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The titles of the Technical Papers of the California Agricultural Experiment Station, which HILGARDIA replaces, and copies of which may be had on application to the Publications Secretary, Agricultural Experiment Station, Berkeley, are as follows:

4. Effect of Sodium Chlorid and Calcium Chlorid upon Growth and Composition of Young Orange Trees, by H. S. Reed and A. R. C. Haas. April, 1923.
5. Citrus Blast and Black Pit, by H. S. Fawcett, W. T. Horne, and A. F. Camp. May, 1923.
6. A Study of Deciduous Fruit Tree Rootstocks with Special Reference to Their Identification, by Myer J. Heppner. June, 1923.
7. A Study of the Darkening of Apple Tissue, by E. L. Overholser and W. V. Cruess. June, 1923.
8. Effect of Salts on the Intake of Inorganic Elements and on the Buffer System of the Plant, by D. R. Hoagland and J. C. Martin. July, 1923.
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10. The Seasonal Variation of the Soil Moisture in a Walnut Grove in Relation to the Hygroscopic Coefficient, by L. D. Batchelor and H. S. Reed. September, 1923.
11. Studies on the Effects of Sodium, Potassium, and Calcium on Young Orange Trees, by H. S. Reed and A. R. C. Haas. October, 1923.
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PHYSICAL AND CHEMICAL CHANGES IN THE RIPENING OF DECIDUOUS FRUITS

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INTRODUCTION

Interest on the part of many growers, shippers and others in determining the most satisfactory degree of maturity of deciduous fruits for eastern shipment has led to considerable investigational work in this field. Two publications, previously issued by the California Agricultural Experiment Station[2, 3] give the results of maturity studies with plums and the Bartlett pear. Recommendations were included for the harvesting of these fruits. The purpose of this publication is not to present additional maturity standards but rather to make available additional data on the ripening changes which take place in the above-mentioned fruits and to present similar data on apricots, peaches, and apples. The discussion includes the more familiar physical and chemical changes which occur during the period of fruit maturity and ripening, together with the results secured in the ripening of fruit by the use of ethylene gas.

INCREASE IN SIZE

Complete growth records, such as determined by Hendrickson and Veihmeyer[9] for peaches, and by Lilleland[20] for apricots, were considered nonessential to a study of ripening changes. However, as certain ripening changes take place previous to the complete sizing of the fruit, growth measurements were taken during the later stages of fruit development. Increase in size was determined by taking

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circumference measurements of from 20 to 40 individual fruits from several trees. During the season of 1924, increase in size was determined by measuring representative fruits of a given color stage as they were harvested. During 1925 and 1926 the individual fruits were tagged and measured on the tree at frequent intervals during the period of greatest color change. In presenting the results, emphasis is placed on the relative increase in volume rather than on actual gain as ascertained by measurement.

Plums.—The attention given the trees, the water content of the soil, and the size of the crop on the tree are all important factors influencing size changes. As pointed out in a previous publication[2] instances were found where plums made practically no increase in size after losing their original green color. The greatest gain over a period of ten to fifteen days immediately preceding or during the period of harvest was found to be 4.5 per cent in volume per day, while in most instances the daily increase varied between 1.5 and 2 per cent. Increase in size of plums was usually slightly greater in the early stages of ripening—from the time the fruit changed from a decided green to slight pink or blue—than it was in the later color stages. Growth does not altogether cease until the fruit attains or closely approaches its full color—a greater degree of maturity than most varieties are allowed to reach before being harvested for eastern shipment. Late-ripening varieties made a smaller daily gain in size than early sorts. Early varieties, however, are the ones most often picked prematurely and a five or six days' delay in harvesting would in many instances not only result in fruit of more desirable size but in an approximate 10 per cent increase in the number of crates produced.

Peaches.—The measurements and observations shown in table 1 taken on the growth and color of peaches from several orchards in Placer County from the time of 'breaking color' until completely colored, show in most instances even a more marked increase in growth during their late development than was found with plums. Peaches are characterized by a decided 'filling out' or 'swelling' after they begin to show some of their characteristic color. Owing to the firmness of the flesh and the fact that they are primarily used locally for canning, clingstone varieties are usually permitted to attain practically their full growth before harvesting. Freestone varieties, grown for shipment to the eastern markets as fresh fruit, are usually harvested while still somewhat immature and undersized. It is recognized that soft fruits such as peaches must be harvested sufficiently early to withstand the necessary physical handling and the delay in transit. On the other hand, the possibility of attaining better

