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Fruit Pressure Testers and Their Practical Applications

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INTRODUCTION

The resistance of fruit, particularly apples, to pressure of the thumb has long been used as an indication of ripeness. In 1917 a simple method of more accurately measuring this resistance of fruit to indentation was devised by Morris (*50*).[1] He used a marble partially embedded in paraffin and resting on a spring scale. The test was made by pressing an apple against the marble until the marble penetrated the apple as far as the paraffin, and the pressure was read in pounds from the scale. Lewis et al. (*40*) developed a more elaborate instrument, in which a cylindrical plunger was used with a lever and the depth of penetration was regulated by electrical contact. This principle was later used in a portable machine devised by Magness and Taylor (*48*). Such instruments have been used commercially to measure picking maturity and ripeness of apples and pears, and these, with other types, have been used extensively in investigations to measure the firmness of various fruits under experimental conditions. Although various types of pressure testers have been used in experimental studies on the various fruits, most of the studies and their

[1] Italic numbers in parentheses refer to Literature Cited, p. 17.

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practical applications have dealt with apples, pears, peaches, and plums, and with the use of the United States Department of Agriculture (Magness and Taylor) or the Oregon-type instrument with a plunger having a diameter of 7/16 or 5/16 of an inch. Since these results are scattered through various publications, the purpose of this circular is briefly to describe the pressure testers, to indicate their applications and limitations, and to summarize in one place the widely scattered data concerning them.

DESCRIPTION OF VARIOUS TYPES OF FRUIT PRESSURE TESTERS

The type of pressure tester described by Magness and Taylor (*48*) is shown in figure 1, as modified and manufactured at the present time. The apparatus consists of a cylindrical metal barrel within which works a plunger attached to the barrel by a steel tension spring. A groove is cut in the barrel to show the plunger sleeve. The calibra-

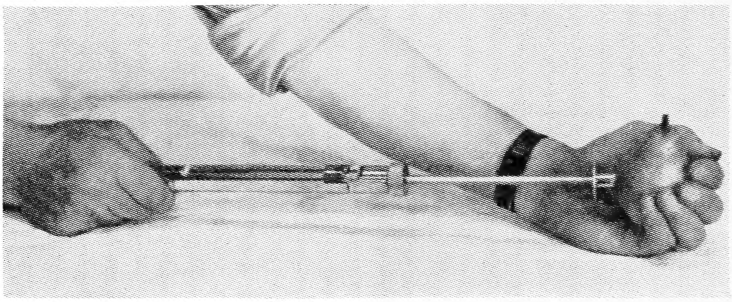

Figure 1.—Fruit pressure tester for apples, pears, and peaches. (Photograph through courtesy of R. Schneider.)

tion in pounds of the pressure required to force the plunger back is marked on the barrel at the side of the groove. An indicator slide that is pushed back by a screwhead on the plunger sleeve loosely encircles the barrel. The pressure-test reading is made at the edge of the indicator slide nearest the plunger. A slightly rounded plunger tip screws into the outer end of the plunger and holds a splash plate in place between the plunger tip and the plunger. The purpose of the plate is to protect the operator from any juice that may squirt out from the fruit being tested. The plunger tip has a mark around it to indicate the proper depth of penetration.

In the tester as originally described by Magness and Taylor the depth of penetration of the plunger was indicated by electrical contact with a flashlight and the reading was made directly. The apparatus as now manufactured differs from the original in that the depth of penetration is determined by the line around the plunger and the reading is made from the indicator slide.

Blake (*9*) described a pressure tester for use with peaches similar to that described by Magness and Taylor (*48*) except that the plunger rod extends through both ends of the barrel and the instrument has an indicator slide. He tried plungers having diameters of 7/16, 5/16, 3/16, and 32/1000 of an inch.

Tests made through the skin of the fruit indicated that with the needle-type plunger (32/1000 of an inch in diameter) the toughness of the skin was a disturbing factor, whereas with a plunger 5/16 of an inch in diameter too great a pressure (18 to 23 pounds) was required to give accurate readings. Blake, therefore, preferred the plunger 3/16 of an inch in diameter, although he stated that either size apparently gives dependable results.

On prunes Hartman (*33*) used an Oregon-type pressure tester with a plunger 6/16 of an inch in diameter. Hartman and Bullis (*34*) described a pressure tester having a plunger 2 millimeters in diameter for use with cherries.

Culpepper and Magoon (*19*) described a needle-type pressure tester with a No. 16 brass wire (27/1000 of an inch in diameter) for a plunger, reading from 0 to 400 grams. This instrument was used to test the toughness of sweet corn kernels in studies of maturity and quality of different varieties for canning. The same type of instrument has been used by Culpepper and his associates in studies of development and maturity of a number of fruits and vegetables, such as peaches (*17*), strawberries (*18*), snap beans (*15*), asparagus (*20*), summer squash (*16*), peas, and other products. For some of these purposes the instrument has been modified by changing the strength of the spring and the range of the scale and by using needles of different diameters.

