatures when harvested.

Storing at 32°F. for 30 to 60 days prior to ripening had little effect on quality but a 120 day storage period at 32° resulted in some loss of quality, especially with the later pickings. The effect of the length of the storage period on the rate of softening is shown in table 22. Little softening occurred at 32°. However, when fruit was removed from 32° storage after 30 days and ripened at 60°, the softening rate was more rapid than when ripened at 60° immediately after harvesting. Storing at 32° for 60 days resulted in still more rapid ripening upon removal from storage to the 60° room. Fruit from the first 2 pickings responded after the 120 day storage period by ripening faster upon removal from storage than did fruit stored 60 days. The later pickings did not ripen as rapidly after 120 days storage at 32° as similar pickings of fruit after 60 days storage. Fruit which ripened slowly after 120 days storage at 32° was of very poor quality.

Further studies on the effect of length of storage at 32° on the behavior of Kieffer pears during the 1934 season included data on firmness, catalase activity, acetaldehyde and alcohol content and respiration as given in table 23. As in 1932, firmness decreased but slightly during storage. The maximum rate of ripening when transferred to 60° was after 98 and 138 days storage, at which time the rate was over twice as great as the rate at 60° at time of harvest. Quality after ripening at 60° was slightly impaired by previous 98 days storage at 32°F. and markedly impaired by 138 days storage. Decay also was quite prevalent after long storage periods. Catalase activity decreased during storage. The decrease was very marked during the later stages when the fruit failed to ripen when removed from storage. Acetaldehyde was quite low throughout, although there was a slight increase up to 172 days. The decrease at 221 days might have been due to the breakdown which was present in the tissue. Harley (19) reported that injured or dead cells of Bartlett pears were either incapable of producing acetaldehyde or unable to retain it. The further rise in acetaldehyde content at 280 days might have been due to appearance of scald on the fruit. Harley and Fisher (20) found that scald in Bartlett pears was associated with high acetaldehyde content. Alcohol began to appear after 70 days, remained fairly constant through the 221 day sampling and then showed a further increase at 280 days. Respiration at 32° continued to increase throughout the storage period until the 280 day period was reached when there was a slight decrease. The rate given for 280 days is slightly higher than it should be, because the temperature was slightly higher in the respiration chamber. The average rate of respiration at 60° during ripening was apparently not influenced by the previous length of storage at 32°. However, the ratio of the respiration at the end to that at the beginning of the ripening period (see last column in table 23) shows marked changes. Immediately after harvesting the rate more than doubled during ripening at 60°. After 35 days there was a 27 percent increase and after 70 days a 35 percent increase. After 98 and 138 days there was only a 19 percent increase. It was after the 98 day storage period when deterioration in quality was first noticed. After 172 days storage at 32° when the rate of ripening when removed to 60° had decreased from the maximum, the respiration rate was only 9 percent greater at the end of the ripening period than at the beginning. After 221 days storage when the fruit failed to ripen after 16 days at 60°, the rate at the end of the 16 day period was considerably slower than that at the beginning. This latter behavior was similar to that of fruit held at 90°, (figure 10) where the rate of respiration decreased while there was practically no softening of the fruit.

It was observed in both seasons that storage at 32°F. for periods up to 60 or 70 days resulted in somewhat more uniform ripening when removed to 60°.

The physiological behavior of Kieffer pears in storage at 32°F. seems to differ from that of Comice pears. Gerhardt and Ezell (15) reported that the failure of Comice pears to ripen after storage at 32° was associated with a marked increase in alcohol and acetaldehyde content and shortly thereafter with a marked decrease in respiratory rate. In the experiments reported herein, there was only a slight decrease in the rate of respiration at 32° and this occurred considerably later than the time the fruit first failed to ripen properly when removed from storage.

Acetaldehyde and alcohol content were much lower than in the case of Comice pears and was not associated with failure to ripen in Kieffer pears. The storage life of Kieffer pears at 32° seems to be limited to 60-70 days after which deterioration in quality occurs. Failure to ripen after removal from storage occurred much later. In Comice, failure to ripen seems to limit the storage life.