TABLE 1

INCREASE IN SIZE AND CHANGE IN COLOR OF PEACHES TEN DAYS TO TWO WEEKS BEFORE PICKING; PLACER COUNTY, 1924–1926

Variety	Date of measurement	Color stage when picked	Average circumference, centimeters	Average volume,* cubic centimeters	Average daily increase in volume between measurements, cubic centimeters
Early Crawford	July 14, 1925	Greenish yellow, slight blush	17.6	92.1	.....
	July 20, 1925	Full yellow, good blush	18.8	112.2	3.35
	July 25, 1925	Full yellow, good blush	20.1	137.2	5.00
Early Crawford	July 1, 1926	Light green, slight blush	15.8	66.6	.....
	July 7, 1926	Greenish yellow, slight blush	16.5	75.9	4.81
	July 12, 1926	Yellow, 1/8 to 1/2 red	19.8	131.1	7.74
Elberta	July 14, 1924	Green to slight greenish yellow	17.1	84.5	.....
	July 22, 1924	Greenish yellow, slight blush	18.9	114.0	4.21
	July 29, 1924	Full yellow, 1/2 red	19.6	127.2	1.89
Elberta	July 18, 1924	Green with slight blush	16.4	74.5	.....
	July 30, 1924	Greenish yellow, 1/4 to 1/3 blush	18.7	110.5	3.66
	August 1, 1924	Greenish yellow, 1/3 blush	19.5	125.2	.....
Elberta	July 20, 1925	Greenish yellow	18.2	101.8	.....
	July 30, 1925	Light yellow, slight blush	21.0	156.4	5.46
	August 6, 1925	Full yellow, good blush	22.4	189.8	4.77
Elberta	July 14, 1926	Green, slight blush	16.9	81.5	.....
	July 23, 1926	Greenish yellow, slight to 1/3 red	18.1	100.0	2.05
	July 27, 1926	Yellow, slight to 1/3 red	18.5	106.9	1.72
Phillips Cling	August 17, 1925	Greenish yellow to yellow	18.9	114.0	.....
	August 25, 1925	Yellow, 1/4 to 1/2 red blush	21.5	167.9	6.73
	September 2, 1925	Golden yellow, 1/4 to 3/4 blush	22.5	192.4	3.06
Triumph	June 5, 1926	Green, 1/4 to 1/2 red	15.4	61.7	.....
	June 9, 1926	Yellowish green, 1/2 to 3/4 red	16.3	73.1	2.85
	June 16, 1926	Full dark red	17.6	92.0	2.70
Tuskena	July 3, 1925	Greenish yellow, slight blush	18.2	101.8	.....
	July 9, 1925	Full yellow, 1/4 blush	20.5	145.5	7.29
	July 13, 1925	Full yellow, 1/2 red	21.8	175.0	7.37
Tuskena	July 17, 1925	Greenish yellow, slight blush	17.8	95.2	.....
	July 20, 1925	Full yellow, 1/4 to 3/4 red	18.6	108.8	4.53
	July 27, 1925	Full yellowish red	20.0	135.1	3.75
Tuskena	July 6, 1926	Greenish yellow, slight to 1/2 red	16.2	71.8	.....
	July 9, 1926	Yellow, 1/2 to 2/3 red	17.3	87.4	5.20
	July 13, 1926	Yellow, 3/4 to full red	18.5	106.9	4.87
	July 16, 1926	Yellow, mostly full red	19.2	119.5	4.20

* In most instances it was necessary to compute the volume from the diameter or circumference of the fruit. $\left(\text{Vol.} = 1/6\pi\ D^3 \text{ or } \frac{C^3}{6\pi^2}.\right)$ For comparative purposes the fruit was assumed to be spherical and to show little change in form as it developed.

size and better quality in such fruits should encourage growers to avoid 'rushing the season.'

Pears.—In the early sections of the state, commercial practice dictates that the harvesting of Bartlett pears begin as soon as the fruit attains a diameter of 2¼ inches (5.7 centimeters, or a circumference of 18 centimeters). Unless produced on weak, overloaded

TABLE 2

INCREASE IN SIZE AND CHANGE IN COLOR OF BARTLETT PEARS PREVIOUS TO AND DURING THE PERIOD OF COMMERCIAL HARVEST; PLACER COUNTY, 1924–1926

Orchard No.	Date of measurement	Color stage when picked	Average circumference, centimeters	Average volume, cubic centimeters	Average daily increase in volume between measurements, cubic centimeters
1	July 18, 1924	Green	19.9	133.1	.....
	*July 30, 1924	Yellowish green, slight blush	21.3	163.2	2.50
	August 6, 1924	Greenish yellow	21.6	170.2	1.00
2	July 18, 1924	Green	19.7	129.1	.....
	*July 30, 1924	Yellowish green, slight blush	20.6	147.6	1.54
	August 6, 1924	Yellowish green, slight blush	21.6	170.2	3.23
	August 15, 1924	Greenish yellow, firm ripe	22.5	192.4	2.46
3	July 10, 1925	Green	18.9	114.0	.....
	*July 20, 1925	Green to yellowish green	19.7	129.1	1.51
	July 30, 1925	Greenish yellow, slight blush	20.7	149.8	2.07
4	June 11, 1926	Green	15.1	58.1	.....
	June 18, 1926	Green to slight yellowish green	16.3	73.1	2.14
	June 25, 1926	Yellowish green	17.1	84.4	1.61
	*July 2, 1926	Yellowish green	17.6	92.0	0.95
	July 9, 1926	Greenish yellow	17 8	95.2	0.45
	July 16, 1926	Greenish yellow to light yellow	18.0	98.5	0.47

* Beginning of commercial harvest.

trees or those growing under drought conditions, fruit of this size is harvested at a great sacrifice in yield. Under favorable growing conditions very material and consistent gains in size are made until the fruit is considered too mature for commercial shipment to distant markets. Table 2 illustrates some of the measurements taken in Placer County during 1924–1926.

Apples.—Measurements taken on Gravenstein apples in two large commercial orchards of the Sebastopol district show that this fruit also continues to increase in size beyond the time when usually picked commercially. As this variety is the first boxed apple of the season

to appear on the markets, harvesting is practically at its height when the fruit is making rapid gain in size. Initial pickings are usually made by July 1. Table 3 illustrates the growth which is being made by the fruit at this time.

TABLE 3

INCREASE IN SIZE AND CHANGE IN COLOR OF GRAVENSTEIN APPLES PREVIOUS TO AND DURING THE PERIOD OF COMMERCIAL HARVEST; SEBASTOPOL, 1926

Orchard No.	Date of measurement	Color stage when picked	Average circumference, centimeters	Average volume, cubic centimeters	Average daily increase in volume between measurements, cubic centimeters
1	June 17	Yellowish green	20.5	145.5	.....
	June 24	Yellowish green to greenish yellow	21.7	172.6	3.87
	July 1	Yellowish green to greenish yellow	23.5	219.2	5.82
	July 7	Yellowish green to greenish yellow	24.0	233.5	2.38
	July 21	Greenish yellow to light yellow	24.5	248.4	1.06
2	June 18	Yellowish green	20.5	145.5	.....
	June 25	Yellowish green to greenish yellow	22.0	179.9	4.91
	July 2	Yellowish green to greenish yellow	23.0	205.5	3.20
	July 8	Yellowish green to greenish yellow	24.0	233.5	4.66

DEVELOPMENT OF COLOR

Color changes in deciduous fruits may be divided into two classes, those affecting the ground or undercolor, and those affecting the development of the red, blue, and other overcolors. The former, brought about by the loss of chlorophyll and the unmasking and development of the yellow pigment or carotin material in the plastids of the cell is of major importance to commercial fruit growers in determining maturity. This 'breaking' of the original green color takes place independently of sunlight although influenced by it.