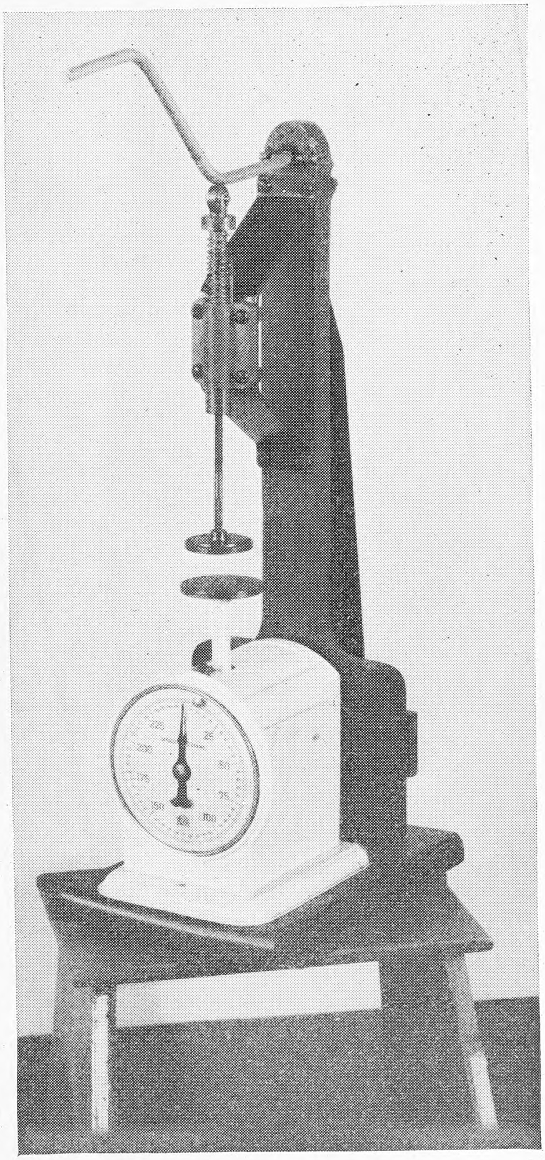

FIGURE 2.—The Idaho pressure tester for stone fruits (except peaches) and strawberries.

Verner (*60*) described a different type of pressure tester for use with stone fruits, in which the fruit is squeezed between two flat surfaces or disks for a given distance. A modification of this instrument (fig. 2) has been used to test the firmness of strawberries (*28*, *56*) also.

METHODS OF MAKING PRESSURE-TEST DETERMINATIONS

With apples and pears it is customary to make 2 or 3 tests on each fruit at about equal distances around the periphery and midway between the stem and calyx ends. With peaches 2 tests, 1 on each cheek of each fruit, have generally been made (*14*, *31*, *42*). Culpepper and Caldwell (*17*), using a needle plunger, made 10 tests on each peach: 6 on the cheeks, 1 at each end, 1 at the suture, and 1 opposite the suture. Blake and Davidson (*10*) made 12 tests on each peach: 1 on each cheek, 1 at the suture, and 1 opposite the suture, at each of 3 points on the fruit—the top (stem end), the middle, and the apex. Coe (*14*) varied the point of pressure testing somewhat from season to season; but in the last season of his investigations he made the tests on the cheeks, as the suture became too soft for a reliable measure of firmness and did not represent the position most subject to bruising.

Magness and Taylor (*48*) showed that the skin of apples may mask the firmness of the flesh. They recommended that the skin should be sliced off at the points to be tested, and this is the customary practice with both apples and pears. With peaches also, the skin was removed before testing by Magness and Allen (*42*) and by Harding and Haller (*31*). Coe (*14*) and Blake and Davidson (*10*) made tests on both the peeled and unpeeled fruit but based their recommendations on tests with the peel intact. Morris (*51*) also tested peaches without peeling them. Blake and Davidson (*10*) observed that tests through the skin required less time, and they considered it desirable to test through the skin, because skin texture as well as flesh firmness may be a factor in the capacity of a peach variety to withstand handling and shipping. They found that the skin offered less resistance to puncturing when the peaches were soft ripe than when they were shipping ripe. This is contrary to results with apples, in which Magness and Taylor (*48*) found greater resistance to penetration through the skin in the riper fruit. Although skin texture may be important in comparing peach varieties, it seems likely that flesh texture would be most important in following the softening changes within a variety in relation to maturity or ripening, and therefore it would be desirable to remove the peel from peaches as well as from apples and pears before making pressure tests.

A plunger $\frac{7}{16}$ of an inch in diameter and with a penetration of $\frac{5}{16}$ of an inch has been used with apples. A plunger with the same depth of penetration but with a diameter of only $\frac{5}{16}$ of an inch has been used with pears. Generally, a plunger of the same size and depth of penetration has been used with peaches as with pears. However, Blake and Davidson (*10*) used a pressure tester in which the plunger rod extended through both ends of the barrel and it was necessary to hold the tester by the side; consequently, it was found desirable to use a small plunger so that less force was required. The United States Department of Agriculture tester can be held at the end, and this permits a steady application of a considerably greater pressure. With the 3/16-inch plunger used by Blake and Davidson (*10*) the extremes of pressure test were 10 pounds for green-shipping ripe and 1 pound for soft ripe, whereas for the 5/16-inch plunger they gave corresponding extremes of 20 pounds and 2 pounds. They stated that plungers of either size give dependable results. The much greater range in pressure test (18 pounds compared with 9) obtained with the 5/16-inch plunger should make this more accurate and sensitive.

From the foregoing discussion it is apparent that a rather uniform method of testing apples and pears has been adopted but that the method of testing the firmness of peaches has varied greatly in the number of tests per peach, the points at which the tests were made, the size of the plunger, and as to whether the tests were made on the pared or unpared surface. Blake and Davidson (*10*) deplored this lack of uniformity, yet added to it by adopting a plunger size differing from that used originally by Magness and Allen (*42*) and subsequently by most other investigators (*14*, *31*, *51*). For the sake of uniformity it is suggested that the following method of testing peaches be adopted:

(1) That a plunger 5/16 of an inch in diameter with a penetration of 5/16 of an inch be used. This size has been most generally used and does not give readings that are too high when used with the United States Department of Agriculture tester.

(2) That 2 tests be made on each peach; 1 on each pared cheek. Making 10 or 12 tests on each peach greatly increases the time and labor required, and as the average of 12 tests, as reported by Blake and Davidson (*10*), did not differ appreciably from the average of the 2 tests, 1 on each cheek, it would seem unnecessary to make so many tests. Although ripening may progress more rapidly at the suture or other points, it is likely that tests on the cheeks would give an equally satisfactory measure of maturity or ripeness. After making tests at various points, Coe (*14*) concluded that tests on the cheeks were more satisfactory than those on the suture. As with apples and pears, the firmness of the flesh rather than the texture or toughness of the skin should be the best measure of maturity or ripeness, and therefore the skin should be removed before making a test.