Table 22 -- Days Required to Reach a Pressure Test of 3 Pounds at 60°F. after Storage at 32° for Periods Indicated. (Beltsville, 1932)

Date of Picking	Days in Storage at 32°F.				
	0	30	60	120	180
September 16	21	18	13	7	18
September 24	19	15	11	6	
October 4	20	15	9	12	
October 13	18	13	7	--	
October 25	21	12	9	14	

Table 23 -- Influence of Length of Storage at 32°F. on Firmness, Rate of Ripening when Removed from Storage, Respiration, Catalase Activity, and Alcohol and Acetaldehyde Content. (Beltsville, October 1, 1934)

Days in Storage at 32°F.	Firmness	Days to Ripen at 60° when Removed from 32°	Catalase Activity O_2 Liberated in 10 Minutes	Milligrams per 100 Grams		Respiration Mg. per Kg. Hour		Increase in Respiration at 60° during Ripening
				Acetaldehyde	Alcohol	32°	60°	
0	12.0	23	11.1	0.0	0.0	2.16	16.39	2.23
35	10.4	16	9.85	.2	0.0	2.35	15.41	1.27
70	10.4	12	10.4	.2	8.7	2.40	17.03	1.35
98	10.1	10	6.8	.4	11.0	2.64	15.89	1.19
138	10.6	10	8.0	.6	8.7	2.74	16.26	1.19
172	10.7	12	6.7	.9	8.7	2.97	18.56	1.09
221*	10.0	Not Ripe in 16 Days	4.4	.2	10.6	3.33	16.63	0.79
280**	--	--	2.2	1.5	39.6	3.26***		

* Breakdown when Removed from Storage.
** Scald Appearing.
*** Temperature Slightly High in Respiration Chamber.

Influence of Various Esters and Rapid Air Circulation.

Brooks, Cooley and Fisher (6) have demonstrated that apple scald was evidently due to the accumulation of volatile esters around the fruit and could be prevented by the use of oiled wraps or by air circulation. Experiments were designed to determine if the retardation in ripening of Kieffer pears at high temperatures were due to similar causes. That this is not true, however, is evidenced by the results given in table 24 which shows that rapid air circulation did not hasten softening at 80°, table 25 which shows that at 58° ethyl butyrate, ethyl acetate and amyl acetate in concentrations high enough to injure the fruit retarded the softening appreciably less than normal 80° air, and table 26 which shows that oiled wraps do not hasten softening at this temperature.

Table 24 -- Influence of Rapid Air Circulation on Rate of Softening of Kieffer Pears. (Beltsville, September 14, 1934)

Treatment	Firmness after -- Days 0	7	14
60°F. -- Check	14.2	12.3	6.2
80°F. -- Check	14.2	15.5	10.2
80°F. -- Rapid Air Circulation*	14.2	16.8	11.8

*Air circulation was accomplished by directing a current of air from an electric fan running at high speed over pears spread out on a false floor.

Table 25 -- Influence of Various Esters on the Rate of Softening at 58°F. (Beltsville -- Harvested September 14 and Held at 32° for 26 Days before Treatment)

Ester	Firmness at Start	Firmness after 20 Days
	Pounds Pressure	
Ethyl Butyrate	11.9	5.4*
Ethyl Acetate	do	6.4*
Amyl Acetate	do	5.5*
Check -- 58°	do	4.6
Check -- 80°	do	8.2

*Some of the fruit was injured by this treatment which consisted of placing 50 cc. of the ester about 4 inches below the fruit in a loosely stoppered 5 gallon jar for 38 hours.

Influence of Ethylene.

As can be seen in table 26, applications of ethylene at the rate of 1-1000 did not hasten softening at 80°F. The ethylene was applied twice daily and the chamber ventilated for 30 minutes before each "shot" of ethylene.

Table 26 -- Influence of Ethylene and Oiled Paper Wraps on Softening of Kieffer Pears. (Beltsville -- Harvested September 14 and Held at 32°F. for 26 Days before Treatment)

	Firmness at Start	Firmness after 20 Days
Check -- 80°	11.9	8.2
Ethylene -- 80°	do	8.6
Regular Northwestern Oiled Wraps -- 80°	do	8.7
Check -- 60°	do	4.1

Effect of Time of Harvesting on Composition, Quality and Yield.