The overcolors characterizing the fully ripened fruit are usually ascribed to some of the anthocyanin pigments dissolved in the cell sap, or perhaps to a combination of these with the carotin-like materials in the plastids. Strawberries, blackberries, grapes, cherries, and plums are usually considered able to develop their mature color, though perhaps to a less degree, when sunlight is excluded. Overholser,[31] however, reports that owing to delayed maturity, blackberries, cherries, and plums of the *Prunus americana* species colored only in part when they were enclosed in black bags. Smith and Smith[34] report that Elberta peaches thus enclosed developed a higher

carotinoid content than unbagged fruit, but that the reverse was true with the Humboldt nectarine and the Royal apricot. That some of the more important varieties of *Prunus domestica* and *Prunus salicina* will color satisfactorily without light, has been shown in a previous publication.[2] Apples, peaches, nectarines, pears, and apricots are generally regarded as requiring sunlight for the development of their red color. Overholser found that the Williams apple developed some slight color when ripened under black cloth bags.

Not only is light essential for the coloring of most of the more important tree fruits but Magness,[26] and also Fletcher,[8] point out the particular value of the ultraviolet rays of light. They also found that red color intensity is closely associated with the carbohydrate or sugar content of the fruit. In fact, Magness, regulating the potential carbohydrate food supply of the individual fruits by controlling the leaf area, states that the first determining factor in the coloring of apples is chemical composition rather than weather and light conditions. Fletcher reports securing an increase in color through the addition of sugar to the soil. That there is also some correlation between color development of plums and the soluble solids in the juice and sugar content of the fruit is shown by the data in table 19. Since, however, it is difficult to control accurately the chemical composition of the different specimens it cannot be stated definitely whether the excess sugar was fundamental to, or simply accompanied, the coloring. In contrast to an increase in color development with a high carbohydrate supply it is generally recognized that nitrogen causes a decrease in color, probably due to shade.

The commercial orchardist recognizes that local climatic conditions and the variety in question are also important factors influencing the amount and rapidity of coloring. Stone fruits, grown under interior valley and foothill conditions, undergo rapid changes in color from ten days to two weeks before becoming ripe. The red color of cherries, the yellow of apricots, and the red and blue color of plums quickly follow the earlier changes in the ground color. The blush on the exposed side of peaches may even precede any appreciable change in ground color.

Plums.—The varieties of European (*Prunus domestica*) and Japanese (*P. salicina*) plums grown in California are numerous, and the different varieties show differences in the amount and rate of coloring. Kelsey plums show almost no color change at any time. Wickson and Formosa change only to a yellow or slight pink, while Santa Rosa, Tragedy, Diamond, and President should, when in prime eating condition, be of very dark red, blue, or purple color. Table 4

TABLE 4

DEVELOPMENT OF COLOR IN PLUMS PREVIOUS TO AND DURING THE PERIOD OF COMMERCIAL HARVEST; PLACER COUNTY, 1926

Variety	Date	Color stage
Beauty	May 26	Green
	May 30	Straw tip to light straw
	*June 2	Light pink to pink tip
	June 8	¼ to ½ red
Formosa	June 3	Straw tip to light straw
	*June 8	Full straw to yellow..
	June 16	Slight to ⅓ pink
	June 18	½ to ¾ pink
Santa Rosa	June 5	Green
	June 11	Straw tip to straw
	June 16	Pink tip to ¼ pink
	*June 20	¾ to full red
	June 23	Full dark red
Climax	June 5	Green
	June 10	Straw tip to light straw
	June 15	Full straw
	*June 20	Pink tip to slight pink
	June 22	¾ to full red
Wickson	June 8	Green
	June 16	Straw tip
	June 23	Light straw
	*July 1	Full straw to yellow
Burbank	June 17	Green to light straw
	June 24	Full straw to trace pink
	*June 30	Slight pink to ¼ red
	July 6	Full yellow to ¾ red
Duarte	June 23	Green to straw tip
	June 30	Pink tip to ⅓ light pink
	*July 6	½ pink to pink
	July 12	Full red
Diamond	June 30	Trace blue to blue tip
	*July 7	⅓ to ¾ blue
	July 12	Full blue
	July 16	Full dark blue
Giant	July 7	Straw to trace pink
	July 12	Slight to ½ pink
	*July 23	¾ to full pink
	July 28	¾ to full red
President	July 23	Slight to ⅓ purple
	July 27	½ to ¾ purple
	*July 30	Full purple

* Approximate time of first commercial pickings.

illustrates the color changes of marked specimens of some of these varieties previous to their removal from the tree. Seasonal variations will influence coloring in different years but these data are comparable and are typical of the color changes in most seasons.

Plums are a striking example of a fruit, which, unless picked before there is any change in the original ground color, will assume its full color after harvesting. As shown previously[2] the rate of development of red or blue color depends upon the temperature to which the fruit is exposed. Under ordinary air temperatures at harvest time, a week may be sufficient to attain full color. Under temperatures existing in the top of refrigerator cars (50°–55° F) the fruit picked with only very slight color will be well colored on arrival in the eastern markets some ten days later. Similar fruit carried in the cooler parts of the car where the temperature is 10° to 15° lower will show only slight changes in color.

Apricots and Peaches.—Early and midseason apricots are in prime eating condition as soon as they attain a medium yellow color. Tilton, a late variety, usually assumes, under California valley conditions, a rich golden yellow a week or ten days previous to becoming soft. Similar differences in color are noted between such varieties of peaches as the Early Crawford or the Elberta and the later varieties such as Tuskena and Phillips Cling. The time required for the yellow or red color to develop to a maximum consistent with good shipping conditions will vary, as shown by table 1, from ten to fifteen days. Apricots and peaches normally develop their yellow color rapidly after harvesting, and as with plums, the rapidity with which this occurs, again is controlled by temperature. Characteristic color changes for five varieties of peaches held for 10 days under temperatures usually existing in the bottom and top half of the load in refrigerator cars are shown in table 5. While it is generally conceded that these fruits are unable to take on additional red color under storage or transit conditions, the red color of the Tuskena peach becomes much more noticeable with the disappearance of the green ground color.