A random sample of 20 to 30 fruits is generally used for pressure testing. In fairly uniform lots of apples and pears the mean of such a sample will usually have a standard error of about 0.1 to 0.2 of a pound; this is sufficiently accurate for nearly all purposes. As peaches often vary more than apples or pears, at least 30 fruits to the sample would perhaps be desirable.

In making a test the skin is removed at the points to be tested by slicing off pieces of somewhat greater diameter than that of the plunger point. The fruit is held in one hand, and with the other hand the plunger point is directed squarely against the cut surface, and the pressure is gradually increased until the plunger penetrates to the mark on its side. When the mark is reached, the pressure is released and the reading indicated by the slide is recorded. The slide is then returned to the zero position, and the next test is made. If the fruit is hard, a steady application of the force can be obtained by holding the fruit against a wall or other convenient surface and bearing the weight of the body against the opposite end of the instrument or the hand holding it.

FACTORS INFLUENCING PRESSURE-TEST READINGS

Variations in Methods of Making Tests

Various factors that might affect the pressure-test reading have been studied. Magness and Taylor (*48*) determined that if the pressure is applied very rapidly the results may be about 0.5 of a pound higher than if it is applied slowly. This would represent an extreme difference, as the rate of application varied more than is likely to occur in practice. The rate of application of pressure, therefore, is not likely to be an important source of error.

The tip of the plunger as furnished with the testers is uniformly slightly rounded. Magness [2] compared plungers having a flat tip, a hemispherically rounded tip, and a tip intermediately round. The average pressure test of four varieties was 13.5 pounds for the rounded tip, 13.7 for the slightly rounded one, and 13.8 for the flat one. These extreme differences in shape did not cause significantly different results. However, Ryall [3] compared a rounded-tip plunger originally furnished with the testers with a plunger having the less rounded tip of the later models and found that pressure tests with the rounded tip were sometimes as much as a pound less than with the slightly rounded tip. Apparently differences in the shape of the tip may cause appreciable error, and the shape should therefore be kept uniform.

Pressure testers should be calibrated occasionally to insure that they are reading correctly. This can be conveniently done by placing the plunger of the tester against the platform of an accurate set of scales and pressing down until the scale registers a given amount and checking this against the pressure-test reading. The calibration should be made at various points on the scale of the pressure tester, as the correction may vary for the different points. If the tester is held upright on the scales in calibrating, the weight of the plunger rod, theoretically, should be deducted from the scale reading. Practically, this is not important and is not done in the original calibration of the instrument. If an instrument is found to read incorrectly, the readings should be corrected or the instrument should be returned to the factory for recalibration.

Maturity and Ripeness of Fruit

As the fruit becomes more mature on the tree or ripens after harvest, there is a gradual softening of the flesh. Softening of the fruit after harvest has been associated with the hydrolysis of the insoluble cell-wall cementing material, protopectin, to soluble pectin in peaches (*1, 8, 53*), apples (*12, 13, 25*), and pears (*22, 24, 41*). As the fruit matures on the tree it is likely that the increase in the size of the cells and possibly the stretching and thinning of the cell walls are important factors influencing the softening of the fruit.

Magness et al. (*46*) observed that apples grown in districts with long growing seasons were generally softer when picked than those grown in districts of short growing seasons. This was attributed in part to greater maturity at time of picking for apples grown with

[2] Unpublished data by J. R. Magness.
[3] Unpublished data by A. L. Ryall.

long seasons, but it might also be due to the difference in temperatures at the time of ripening.

The pressure tester has been used extensively in studies of the maturity and ripening of fruit, but factors other than maturity may influence the firmness of the fruit.

Temperature of Fruit

The condition of the fruit at the time of the test may also influence the pressure test. Hawkins and Sando (*37*), using a needle plunger, found that strawberries, raspberries, blackberries, and cherries required more pressure to puncture the epidermis at low temperatures than at high. Rose et al. (*56*), using a ¼-inch plunger, found that strawberries had a considerably greater resistance to penetration at low temperatures than at high temperatures; however, with a squeeze tester the difference, although statistically significant, was of no practical importance. Using a plunger ½ inch in diameter, Hartman (*32*) found pears to be 3.4 pounds (10 percent) firmer at 51° F. than at 97°. Hartman and Bullis (*34*), using a plunger 2 millimeters in diameter, found the resistance to penetration of cherries to be nearly 30 percent less at 90° than at 32°.

To determine the effect of temperature on the resistance to penetration of apples, duplicate 10-apple samples were removed from storage at 32° F. and held at various temperatures from 80° to 32° for 3 to 6 hours. This was long enough to permit the fruit to attain approximately the temperature of the room but not long enough to permit any appreciable ripening to occur. The pressure-test determinations were made at room temperature (about 75°) and were completed for each sample within 5 minutes after removal from the various temperatures, during which time no appreciable change in the temperature of the fruit occurred. That temperature of the fruit at the time of testing had no significant effect on the pressure-test readings of apples is shown by the data presented in table 1. The effect of temperature on the resistance to penetration of peaches is not known.

The results indicate that temperature may be an important source of error and that the temperature should be controlled within somewhat narrow limits for some fruits, but that this is not necessary with apples.