Tables 27 to 30 inclusive show the influence of time of harvest on the firmness, color and composition of Kieffer pears.

As would be expected, there was generally a decrease in firmness during the harvesting season although it was not as great as has been reported for many other varieties. During a season, the maximum difference observed with Kieffer pears in these experiments was 4 pounds. Magness, Diehl and Allen (35) reported differences as much as 11.1 pounds between the beginning and end of the season with Bartletts.

Color changes as determined by a color chart (35) showed a gradual change from green to yellow during the season. A figure of 1 on this color chart represents green, 2 represents light green, 3 represents turning and 4 represents yellow.

The principle effect of date of harvest on chemical composition was a marked decrease in alcohol insoluble solids during the season. This was apparently to a considerable extent, due to increase in size of the pears with only a slight change per fruit in this constituent which consists largely of the structural material in the cell walls and the stone cells. Thus, in table 31 it can be seen that while the volume per fruit increased about 79 percent from September 1 to October 4, the percentage of alcohol insoluble solids in this fruit was 55 percent greater on August 30 than on October 8 (table 29).

There was generally a slight increase in sugar content during the season except in 1934, and a tendency towards a decrease in acidity. The sugar content was low in all pickings reported in table 28 because the trees from which this fruit was obtained were rather seriously defoliated by leaf spot.

The time of harvest seemed to have but slight effect on the quality of the fruit in 1932 and 1934. The chief difference observed was that the proportion of stone cells decreased somewhat as the season advanced, apparently the result of increasing size of the fruit. The fruit from the first picking seemed to have slightly less flavor and sweetness than in the succeeding pickings although when properly ripened, it was quite satisfactory. In 1933, the intermediate pickings were of somewhat better quality than either the first or last picking. Since quality is not appreciably affected by date of harvest, it is evident from the foregoing results that the proper harvest date for Kieffer pears is the time when maximum tonnage can be obtained.

As can be seen in table 31, there was a marked increase in size of the fruit during the harvesting season. Dropping did not become appreciable until September 24. As a result, the maximum yield would have been obtained during the September 17 to September 24 period. (See last column in table 31). After September 24, by calculation, there would have been a decrease from this maximum owing to the fact that there was more loss from dropping than there was gain from increase in size of fruit. In other words, when the fruit starts to drop appreciably, it should be harvested.

Dropping was determined by conspicuously tagging 200 fruits on 10 trees on September 1 and counting the fruit remaining on the trees at intervals. Increase in size was determined by measuring the circumference of 50 additional pears distributed on the 10 trees. Owing to dropping due to natural causes and to that incident to measuring the fruit, only 31 fruits were left at the end, and the data on increase in size is based on these specimens. Size was calculated from the circumference data on the basis that the fruit is a sphere. This, of course, is not exactly true, but since all calculations were made on this basis, the data presented on relative increase in size are an accurate estimate.

Table 27 -- Influence of Date of Harvest on Firmness and Composition of Kieffer Pears. (Beltsville -- 1932)

Date of Harvesting	Firmness Pounds Pressure	Percentage Composition on Fresh Weight Basis					
		Alcohol Soluble Solids	Alcohol Insoluble Solids	Total Solids	Reducing Sugar	Total Sugar	Acid (as Citric)
September 16	14.5	12.16	4.76	16.92	5.48	5.76	.245
September 24	12.7	12.48	4.20	16.68	6.02	6.22	.228
October 4	13.0	13.00	3.86	16.86	6.71	6.84	.235
October 13	12.2	12.68	3.77	16.45	6.88	7.30	.205
October 25	12.0	12.92	3.23	16.15	6.58	6.90	.208

Table 28 -- <u>Influence of Date of Harvest on Firmness, Color, and Composition of Kieffer Pears. (Arlington Farm -- 1933)</u>