Pears.—Observations on the handling of pears show that both the variety and the location are factors influencing the amount and rate of coloring. Bartletts from the Sierra foothill areas and those grown in other sections of higher altitudes may possess a distinct yellow color before harvesting. In contrast, fruit from the Santa Clara Valley is picked while of a distinctly green color and loses little of its green color until the flesh has become overripe. Between these extremes, pears from the Sacramento River area picked when of a light green color, will, when subsequently exposed to room tempera-

TABLE 5

CHANGES IN COLOR OF PEACHES UNDER REFRIGERATOR CAR TEMPERATURES

Variety	Color when picked	Color after 10 days at	
		43° F	52° F
Early Crawford	Light green, faint blush	Yellowish green, faint blush	Greenish yellow to light yellow, faint blush
	Greenish white, slight blush	Greenish yellow to light yellow, slight blush	Full yellow, slight blush
	Light yellow to yellow, ¼ blush	Full yellow, ¼ blush	Full yellow, ¼ blush
	Full yellow, ¼ to ½ blush	Deep yellow, ¼ to ½ blush	Deep yellow, ¼ to ½ blush
Elberta	Light green to yellow green	Yellowish green	Greenish yellow
	Greenish yellow	Greenish yellow	Yellow
	Greenish yellow to yellow, slight blush	Greenish yellow to light yellow, slight blush	Full yellow, slight blush
	Light yellow to full yellow, ⅓ blush	Full yellow, ⅓ blush	Full yellow, ⅓ blush
Tuskena	Greenish white, slight blush	Greenish yellow, slight blush	Yellow, slight blush
	Yellow, ⅓ blush	Yellow, ⅓ blush	Yellow to reddish yellow, ⅓ blush
	Yellow to ½ dark red	Reddish yellow to ½ dark red	Reddish yellow to ½ dark red
Triumph	Greenish white, slight red	Greenish yellow, slight red	Full yellow, distinct blush
	Yellowish green, ⅓ red	Greenish yellow, ⅓ red	Light yellow, ⅓ red
	Yellowish green, ½ red	Greenish yellow, ½ red	Yellow, ½ red
	Yellow, ½ red	Yellow, ½ red	Full yellow, ½ red
Phillips Cling	Greenish yellow to yellow	Greenish yellow to yellow	Full yellow
	Yellow, ¼ to ½ blush	Yellow, ¼ to ½ blush	Golden yellow, ¼ to ½ blush

tures of 70° to 80° F, assume an attractive yellow in 5 to 8 days. If stored under transit temperatures of 50° for 10 days the same degree of coloring will develop in 2 to 4 days after being exposed to the above room temperatures. Fruit held continuously at 32° will gradually assume its characteristic color.

Late varieties of pears, grown primarily in the Santa Clara Valley, are usually harvested after only a very slight change in color. Held at 70° F following harvest, Comice will show a color change in

TABLE 6

CHANGES IN COLOR OF GRAVENSTEIN APPLES UNDER REFRIGERATOR CAR AND ROOM TEMPERATURES; 1930

Orchard No.	Date picked	Color*				
		When picked	After 12 days at 43° F	Followed by 1 week at 70° F	After 12 days at 52° F	Followed by 1 week at 70° F
1	June 9	1-2	1½-2	4+	1½-2	4+
	June 25	2-3	3	4+	3	4+
	July 8	2-2½	2½-3	4+	3	4+
2	June 11	1-2	1½-2	3	2	3
	June 25	2-2½	2½	2-3	2½	2½
	July 8	2-3	2½-3	3½-4	3	3-4+
3	June 11	1-2	1½-2	2-3	2	4+
	June 25	2-2½	2½	4	3½	4+
	July 8	2½	2½	3½-4	3½-4+	.....
4	June 25	2-2½	2½	4	3	4+
	July 8	2-3	3	4+	3-4	4+

* Color was determined by comparison with the standard color chart used by the California State Department of Agriculture where the numerical values indicate: 1. original green; 2. light green; 3. yellowish green; 4. greenish yellow to light yellow.

5 to 9 days similar to Bartlett. Most other late varieties show a slower change after picking. Very late varieties such as Winter Nelis, Glou Morceau, Easter Buerre, and P. Barry require from 8 to 20 days to show any material change in color, even after a period of several months in storage. Efforts to ripen these varieties immediately after harvesting most frequently result in the fruit shriveling and becoming tough without any appreciable change in color. Winter Nelis pears, however, have been successfully ripened in a period of four weeks, when held under a temperature of 50°.

Apples.—Since the leading varieties of apples grown in California are of the green or yellow sorts—Yellow Newtown, Yellow Bellflower, and Gravenstein—color changes previous to harvesting are limited

primarily to the initial breaking of the ground color. Yellow Bellflower, harvested when of a light to yellowish green color, quickly changes to a light yellow under ripening temperatures. The Yellow Newtown—some of the fruit being light green and some light yellow when harvested—increases its color very little under storage temperatures. The Gravenstein may be allowed to develop some of its characteristic striping; however, early picking in order to place this variety on the market in the forepart of July largely precludes the development of this overcolor. The fruit is therefore harvested when of a light green to yellowish green and when fully ripe is of a light yellow with the better-colored specimens showing some red streaks. Table 6 gives the rapidity of these changes under refrigerator car temperatures while in transit, and under ordinary room temperatures after arrival at destination. Temperatures of 43° and 52° F represent the average temperatures usually existing in the bottom and top halves of the load.

SOFTENING OF THE FLESH

Softening of the flesh has long been recognized as one of the principal ripening changes in deciduous fruits but it appears that only recently were any attempts made to measure it. Several years before publishing the fact, Morris[28] conceived the idea of measuring by mechanical means the rate of softening of apples in storage. Later, the simple device used by Morris was improved by Murneek[29] and also by Magness and Taylor.[23] With these two instruments, or pressure testers, together with still more recent modifications, a large amount of investigational work on fruit softening has been done by Magness and his associates,[22, 24, 25] by Hartman,[11, 12, 13, 14, 15] Morris,[28] Plagge, Maney and Gerhardt,[32] and others.

Modified pressure or puncture tests with cherries and the small fruits have also been reported on by Hawkins and Sando,[17] Hartman,[12, 16] Willaman, Pervier and Triebold,[39] and Verner.[41] The ability to measure definitely the firmness of the flesh or the toughness of the skin or outer covering has thus served to add considerably to the knowledge of fruit maturity, handling, shipping, and storage problems.