Table 1.—*Relation of temperature to firmness of apples*

Temperature of fruit (°F.)	Pressure-test reading of—								
	Rome Beauty		Gallia Beauty		Winesap		Stayman Winesap		Average
	a [1]	b [1]	a [1]	b [1]	a [1]	b [1]	a [1]	b [1]	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
33.5	19.1	19.3	20.1	19.6	21.8	21.9	19.0	19.3	20.0
40.5	18.2	19.1	19.5	19.1	21.7	22.0	20.7	19.0	19.9
48.5	17.9	19.5	19.1	20.2	22.1	22.6	18.6	19.1	19.9
55.5	19.9	19.7	20.6	19.7	22.9	22.4	19.3	19.3	20.5
68.5	19.5	19.0	20.0	19.7	22.7	23.2	19.2	18.9	20.3
77.0	18.6	18.6	19.5	20.3	22.9	22.0	19.5	19.4	20.1

[1] a and b represent duplicate 10-apple samples.

Turgidity and Moisture Content of Fruit

Murneek (*52*) has observed that pears held at room temperature for 30 hours tested higher than those held for 6 hours. A similar increase in firmness of apples is indicated by results published by Magness et al. (*46*). Hartman (*32*) attributed this increase in firmness to loss of turgidity, as pears held at high relative humidities softened whereas those held at low humidities became firmer. He further observed an increased firmness of pears on the tree under drought conditions. Morris (*50*) observed a considerable increase in the pressure test of apples in storage, and he attributed it to wilting. That the increase in firmness after harvest may be due in part to some factor other than turgidity seems likely, since such increases have been observed in fruit held at high humidities. In studying the firmness of fruit as it matures on the tree, these results emphasize the importance of making tests promptly after harvest. They suggest also the desirability of picking fruit for testing in the early morning when it is most likely to be turgid.

The moisture content of fruit as well as turgidity may influence its firmness. Haller et al. (*28*) reported an indirect relation between the moisture content of strawberry varieties and their resistance to flattening. An increased soil-moisture content has been found to result in an increase in moisture content and reduction in firmness of strawberries by Kimbrough (*38*), of apples by Haller and Harding (*26*), and of pears by Ryall and Aldrich (*57*). The firmness of the fruit might also be influenced by climatic or other cultural conditions that would affect the moisture content of the fruit. Thus, Magness, Diehl, and Allen (*44*) found that Bartlett pears grown in California under high temperatures and at low humidity, which would tend to produce fruit of low moisture content, were distinctly firmer than those grown under coastal influences where lower temperatures and higher humidities prevailed. Similar results with Gravenstein apples have been obtained by Allen (*6*).

Blake et al. (*11*) observed that rapidly growing peaches on trees with a high-nitrogen growth status were softer previous to the shipping-ripe stage than peaches from trees having a high-carbohydrate growth status. Although there was very little difference, peaches of the high-nitrogen growth status averaged slightly less in percentage of dry matter.

Fertilization

Somewhat conflicting results have been obtained relative to the effect of nitrogen fertilization on the firmness of apples. Magness and Overley (*47*) reported no difference in firmness or rate of softening in storage between apples from nitrated and nonnitrated plots when fruits of the same size and color were used from each treatment. Overley and Overholser (*54*), however, reporting on the same project, found the apples from the nitrated plots slightly softer when samples representative of the fruit produced by the different treatments were compared. Knowlton and Hoffman (*39*), finding the apples from nitrated plots significantly softer in most instances but with no differences in other instances, considered the differences obtained of no practical importance. Verner (*61*) reported that apples from nitrated plots were considerably softer at harvest but not after storage. Aldrich (*2*) obtained inconsistent results in that in most instances nitrogen fertilization had no effect on firmness, but in one instance it resulted in softer apples and in other instances in firmer apples. Degman and Weinberger (*21*), working with apples and peaches, concluded that it was impossible to find any direct influence of nitrogen on the firmness of the fruit. Haller and Harding [4] found that nitrogen fertilization considerably reduced the firmness of York Imperial apples when thinned to the same leaf-to-fruit ratios and in seasons of deficient rainfall.

In a report by Degman and Weinberger (*21*), Weinberger concluded that peaches from plots receiving potash in addition to nitrogen were no firmer than those from plots receiving nitrogen alone. The same conclusion was applicable to apples, except that one source of potash (sulfate of potash magnesia) resulted in a definite increase in firmness. Phosphate fertilizer did not affect the firmness of apples or peaches.

Thinning and Size of Crop

Hartman (*32*) determined the firmness of pears from 50 heavily loaded and 50 lightly loaded trees and found the fruit from heavily loaded trees to be much softer (4.5 to 5.5 pounds). He attributed the lower test to the more advanced maturity of the fruit on heavily loaded trees. Haller and Magness (*30*), studying apples grown on ringed branches with different leaf-to-fruit ratios, found that Ben Davis apples were softer when grown with a large leaf-to-fruit ratio representing a light crop. With York Imperial, Baldwin, and Jonathan apples, however, the softest apples were those grown with intermediate leaf areas (medium-size crop), and those with large leaf areas (light crop) were firmer. Other factors indicated that the firmer apples grown with large leaf areas were also more mature. With treatments applied to whole apple trees, Haller and Harding [4] found that fruit from heavily loaded trees was firmer at harvest than that from lightly loaded (thinned) trees. However, the apples from the heavily loaded trees softened more rapidly in storage and became softer after 6 months at 32° F. These results indicate that the size of the crop may influence the firmness of fruit, but in either direction. It is doubtful whether this indicated a corresponding change in maturity.

A heavy preliminary picking of pears has been reported (*32*) to retard the softening of the fruit remaining on the trees even though it continues to mature. On the other hand, Allen (*6*) found that a preliminary picking had no effect on the softening of the remaining fruit.

Fruit Size

Murneek (*52*) reported that the size of the pears on a tree did not influence their pressure test. However, heavy irrigation of trees under deficient soil-moisture conditions has increased the size and reduced the firmness of apples (*26*). On the other hand, when the

[4] Unpublished data by M. H. Haller and P. L. Harding.

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size of apples was increased by an increased supply of elaborated foods (increased leaf area per fruit), the firmness of the fruit was increased (*30*). Thus, whether size increases or decreases the firmness may depend on the cause of the difference in size.