Date of Harvesting	Firmness Pounds Pressure	Color	Percentage Composition on Fresh Weight Basis: Alcohol Soluble Solids	Alcohol Insoluble Solids	Total Solids	Reducing Sugar	Total Sugar	Acid (as Citric)
August 18	17.2	1	9.60	6.66	16.26	4.25	4.45	.309
August 30	15.9	1	10.40	5.01	15.41	5.20	5.34	.276
September 13	15.8	1 3/4	10.02	4.61	14.63	5.65	5.65	.299
September 21	14.4	2	11.06	3.94	15.00	5.58	5.89	.286

Table 29 -- <u>Influence of Date of Harvest on Firmness, Color, and Composition of Kieffer Pears. (Arlington Farm -- 1934)</u>

Date of Harvesting	Firmness Pounds Pressure	Color	Percentage Composition on Fresh Weight Basis after Ripening: Alcohol Soluble Solids	Alcohol Insoluble Solids	Total Solids	Reducing Sugar	Total Sugar	Acid (as Citric)
August 30	13.81	1 1/2	12.04	4.32	16.36	7.10	7.49	.34
September 10	15.1	2	12.00	4.16	16.16	7.06	7.45	.33
September 23	12.4	2	11.60	3.10	14.70	7.15	7.79	.22
October 8	12.1	2 3/4	12.10	2.79	14.89	7.33	7.40	.25
October 19	Not determined.							

Table 30 -- Influence of Date of Harvest on Firmness and Color of Kieffer Pears. (Beltsville -- 1934)

Date of Harvest	Firmness	Color
September 4	14.6	1 3/4
September 14	13.0	1 3/4
October 1	12.0	2
October 12	11.5	2 1/2
October 26	10.6	3 1/4
November 6	12.4	Deeper than 4

Table 31 -- Increase in Size, Dropping, and Total Volume of Fruit per Tree during the Harvesting Season.

Date	Average Volume per Fruit % of Original	Number of Pears Remaining on the Tree % of Original	Relative Yield (Volume x Number) % of Original
September 1	100	100	100
September 10	122.9	99.5	122.3
September 17	140.8	98.0	139.0
September 24	160.9	87.0	140.8
October 4	179.1	64.5	115.5

Leaf Area per Fruit in Relation to Quality and Composition.

In 1934, the crop in the Beltsville orchard was very irregular. Some trees had a crop of only a few pears while others had as much as 10 bushels. Chemical composition and quality was determined of fruit ripened for 19 days at 60°F. including samples from each of 4 trees bearing a heavy crop (25-50 leaves per fruit) and 4 trees with a light crop (150-250 leaves per fruit). Thus, it was possible to study the influence of leaf area on chemical composition, as given in table 32. Although there was a very great difference in the leaf area per fruit in the light and heavy crop trees, the difference was not reflected in the chemical composition and quality of the fruit. There was a slightly higher sugar content in the fruit which was produced with the greater leaf area. The difference in quality between the lots was very slight. In the fresh state, it was noted that the fruit produced with the greater leaf area was slightly sweeter than those produced with the small leaf area, although the difference was not marked. Some observers noted a slight difference in favor of the high leaf area fruit in the canned state, while others observed no difference between the various lots.

Table 32 -- Influence of Leaf Area on Size and Chemical Composition of Kieffer Pears. (Beltsville, September 26, 1934)

Tree	Crop per tree: Bushels	Leaves per Fruit	Average Weight of Fruit (Pounds)	Percentage Composition on Fresh Weight Basis after Ripening 19 Days at 60°F.: Alcohol Soluble Solids	Alcohol Insoluble Solids	Total Solids	Reducing Sugar	Total Sugar	Acid (as Citric)
A	2.5	25	.47	11.00	3.58	14.58	6.62	7.10	.31
B	4.0	50	.55	11.84	3.11	14.95	5.76	7.24	.28
C	10.0	25	.36	11.20	2.93	14.13	6.19	7.27	.21
D	7.0	25	.34	11.20	2.98	14.18	6.62	6.97	.23
E	1.0	200	.53	11.84	3.06	14.90	6.69	7.56	.24
F	0.5	250	.46	11.92	3.11	15.03	6.26	7.48	.26
G	0.75	200	.52	12.10	3.11	15.21	7.08	7.54	.28
H	1.0	150	.53	12.24	3.04	15.28	7.33	7.75	.30
Average Heavy Crop (A to D Inclusive)	5.9	31.2	.43	11.31	3.15	14.46	6.30	7.15	.26
Average Light Crop (E to H Inclusive)	0.8	200.0	.51	12.02	3.08	15.10	6.84	7.58	.27

SUMMARY AND CONCLUSIONS.