Tests to determine the rate at which a number of the deciduous fruits soften both before and after harvesting were begun at the California Agricultural Experiment Station in 1924. Firmness was recorded by the use of the Magness and Taylor tester. A plunger point 7/16 inch in diameter was used for plums, apricots, and apples

and a 5/16-inch point for peaches and pears. After removing the skin, tests were made on opposite sides of each of 10–20 representative fruits, and the readings averaged to constitute the firmness of the sample. A part of each lot of fruit obtained was tested for firmness immediately upon harvesting. Other portions were used for sugar and acid analyses or held for various lengths of time under different cold storage and refrigerator car temperatures.

From the beginning it was evident that not only different fruits but different varieties of the same fruit were of different texture at the time of harvesting. Moreover, it was soon apparent that Bartlett pears grown under relatively cool temperatures and high humidities were of a softer texture, compared to their color development, than fruit grown in the warmer, drier districts. The reasons for these differences are now being investigated. It would appear, however, from the work of other investigators that differences in firmness and comparative rate of softening are closely associated with differences in thickness or anatomical structure of the cell walls and upon the rapidity of certain chemical or enzymatic changes affecting their decomposition. Appleman and Conrad[5] report that the softening of peaches parallel the transformation of protopectin into pectin. Haller[10] working with apples believes this to be true with apples held in storage but that it does not account for softening on the tree or for the differences in firmness between varieties. Addoms, Nightingale and Blake[1] report that with the maturation of Elberta peaches the cell walls thin rapidly and show a rounding off. There is also a breaking of some of the walls resulting in a more juicy flesh. In the Shipper Cling variety these changes did not occur.

Softening of fruit following its removal from the tree is primarily dependent upon the temperature at which it is held. Softening, however, may be materially checked by the use of artificial or controlled atmospheres as has been amply demonstrated by Kidd, West and Kidd[18] and by Thornton.[38] The results on softening reported upon in this publication, however, apply only to fruit held in a normal atmosphere.

Plums.—Table 7, briefly summarizing some of the data presented previously[2] is sufficient to show the rapid softening of plums after changing their ground color. The pressures presented also serve to illustrate the range of softening between early and late varieties. In correlating the rate of softening with color changes, the early, soft-fleshed varieties such as Beauty, Formosa or Climax, often showing a reduction in firmness of one pound a day, must be harvested when of a straw color or when showing only slight red color

at the tip. Numerous varieties similar to Duarte and Diamond may safely be allowed to develop 50 to 75 per cent of their color, whereas President, a late, firm-fleshed variety, softening approximately only 25 per cent as rapidly as Beauty, should be allowed to develop full

TABLE 7*

SOFTENING AND COLOR CHANGES IN PLUMS

Variety	Color stage when picked	Firmness, pounds
Beauty	Green to straw tip	13.2
	†Straw to slight pink tip	9.0
	Straw to red tip	6.1
	½ to ¾ red	4.9
Burbank	Straw tip to light straw	20.7
	†Full straw to yellow	15.4
	Yellow to ¼ red	10.9
Climax	Green to faint straw tip	25.1
	Straw to greenish yellow	20.7
	†Greenish yellow to red tip	15.5
	¼ to ¾ red	8.9
Duarte	Green to slight red	15.0
	†½ to ⅔ light red	12.0
	Light to medium dark red	10.4
Diamond	Green, slight purple	16.5
	†½ to ⅔ purple	12.5
	¾ to full purple	9.2
Giant	Slight pink	18.7
	†½ pink	16.3
	⅔ to full red	10.7
President	⅓ blue	13.7
	½ blue	12.2
	¾ blue	10.5
	†Full blue	10.0
Santa Rosa	Greenish yellow to pink tip	19.0
	†¼ to ¾ color	15.4
	¾ to full light red	9.1
Wickson	Green to straw tip	21.2
	†Straw tip to straw	13.6
	Light yellow	8.2

* Averages from table 2, Agr. Exp. Sta. Bul. 428.
† Prime harvesting condition for eastern shipment.

color before harvesting. While, therefore, plums are harvested commercially when at a certain color stage, the amount of color which they are allowed to develop is based upon the texture of the variety and the rapidity of softening.

Under air temperatures at the time of harvesting, stone fruits soften rapidly after picking. Plums, apricots, and peaches, testing from 12 to 20 pounds when picked, will, when in prime eating condition, 6 to 10 days later, give a pressure test of only 1 to 2 pounds. Placed under a temperature of 32° F such fruits may be held for several weeks with little softening. Relative softening of ten varieties of plums held at 43°, and at 52°, for periods of 6 and 12 days is given in table 8. At the end of 12 days, fruit held at 43° is nearly as firm,

TABLE 8*

THE FIRMNESS OF PLUMS AFTER SIX AND TWELVE DAYS UNDER REFRIGERATOR CAR TEMPERATURES

Variety	Number of samples	Firmness when picked	Firmness after 6 days		Firmness after 12 days	
			At 43° F	At 52° F	At 43° F	At 52° F
		pounds	*pounds*	*pounds*	*pounds*	*pounds*
Beauty	4	13.5	8.7	4.1	4.5	2.8
Formosa	3	9.9	9.7	6.3	8.0	3.4
Climax	3	11.4	10.2	4.7	4.7	2.9
Santa Rosa	2	16.0	12.4	4.2	4.6	2.9
Burbank	4	14.3	8.5	4.7	3.9	2.9
Wickson	4	18.2	12.9	11.4	7.9	6.4
Duarte	4	16.2	10.1	7.2	5.0	3.6
Diamond	4	15.7	10.6	7.6	6.4	4.2
Giant	3	19.0	16.0	6.8	5.9	3.5
President	4	11.6	11.0	8.3	6.4	4.0
Average		14.5	11.0	6.5	5.7	3.6

* Summarized from data in table 3, Agr. Exp. Sta. Bul. 428.

and in fact with the early varieties slightly firmer, than comparable samples held only 6 days at 52° F. At the higher temperature plums also soften more rapidly during the first 6 days than during the second 6 days. This is most noticeable with the early varieties. Under a temperature of 43° ripening is more uniform but frequently a smaller change in firmness takes place during the first half of the holding period than during the latter half.