Fruit Color

Highly colored apples were firmer than poorly colored ones and the blush side of apples or of pears was firmer than the unblushed side of the fruit (*5, 50, 61*). The difference between the blushed and the unblushed sides of the fruit makes it important to pressure-test the fruit at two or three points. A sample to be tested should also be representative of the color of the lot sampled.

Rootstock

Allen (*3*) found that Bartlett pears grown on Japanese rootstock [*Pyrus pyrifolia* (Burm.) Nakai] were generally considerably firmer than when grown on French stock [*P. communis* L.] and that Clairgeau and Hardy pears (*4*) were firmer on quince than on French pear stock.

APPLICATION OF PRESSURE TEST TO VARIOUS FRUITS

Apples

Attempts have been made to use the pressure test as an index of maturity in apples. Magness et al. (*46*) found that the rate of softening may vary greatly under different growing conditions and that frequently there was not enough softening previous to harvest for the pressure test to be of value as an index of when to start picking the variety. The actual pressure test at picking time was more uniform, but it also varied too much to be a satisfactory index. They concluded that the value of the pressure test as an index of maturity will be mainly to determine when certain varieties are becoming too soft on the trees for satisfactory storage. Magness et al. (*45*) gave the approximate pressure-test range at which optimum maturity is most likely to occur, and indicated the minimum test value below which certain varieties may be too soft. These data are presented in column 2 of table 2. Magness and Taylor (*48*) in an earlier publication indicated the approximate range at which certain varieties are generally picked, as shown in column 3 of table 2; this generally is a somewhat wider range than the optimum given in column 2. Magness et al. (*46*) noted that apples (particularly those requiring a long season of growth) are generally softer at picking time when grown in a district having a long than in one having a short growing season. They attribute this difference partly to difference in maturity at time of picking. Apples grown in sections with short growing seasons are likely to be picked in the upper limits of the ranges given in table 2, columns 2 and 3, whereas those grown in districts with long growing seasons are likely to fall in the lower limits of the ranges. The lower limits for varieties that are likely to become too soft before harvesting are also indicated in column 2.

TABLE 2.—*Pressure-test limits of certain apple varieties at picking time and at different degrees of ripeness*

[Plunger, 7/16 of an inch in diameter; penetration, 5/16 of an inch]

Variety	Approximate limits of pressure test at picking time according to—		Limits of pressure test at indicated degree of ripeness					
	Magness et al.[1]	Magness and Taylor[2]	Hard[3]	Firm[3]	Firm ripe[3]	Ripe[3]	Prime eating[2]	Over-ripe, upper limit[2]
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Arkansas (Mammoth Black Twig)	20±	24 to 19	25 to 18	19 to 15	16.5 to 13	15 to 11	14 to 10	10
Arkansas Black	25±							
Baldwin	22 to 18	22 to 18					12 to 9	9
Ben Davis	20 to [4]17	24 to 18	24 to 17.5	18 to 14.5	15 to 12	13.5 to 8	13 to 9	9
Bonum			30 to 18.5	19.5 to 15.5	16.5 to 12	13 to 8		
Delicious	18 to [4]16	20 to 16	20 to 16.5	17.5 to 14	15 to 11	12 to 8	12 to 8	8
Esopus Spitzenburg	18+							
Gano	18±							
Golden Delicious			20 to 16	16.5 to 13	14 to 11	11.5 to 8		
Grimes Golden	20 to 18	21 to 17	27 to 18	18.5 to 15	16 to 12.5	13.5 to 9	12 to 8	8
Jonathan	16 to [4]15	20 to 16	21 to 16	16.5 to 13.5	14 to 10.5	12 to 8	12 to 8	8
King David	18±	21 to 17					12 to 8	8
McIntosh	16 to [4]14	19 to 15					11 to 7	7
Northern Spy	17 to 16							
Oldenburg (Duchess)			21.5 to 16	17 to 13	14 to 10.5	13 to 7		
Rhode Island Greening	22 to 18	21 to 17					12 to 8	8
Rome Beauty	17+	22 to 16	23 to 18	19 to 15	16 to 12.5	13.5 to 9	13 to 9	9
Stark	20 to [4]18							
Stayman Winesap	18 to [4]16	20 to 16	21 to 16	16.5 to 13	14 to 11	12 to 7	12 to 8	8
Wagener	18±							
Wealthy			20 to 16	17 to 13	14 to 10	11 to 6		
Williams (Early Red)			26 to 16	17 to 12	13 to 10	12 to 6		
Winesap	19+	23 to 19	27 to 18	19 to 15	16 to 12.5	14 to 9.5	13 to 9	9
Winter Banana	20±							
Yellow Newtown (Albemarle Pippin)	20 to 18	25 to 20	21.5 to 18	19 to 15	16 to 12	13 to 10	13 to 9	9
Yellow Transparent			22 to 16	17 to 13	14 to 10	11 to 6		
York Imperial	19±	24 to 19	24 to 18	19 to 16	17 to 14	15 to 9	13 to 10	10

[1] Taken from Magness et al. (*45*).
[2] Taken from Magness and Taylor (*48*).
[3] Taken from Haller et al. (*29*). Degree of ripeness based on definitions in the United States Standards for Apples.
[4] Apples testing lower are likely to be too soft for satisfactory storage.

It should be emphasized that factors other than pressure test have been used as primary indexes of maturity and that the ranges indicated in table 2 are those at which apples are usually picked but that they may be mature even though averaging higher than the upper limits indicated.