The results of the experiments reported herein definitely show that the most rapid ripening and optimum quality were attained at 55° to 65°F. Above and below this temperature range, both quality and rate of ripening decreased markedly with increase or decrease in temperature. Since room temperatures at the time of harvest of Kieffer pears, especially in the southern states, are above 60° to 65°, it is not surprising that the Kieffer pear is generally considered to be of very poor quality. By maintenance of a ripening temperature of 60° to 65°, the Kieffer pear attains reasonably good quality.

Much of the experimental work on the breeding of pears in the eastern United States has had as its object to secure a pear variety which is of better quality than the Kieffer (as ordinarily handled) and still be relatively blight resistant. With proper ripening of Kieffer pears -- of which there is a large acreage already planted, the importance of the application of these results in securing quality are apparent.

Loss in weight and development of decay, especially the latter, increased with increasing temperature. Minimizing this loss is another advantage of ripening at temperatures around 60°F.

The higher quality of Kieffer which had been ripened at 60°F. was not associated with content of solids, sugars or acid.

Retardation in ripening at high temperatures could not be attributed to abnormal accumulation of alcohol or acetaldehyde in the fruit tissue nor to an accumulation around the fruit of esters or other volatile constituents given off by the fruit. Accumulation of carbon dioxide in the fruit was not the primary cause of the retardation although it may have had a slight effect.

Rate of softening was closely associated with conversion of protopectin to pectin. Both of these changes were most rapid at 60°F. and decreased with higher or lower temperatures.

Increase in rate of respiration at 60° to 65°F. during ripening was closely associated with the more rapid softening at this temperature. At a temperature of 90° where there was practically no softening, the rate of respiration decreased markedly during the ripening period.

Catalase activity was generally higher in fruit which had been held at 60°F. than at higher temperatures. The depressing influence of temperatures as low as 70° and 80° on the activity of catalase and the pectic enzymes in Kieffer pears is interesting in view of the generally accepted opinion that optimum enzymatic activity usually occurs at higher temperatures.

A uniform temperature of 60°F. was superior to alternating temperatures of 50° and 70°. Transferring fruit to a high temperature after partial ripening at 60° caused a marked retardation in the ripening rate. The injurious effect of an exposure of 2 weeks at 80° was manifest even after removal to 60°.

Prolonged storage at 32° resulted in the failure of Kieffer pears to ripen properly when removed from storage. This was associated with a decrease in catalase activity and abnormal respiration after removal from storage in the later stages. However, loss in quality which occurred before the time the fruit failed to ripen properly limited the storage life to 60 or 75 days.

Ethylene which has been used in hastening the ripening of Bartlett pears and other fruits failed to influence the rate of softening of Kieffer pears at 80°F.

There was a marked decrease in alcohol insoluble constituents, a slight decrease in firmness, a slight increase in sugar content and generally a slight decrease in acidity with advancing maturity on the tree. Time of picking of Kieffer pears had only a slight effect on the quality of Kieffer pears and was greatly overshadowed by the influence of ripening temperature after harvest. The optimum picking maturity seems to be when, considering rate of dropping and increase in size, maximum tonnage can be obtained.

Quality and sugar content were only slightly influenced by the number of leaves per fruit under ordinary conditions. Severe defoliation did, however, result in low sugar content and only mediocre quality.

ACKNOWLEDGMENTS.

The author wishes to acknowledge the suggestions of Dr. A. L. Schrader, Mr. D. F. Fisher and Dr. J. H. Beaumont in the planning and pursuit of this study, and in the preparation of the manuscript. The data presented on the influence of various factors on the canning quality and composition of solids, sugars and acids were obtained in cooperation with Mr. C. W. Culpepper. Acknowledgment is also due to Mr. Culpepper for suggesting the method used in extracting the internal gases from pears and to Mr. H. H. Moon who assisted in making the determinations of the pectic constituents and some of the internal gas analyses.

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