Peaches.—Although somewhat firmer than plums, peaches ripen similarly to them in that they soften rapidly after they begin to show change of color. In this respect, however, variety differences must again be considered. A comparison of the Elberta with the J. H. Hale, table 9, shows that the latter is much firmer at comparable color stages than the former. It is consequently allowed to attain materially more color before harvesting. The greater color and firmness of J. H. Hale over the Early Crawford and Slappey varieties

TABLE 9

SOFTENING AND COLOR CHANGES IN PEACHES PREVIOUS TO AND DURING HARVEST

Variety	Date harvested	Color stage	Firmness, pounds
Early Crawford	July 1, 1926	Light green, faint blush	18.7
	July 7, 1926	Greenish white, slight blush	14.2
	July 12, 1926	Yellow, slight to ⅓ red	10.0
Early Crawford	July 14, 1925	Yellowish green, slight blush	13.8
	July 14, 1925	Light yellow, ¼ red	11.5
	July 20, 1925	Medium to full yellow, ¼ to ½ red	11.1
Early Crawford	July 14, 1925	Yellowish green, slight blush	20.0
	July 20, 1925	Greenish yellow, ¼ red	16.4
	July 25, 1925	Medium to full yellow, ¼ to ½ red	12.5
Elberta	July 13, 1926	Light green to greenish yellow	16.5
	July 23, 1926	Greenish yellow, slight blush	12.7
	July 23, 1926	Greenish yellow, ⅓ red	7.7
	July 27, 1926	Yellow, ⅓ red	5.7
Elberta	July 13, 1926	Green, slight blush	16.6
	July 23, 1926	Greenish yellow, slight blush	12.3
	July 27, 1926	Light to full yellow, ⅓ red	6.2
Elberta	July 20, 1925	Yellowish green, slight blush	17.6
	July 30, 1925	Cream to light yellow, slight blush	12.4
	August 6, 1925	Full yellow, ⅓ to ½ red	3.7
J. H. Hale	July 28, 1930	Greenish yellow to light yellow	16.0
	July 28, 1930	Full yellow, with blush	9.5
	July 28, 1930	Orange red	6.7
Levy	September 2, 1925	Light green, slight blush	13.6
	September 15, 1925	Greenish yellow, slight blush	7.9
	September 15, 1925	Golden yellow, ½ to ⅔ red	6.7
Phillips Cling	August 17, 1925	Greenish yellow to yellow	12.0
	August 25, 1925	Yellow, ¼ to ½ red	8.8
	September 2, 1925	Golden yellow, ¼ to ¾ red	8.4
Triumph	June 4, 1926	Yellowish green, ⅛ to ½ red	13.3
	June 9, 1926	Greenish yellow, ½ red	13.5
	June 16, 1926	Yellow, ¾ to full dark red	4.7
Triumph	June 5, 1925	Greenish white, slight red	14.8
	June 11, 1925	Yellowish green, ½ red	10.3
Tuskena	July 6, 1926	Greenish white, slight blush	13.5
	July 7, 1926	Yellow, ⅛ blush	11.9
	July 12, 1926	Yellow, ½ red	10.2
	July 16, 1926	Yellow, ¾ to full red	8.8
Tuskena	July 13, 1926	Full yellow, ½ red	10.5
	July 17, 1926	Full yellow, ½ to ¾ red	9.6
	July 20, 1926	Full yellow, ½ to ¾ red	10.5
	July 27, 1926	Full yellowish red	7.5

are mentioned by Blake.[6] Medium and late clingstone varieties are characterized by a firm to slightly tough flesh and a high degree of color before being considered in prime condition for harvesting. Average picking pressures for these varieties approximate 8 to 9 pounds as compared with 12 to 14 pounds for Elberta. The latter variety may often show a reduction in firmness from ½ to 1 pound per day while ripening. Softening as well as coloring of some of the early peach varieties is very uneven, the fruit being perhaps in prime eating condition on the exposed side while still hard and of green color on the opposite side.

TABLE 10

THE FIRMNESS OF PEACHES AFTER SIX AND TWELVE DAYS UNDER REFRIGERATOR CAR TEMPERATURES

Variety	Number of samples	Firmness when picked	Firmness after 6 days		Firmness after 12 days	
			At 43° F	At 52° F	At 43° F	At 52° F
		pounds	*pounds*	*pounds*	*pounds*	*pounds*
Early Crawford	3	14.3	12.4	9.5	5.4	2.2
Elberta	3	12.3	10.8	5.3	4.9	2.5
Elberta	3	11.6	9.4	5.3	6.1	2.5
Triumph	3	12.4	10.4	9.2	7.3	2.2
Tuskena	3	10.3	10.2	9.6	8.7	3.7
Average, 15 samples		12.2	10.6	7.8	6.5	2.6

Table 10 shows that following harvest and while stored under refrigerator car temperatures, peaches soften rather rapidly, the relative amounts of softening being similar to that of plums. Held at 43° F for 12 days the fruit softens less during the first half of the period than during the second half. Under a temperature of 52° there is little difference in this respect.

Apricots.—Limited work with apricots has given results similar to those secured with plums and peaches. Early varieties tend to soften more rapidly and have a lighter yellow color when ripe than most later varieties. Royal, the principal midseason shipping variety is, when grown under valley conditions and fully ripe, of an attractive golden yellow color. During the last week or ten days on the tree it may soften as much as 1 pound per day. Tilton, ripening some two to three weeks later, is characterized by a deep yellow to orange yellow color, often with a considerable blush. The firmness of the flesh and the slower rate of softening makes it possible to allow much more color development on this variety than would be possible in most instances with Royal. Table 11 illustrates both the rate of

softening of the fruit and the correlation of color and firmness when samples of different color development are harvested the same day.

Tests on the softening of apricots after harvesting have been limited to the Blenheim variety grown in the Santa Clara Valley.