Magness, Diehl, and Haller (*46*) have used the pressure test as an indication of the ripeness of apples during storage at various temperatures. They found a gradual softening at low temperatures and a rather rapid rate of softening at high temperatures. Magness and Taylor (*48*) indicated the approximate range of pressure test for a number of varieties of apples when in prime eating condition and the upper limits for the overripe and mealy stage. These are given in columns 8 and 9 of table 2. Haller et al. (*29*) attempted to determine the pressure-test range of a number of apple varieties for the degrees of ripeness as defined in the United States Standards for Apples (*59*). They found that apples of a variety at a given pressure test were generally considered to be of the same ripeness even with different lots that were picked at different maturities or ripened under different temperature conditions. However, it was found that with many lots the pressure test decreased with time to a fairly low point and remained at this point or increased while the fruit continued to ripen. Magness and Burroughs (*43*) showed a similar flattening of the softening curves. With such lots it was frequently not possible to distinguish between firm-ripe and ripe apples by means of the pressure test.

The ranges of pressure test for the different degrees of ripeness are given in columns 4 to 7, inclusive, in table 2. The range of pressure test for prime eating condition as given by Magness and Taylor (*48*) in column 8 agrees well with that given for the ripe stage in column 7. However, Haller et al. (*29*) generally considered that apples in the firm-ripe stage were in prime eating condition and that the ripe stage represented a somewhat mealy condition that was past prime eating. The lower limits of the pressure-test ranges for prime eating are given by Magness and Taylor (*48*) as the upper limits for the overripe condition. The range of pressure test for the overripe condition as determined by Haller et al. (*29*) is not presented in table 2. However, they observed that in some varieties, apples testing in the upper limits of the range for ripe may be overripe as indicated by core browning or an excessively dry and mealy condition of the flesh. Although apples testing less than the lower limits for ripe were overripe, they might also be overripe and the pressure test considerably above the lower limits for ripe.

The hard stage (table 2, column 4) corresponds fairly well with the picking stages (columns 2 and 3) and often extends above the usual limits for picking.

With apples the pressure test has not been found satisfactory as an index of maturity, except to indicate when certain varieties are becoming overmature; but it has been found valuable as a measure of ripeness after harvest.

Pears

Although the pressure test has been found to be one of the most satisfactory indexes of maturity for pears, allowance must be made for the climatic conditions under which the fruit is grown. In California it has been found (*3*, *44*, *55*) that pears grown under hot, dry conditions will be mature with a higher pressure test than pears of the same variety grown under cooler and more humid conditions or with ample irrigation. Consequently, the recommended pressure-test limits for California vary somewhat, depending on the district or conditions in which the pears are grown. With Bartletts this makes a difference of 2 to 3 pounds in the pressure test at which picking may start. The maturity regulations for the State of California recognize this difference and require a pressure test not to exceed 25 pounds in the dry, hot sections and not to exceed 23 pounds in the cooler, more humid sections.

A large proportion of the commercial pear production is in the Pacific Coast States, and most of the investigations on picking maturity have been conducted there. Table 3 summarizes the recommendations on the pressure-test limits at which pear varieties should be picked. The recommendations for Oregon conditions given by Hartman et al. (*36*) are for tests on unpared surfaces and are therefore higher than the recommendations for other districts that are based on tests on pared surfaces. For the other districts the limits recommended for a variety are rather uniform and variations might be attributed to the differences in judgment of the various investigators. Where two values are given for the upper limit of the pressure test, the higher value represents a condition in which the fruit is passable but will generally develop only fair dessert quality and the lower value represents the optimum point at which to start harvesting.

TABLE 3.—*Pressure-test limits recommended for harvesting pear varieties*

[Plunger, 5/16 of an inch in diameter; penetration, 5/16 of an inch]

Variety	Pressure-test limits (pounds): Upper: Passable	Pressure-test limits (pounds): Upper: Optimum	Pressure-test limits (pounds): Lower	Locality	State	Remarks	Literature or footnote reference
Angouleme	----	11	8	Santa Clara Valley and Sacramento River district.	California	Pared	(5)
Anjou	---	14	11	Santa Clara Valley	do	do	(5)
	15	14	----	Sacramento River and Sierra foothills districts.	do	do	(5)
	---	19	15	Rogue River Valley	Oregon	Unpared	(36)
	---	14	----	Grand Junction	Colorado	Pared	(55)
	---	13	10	Wenatchee	Washington	do	(55)
	---	13	12	Hudson River Valley	New York	do	(55)
	---	13	11	Approximate limits applicable generally.		do	----
Bartlett [a]	22	20	17	Coastal and bay districts	California	Pared. Cool, humid districts.	(3)
	23	20	15	Interior valleys and foothills.	do	Pared. Irrigated	(3)
	---	25	20	Interior districts	do	Pared. Hot, dry districts, not irrigated.	(3)
	23	20	17	Santa Clara Valley and Sacramento River district.	do	Pared	(44)
	---	23+	----	Sierra foothills district	do	do	(44)
	---	23	20	Rogue River Valley	Oregon	Unpared	(36)
	---	20	16	Wenatchee	Washington	Pared	(44)
	---	17	15	Yakima	do	Pared. For canning only.	(23)
	23	20	17	Approximate limits applicable generally.		Pared	----
Bosc	---	13.5	10	Santa Clara Valley	California	do	(5)
	---	14	----	do	do	do	(55)
	---	15	----	Sierra foothills district	do	do	(b)
	---	15	12	Sacramento River	do	do	(5)
	16	15	----	Sierra foothills district	do	do	(5)
	---	16	14	Rogue River Valley	Oregon	do	(35)
	---	13	11	Wenatchee	Washington	do	(55)
	15	14	11	Approximate limits applicable generally.		do	----
Clairgeau	---	13	11	Santa Clara Valley	California	do	(5)
	---	13	----	do	do	do	(55)
	---	14	11	Sacramento River district.	do	do	(5)
	---	15	11	Sierra foothills district	do	do	(5)
	---	14.5	----	Hudson River Valley	New York	do	(55)
	---	14	11	Approximate limits applicable generally.		do	----
Comice	---	11.5	9	Santa Clara Valley	California	do	(5)
	---	11.5	9	do	do	do	(55)
	---	12	----	Sacramento River and Sierra foothills districts.	do	do	(b)
	---	12	9	Sacramento River district.	do	do	(5)
	13	12	9	Sierra foothills district	do	do	(5)
	---	11	9	Wenatchee	Washington	do	(55)
	---	11.5	9	Approximate limits applicable generally.		do	----

See footnotes at end of table.

TABLE 3.—*Pressure-test limits recommended for harvesting pear varieties*—Continued

[Plunger, 5/16 of an inch in diameter; penetration, 5/16 of an inch]

Variety	Pressure-test limits (pounds): Upper: Passable	Upper: Optimum	Lower	Locality	State	Remarks	Literature or footnote reference
Easter Beurré	---	16	---	Santa Clara Valley	California	Pared	(*5*)
	---	15	---	do	do	do	(*55*)
	---	15	---	Wenatchee	Washington		(*55*)
Flemish Beauty.	---	13	10	do	do	do	(*55*)
Forelle	15	14	---	Santa Clara Valley	California	do	(*5*)
Glou Morceau	---	13. 5	11	do	do	do	(*5*)
Hardy [c]	---	10. 5	9	do	do	do	(*5*)
	---	10	9	do	do	do	(*55*)
	---	12	---	Sacramento River and Sierra foothills districts.	do	do	([b])
	11	10. 5	---	Sacramento River district.	do	do	(*5*)
	---	11. 5	---	Sierra foothills district	do	do	(*5*)
	---	11			do	do	---
Howell	---	18	12	Santa Clara Valley and Sacramento River districts.	do	do	(*5*)
	---	22	20	Rogue River Valley	Oregon	Unpared	(*36*)
	---	16+	14	Hudson River	New York	Pared	(*55*)
Kieffer	15	13. 5+	12	do	do	do	(*55*)
Lawrence	---	15. 5	13	Grand Junction	Colorado	do	(*55*)
Seckel	---	16	14	Rogue River Valley	Oregon	Unpared	(*36*)
Winter Nelis	---	14	12	Santa Clara Valley	California	Pared	(*5*)
	---	13. 5	12	do	do	do	(*55*)
	---	17. 5	---	Sierra foothills district	do	do	([b])
	15	14	---	Sacramento River district.	do	do	(*5*)
	---	16	---	Sierra foothills district	do	do	(*5*)
	---	18	15	Rogue River Valley	Oregon	Unpared	(*36*)
	---	14	10	Wenatchee	Washington	Pared	(*55*)
	---	14	11	Approximate limits applicable generally.			--

[a] The Federal-State inspection service in California (as of 1940) requires that Bartlett pears to be mature must test not more than 23 pounds unless distinctly yellowish green (No. 3 on pear color chart (*55*)), in which case they must not test more than 25 pounds. If distinctly yellow (No. 4 on color chart) at time of picking, they shall be considered mature regardless of pressure test.

[b] Unpublished data by W. T. Pentzer.

[c] The Federal-State inspection service in California (as of 1940) requires that Hardy pears to be mature must test not more than 11 pounds.

Studies have been conducted on the softening of pears at various temperatures after harvest. With many varieties there is practically no softening or ripening at low temperatures (30° to 32° F.). Changes take place in the fruit, however, so that it loses its capacity to ripen or develops internal break-down. Consequently, the pressure test of the fruit in cold storage cannot be used to follow ripening or physiological changes or to indicate when it should be removed for marketing. At high temperatures also (90° to 100°) the fruit may fail to ripen and soften. Lutz and Culpepper (*41*) have shown that the most rapid softening and ripening of Kieffer pears takes place at 60° to 65° and that the rate of softening is retarded by temperatures either above or below the optimum.

The range of pressure-test values representing different degrees of ripeness in pears has not been determined. Magness et al. (*44*) stated that Bartlett pears testing 3 pounds are in full eating-ripe condition. Mallison and Powell (*49*) indicated a range of pressure-test values of 12 pounds or more for Bartlett pears in a hard condition, 11.5 to 8 pounds for firm fruit, and 7.5 pounds or less for ripe fruit. With Hardy pears, Pentzer [5] found that the fruit in the hard condition described by the Agricultural Marketing Service as giving to the thumb pressure with a cracking noise tested 8 pounds or more; firm pears, giving to pressure without breaking, tested from 7.9 to 5.6 pounds; and firm-ripe pears tested from 5.2 to 3 pounds. Lutz and Culpepper (*41*) stated that Kieffer pears testing 3 to 4 pounds were at optimum dessert or canning quality.

With pears, the pressure test has been found of value as an index of maturity, but has not proved satisfactory as a measure of ripeness during cold storage.

Peaches

Peaches tend to mature unevenly on the tree and fruit of different degrees of maturity are present at a time; consequently, several pickings are generally made, and the larger fruit of lighter green color is picked first. The firmness or pressure test cannot be used as an index to maturity except to indicate the size or color of fruit that should be picked. Morris (*51*) studied the maturity and ripening of peaches and concluded that the pressure test could often be used to determine the color standards for each picking, but he did not recommend pressure-test ranges for this. He indicated that the firmness or standards may vary, depending on growing conditions. Coe (*14*) also indicated that the pressure test and color standard may vary but considered the tree vigor to be an important factor. Blake and Davidson (*10*) also found that tests for the firmness of flesh should be employed as a supplement to the color basis for judging degree of maturity or ripeness and gave two sets of standards, depending on the distance of shipping.