TABLE 11

SOFTENING AND COLOR CHANGES IN APRICOTS DURING HARVEST, 1930

Orchard No.	Variety	Date picked	Color stage	Firmness, pounds
1	Derby	June 2	Yellowish green	16.6
	Royal	June 7	Greenish yellow	13.8
1	Early Royal	June 3	Light green to yellowish green	18.5
		June 3	Yellowish green to greenish yellow	15.8
1	Royal	June 2	Yellowish green	19.6
		June 7	Yellow	13.4
2	Royal	June 17	Yellowish green	19.0
		June 17	Yellow to orange	10.2
3	Royal	June 18	Yellowish green	14.5
		June 23	Greenish yellow	10.0
		June 23	Greenish yellow to yellow	7.1
		June 23	Yellow to orange	4.1
4	Royal	June 20	Yellowish green	17.4
		June 20	Greenish yellow	13.2
		June 20	Yellow to orange	5.8

TABLE 12

THE FIRMNESS OF APRICOTS AFTER TWELVE DAYS UNDER REFRIGERATOR CAR TEMPERATURES; 1930

Date picked	Firmness when picked	Color when picked	Firmness after 12 days at 43° F	Color after 12 days at 43° F	Firmness after 12 days at 52° F	Color after 12 days at 52° F
	pounds		*pounds*		*pounds*	
June 23	23.4	Straw	3.6	Greenish yellow	3.0	Greenish yellow
June 23	7.4	Light yellow	1.5	Light to full yellow	1.7	Light to full yellow
June 23	4.9	Full yellow	1.2	Full yellow	1.1	Full yellow

Fruit picked at a straw color stage with a firmness of 23.4 pounds softened in 12 days at 43° F, to 3.6 pounds, and to 3 pounds when held at 52°. The fruit was eating ripe in both instances 2 days later. Additional samples picked when light yellow and at a pressure of 7.4 pounds were fully ripe after 12 days. Fruit averaging 4.9 pounds when picked shows similar ripening but was slightly softer

and of higher color than that picked at a pressure of 7.4 pounds (table 12). It would appear, therefore, that apricots soften very rapidly at temperatures as low as 43° F. Pressure tests were not recorded on fruit held at 32° for four to eight weeks. In observing such lots, however, it was noted that unless the fruit was well advanced in its maturity when stored, the flesh became tough and leathery rather than soft.

Pears.—Extensive tests on the softening of Bartlett pears were made during the seasons of 1925–1928 and the results given in detail in two previous publications.[3, 27] Under moderate temperature and humidity conditions with a continuous supply of available soil moisture, the firmness of Bartlett pears, between the earliest and latest pickings, was found to decrease from 2 to 3 pounds every 10 days. This softening not only occurs during and immediately preceding the harvest period, but the data in table 13, representing the results from four individual orchards in different districts, shows that it can be measured from the time the fruit is one-third to one-half grown, and that the rate of softening in the earlier stages of development does not appear to be materially different from that six to eight weeks later (table 13 and fig. 1).

Softening as indicated by the fruit from these orchards may be considered as typical for the Bartlett variety. Climatic influences and the relative length of time during the development of the fruit that the trees may suffer from a shortage of available soil moisture are, however, important influencing factors upon both softening and color development. Fruit grown in the hotter districts with a low humidity and under a deficiency of soil moisture may attain a high color with relatively little softening. In the cooler districts, subject to coastal influences, changes in texture of the flesh are much more marked than changes in color. Aside from soil moisture and climatic influences Bartlett pears produced on trees growing on the Japanese (*Prunus serotina*) rootstock were found to have a somewhat firmer flesh than those grown on French (*P. communis*) roots.[4]

Detailed storage tests of Bartlett pears have shown that fruit held at 31° F exhibited a reduction in firmness of only 1 to 2 pounds in three months, while at 36° the softening was found to be from two to three times as rapid. Held at 43° the fruit showed only slight softening (a reduction in firmness of 1 to 2 pounds) for the first 12 to 18 days. Following this initial period, however, softening was relatively rapid, pressure test readings decreasing approximately 2 pounds a day. Under a temperature of 52° F samples having a firmness of 18 to 20 pounds when picked, tested only 5 pounds after

12 days, or softening over 50 per cent more rapidly than comparable samples held at 43° F. Initial softening was apparent within 6 days after harvesting. Differences in ripening between 43° and 52° F are due primarily to the more rapid initial softening at the higher temperature.[27]

TABLE 13

COLOR CHANGES AND SOFTENING OF BARTLETT PEARS PRECEDING AND DURING THE PERIOD OF HARVESTING; 1927

Location of orchard	Date picked	Diameter of fruit, inches	Color*	Firmness, pounds	Average amount of softening each 10 days, pounds
Santa Clara Valley	June 15	¾	1	28-30+	
	July 1	1½	1	29.0	
	July 13	1½-2	1½	27.4	
	July 20	2 -2¼	1½	23.4	
	July 27	2½	1½-2	21.3	
	†August 4	2½	2	19.4	
	August 10	2½	2 -2½	18.0	
	August 23	2½	2½	16.0	
					2.0
Sacramento River district	June 20	1¼-1½	1	28-30+	
	June 29	2 -2¼	1 -1½	26.9	
	†July 6	2¼	1 -1½	23.5	
	July 19	2¼-2½	1½-2	22.6	
	July 26	2½	2	19.5	
	August 6	2½	2½	17.3	
					2.7
Newcastle	July 1	1¾-2	1 -1½	29.2	
	July 13	1¾-2	1 -1½	28.6	
	†July 20	2 -2¼	1½-2	26.9	
	July 27	2½-2¾	1½-2	21.5	
	August 3	2½	2 -2½	21.0	
	August 17	2½	2½	17.5	
	August 25	3	3	15.2	
					2.5
Placerville	July 14	2	1	30.0+	
	July 25	2	1	29.2	
	†August 3	2¼	2	24.8	
	August 10	2½-2¾	2	20.5	
	August 17	2¾	2½	17.6	
	August 24	2½	2½	17.0	
	September 1	2¾	3	15.8	
					2.9

* The colors corresponding to the numerical values are: 1. original green; 2. light green; 3. yellowish green; 4. greenish yellow to light yellow.

† Dates on which the first fruit was picked commercially.