Pressure-test standards of maturity that have been determined for peaches are presented in table 4. The standards for Colorado and New Jersey are generally higher than those for California and Virginia, as they are based on tests of unpared peaches. With Elberta peaches, tests on the unpared surface are reported (*10*) to be 2.5 pounds higher with soft-ripe fruit and 6.4 pounds higher with shipping-ripe fruit than tests on pared surfaces. If such allowance is made for the skin, the New Jersey and Colorado results become as low as or lower than those reported for California and Virginia. Based on 1 year's results with several varieties (Hiley, Champion, Early Crawford, Late Crawford, Augbert (Roberta), and Slappey), Haller and Harding (*27*) stated that the pressure tests were fairly uniform for the different varieties and indicated that for many eastern-grown varieties a pressure test of 14 to 10 pounds at harvest represents a condition of the fruit at which it ripens with good dessert quality and would hold up well for shipping. Additional studies might indicate a modification of these recommendations. In view of the results for other varieties it seems likely that the recommendation for Carman, given in table 4, should also be somewhat higher (i. e., probably 13 and 10 pounds).

As with pears, the pressure tester has not been found of value in following the ripening of peaches in cold storage. Haller and Harding (*27*) reported very little or no softening of shipping-ripe peaches at

[5] Unpublished data by W. T. Pentzer.

32° F., and such fruit lost its capacity to ripen while still firm and apparently sound. At higher temperatures (50° to 80°) the peaches soften as they ripen. Blake and Davidson (*10*) designated three degrees of ripeness with the pressure-test range characteristic of each. Peaches testing 14 to 12 pounds (5/16-inch plunger on unpared surface) were designated hard ripe; those testing 11 to 8 pounds were firm ripe; and those testing 6 pounds or less were soft ripe or in prime edible condition. Haller and Harding (*27*) indicated the soft-ripe condition is attained in peaches testing about 2 pounds (with the skin removed).

Although methods of testing firmness of peaches have varied considerably, it is usually considered that pressure-test readings are of value in establishing color standards for picking peaches. These standards may vary somewhat, depending on variety, condition of tree, distance to market, refrigeration, and method of testing. As with pears, the pressure test has not been found of value in following ripening of peaches in cold storage.

TABLE 4.—*Pressure-test limits recommended for indicating color standards for picking peach varieties*

[Plunger, 5/16 of an inch in diameter; penetration, 5/16 of an inch]

Variety	Pressure-test limits (pounds)		State	Remarks	Literature reference
	Upper	Lower			
Belle	14	12.5	Virginia	Pared	(*27*)
Carman	12	9	do	do	(*27*)
Early Crawford	20	14	California	do	(*42*)
Early Elberta	18	14	Utah	Unpared	(*14*)
Elberta	16	12	California	Pared	(*42*)
	20	12	Utah	Unpared; trees weakly vigorous	(*14*)
	18	12	do	Unpared; trees moderately vigorous	(*14*)
	18	15	do	Unpared; trees highly vigorous	(*14*)
	17	15	New Jersey	Unpared; for nearby shipping	(*10*)
	20	17	do	Unpared; for long-distance shipping	(*10*)
	14.5	11	Virginia	Pared	(*27*)
Eclipse	17	15	New Jersey	Unpared; for nearby shipping	(*10*)
J. H. Hale	17	12	Utah	Unpared	(*14*)
	17	15	New Jersey	Unpared; for nearby shipping	(*10*)
	20	17	do	Unpared; for long-distance shipping	(*10*)
	15.5	11.5	Virginia	Pared	(*27*)
Triumph	14	11	California	do	(*42*)
Tuscan (Tuskena)	14	8	do	do	(*42*)

PLUMS

The color and firmness of plums have been used as indexes of maturity. As with peaches, the firmness is a better measure of the carrying quality and is used largely to determine the color standard for picking. Pressure-test standards for maturity of plums have been determined only in the Western States. These standards are summarized in table 5 and are for use in long-distance shipment to market. It will be noted that when the fruit can be promptly cooled and shipped under relatively low temperatures it can be picked in a considerably softer and more mature condition, with a consequent improvement in dessert quality.

TABLE 5.—*Pressure-test limits recommended for picking plum varieties for long-distance shipments*

[Plunger, 5/16 of an inch in diameter; penetration, 5/16 of an inch]

Variety	Pressure-test limits when shipped standard refrigeration (pounds)				State	Literature reference
	Without precooling		With precooling			
	Upper limit	Lower limit	Upper limit	Lower limit		
Beauty	13	9	8	6	California	(7)
Burbank	20	14	13	8	California	(7)
Climax	18	13	12	8	California	(7)
Diamond	20	15	14	10	California	(7)
Duarte	15	11	10	8	California	(7)
Giant	16	11	10	8	California	(7)
Santa Rosa	18	12	12	9	California	(7)
Wickson	15	12	11	8	California	(7)
Formosa	13	9	8	6	California	(7)
President	16	11	10	7	California	(7)
Italian Prune	12	8.5			Idaho	(58)
Do [1]	15	12			Oregon	(33)

[1] Plunger, 5/16 of an inch in diameter.

SUMMARY

Various types of fruit pressure testers used to determine the firmness of fruit are briefly described. Methods of making the determinations are also described, and the desirability of standardizing the methods is discussed.

As fruits mature and ripen there is a decrease in firmness; the principal objective of the pressure tester is to measure the maturity and ripeness of the fruits. However, other factors, such as temperature of the fruit, turgidity and moisture content of the fruit, soil fertilization, soil moisture, thinning, and rootstocks, may also influence the readings and mask the relation of pressure-test determinations to maturity and ripeness.

Pressure-test determinations have not been found to form a reliable index to maturity of apples except to indicate when certain varieties are becoming too soft and overmature for storage. They do constitute, however, a fairly accurate guide to the ripeness of apples. Data are presented showing the pressure-test range, representing different degrees of ripeness of a number of commercially important apple varieties.

On the other hand, with pears the pressure test has been found of primary importance for establishing picking maturity standards; such standards are presented for a number of varieties. It has not proved as satisfactory as a measure of ripeness during cold storage.

With peaches and plums the pressure test may be used to establish the color standards for picking.

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