Maturity studies extending over three seasons on late summer, fall and winter varieties show that these have a flesh only one-half to two-thirds as firm as that of the Bartlett. Changes in firmness immediately preceding and during the period of harvesting are correspondingly less marked, except for short periods in occasional

instances. Beurre Hardy, Comice, Anjou, Beurre Bosc, Winter Nelis, and Easter Beurre, have occasionally been noted to have softened between early and late pickings as rapidly as the Bartlett; while in other instances the fruit may fail to show any softening over a 10-day period.

Between the above extremes, found in a few cases, most samples softened from ½ to 1½ pounds in 10 days or approximately half as much as most usually occurs in the Bartlett. Table 14 illustrates a few typical cases of softening of the most important commercial varieties. In general the rate of softening of the different varieties does not vary greatly. On the average, Beurre Hardy and Winter Nelis failed to soften quite so rapidly as Comice, Anjou, Beurre Bosc and Easter Beurre. Winter Nelis was rather variable in softening, frequently showing little or no change in firmness over a period of two to three weeks.

TABLE 14

THE SOFTENING OF FALL AND WINTER PEARS PRECEDING AND DURING THE PERIOD OF HARVESTING

Variety	Orchard No.	Date picked	Color*	Firmness, pounds	Average amount of softening each 10 days, pounds
Beurre Hardy	1	July 24, 1928	1	12.3	
		August 11, 1928	2	10.8	
		August 30, 1928	2½-3	8.6	
					1.0
	2	July 24, 1928	1	11.4	
		August 11, 1928	2	10.9	
		August 20, 1928	2	10.5	
					0.3
	1	August 9, 1929	2	11.8	
		August 21, 1929	2-2½	10.8	
		September 1, 1929	2-2½	9.8	
					0.9
	2	August 9, 1929	2½	11.3	
		August 21, 1929	2½	10.5	
					0.6
	3	August 9, 1929	2	10.8	
		August 22, 1929	2½	9.7	
					0.9
	4	August 9, 1929	2 -2½	10.7	
		August 22, 1929	2½-3	9.8	
					0.7
Comice	1	September 1, 1929	3	9.4	
		September 11, 1929	4	8.7	
					0.7
	2	August 22, 1929	2½	12.0	
		September 1, 1929	2½	10.3	
					1.7

* The colors corresponding to the numerical values are: 1. original green; 2. light green; 3. yellowish green; 4. greenish yellow to light yellow.

TABLE 14 (*Continued*)

Variety	Orchard No.	Date picked	Color*	Firmness, pounds	Average amount of softening each 10 days, pounds
Comice	3	August 22, 1929	2-3	12.4	
		September 1, 1929	3	10.5	1.9
	4	August 13, 1930	2-3	10.0	
		August 22, 1930	3	10.3	
		August 30, 1930	3	9.1	0.5
	5	August 14, 1930	2-3	9.4	
		August 23, 1930	3	9.3	
		August 30, 1930	2-2½	8.6	0.5
	6	August 28, 1930	3	9.8	
		September 17, 1930	4	6.7	1.5
	7	August 19, 1930	2	10.7	
		August 30, 1930	2-3	9.6	
		September 20, 1930	2½	7.7	0.9
Anjou	1	August 9, 1929	2	15.8	
		August 22, 1929	2	13.2	2.0
	2	August 22, 1929	2	14.2	
		September 1, 1929	2	12.5	1.7
	3	August 13, 1930	2	14.3	
		August 30, 1930	2	13.0	0.8
	4	August 29, 1930	2½	12.0	
		September 20, 1930	2-2½	9.8	1.0
Beurre Bosc	1	August 20, 1928	1 -1½	15.0	
		August 30, 1928	1½-2	12.2	
		September 26, 1928	2-3	9.7	1.4
	1	August 22, 1930	2½	13.2	
		August 30, 1930	3	9.9	
		September 12, 1930	3	9.5	1.6
	2	August 22, 1930	2½-3	12.4	
		August 30, 1930	3	11.1	
		September 12, 1930	3	10.0	0.7
	3	July 30, 1930	1-2	15.5	
		August 11, 1930	3	14.5	
		August 13, 1930	3	13.9	1.1
Winter Nelis	1	September 1, 1929	.....	15.5	
		September 10, 1929	.....	15.6	
		September 18, 1929	.....	15.3	0.1
	1	September 12, 1930	.....	13.5	
		September 23, 1930	.....	13.5	0.0

* The colors corresponding to the numerical values are: 1. original green; 2. light green; 3. yellowish green; 4. greenish yellow to light yellow. Winter Nelis predominantly russet.

TABLE 14 (*Continued*)

Variety	Orchard No.	Date picked	Color*	Firmness, pounds	Average amount of softening each 10 days, pounds
Winter Nelis	2	September 1, 1929	.....	16.9	
		September 10, 1929	.....	16.6	
		September 19, 1929	.....	15.6	
					0.7
	2	August 30, 1930	.....	15.9	
		September 12, 1930	.....	14.8	
		September 23, 1930	.....	14.0	
					0.8
	3	September 19, 1929	.....	15.5	
		September 27, 1929	.....	15.4	
					0.1
	3	August 23, 1930	.....	14.8	
		August 30, 1930	.....	14.0	
		September 12, 1930	.....	13.9	
		September 23, 1930	.....	12.0	
					0.9
	4	September 18, 1929	.....	14.8	
		September 28, 1929	.....	13.7	
					1.1
	5	August 28, 1930	.....	20.8	
		September 9, 1930	.....	19.8	
		September 20, 1930	.....	17.7	
					1.3
Easter Beurre	1	October 11, 1928	2	15.9	
		October 20, 1928	2	14.7	
					1.3
	2	September 11, 1930	1½-2	17.0	
		September 18, 1930	2	16.3	
					1.0
	2	August 30, 1930	2	16.0	
		September 12, 1930	2	14.7	
					1.0
	3	August 30, 1930	1	16.3	
		September 10, 1930	2	15.0	
					1.2
	4	August 30, 1930	1	18.9	
		September 12, 1930	2	15.3	
		September 22, 1930	1	11.8	
					3.0
	5	August 30, 1930	1	14.5	
		September 22, 1930	1	13.0	
					0.6

* The colors corresponding to the numerical values are: 1. original green; 2. light green; 3. yellowish green; 4. greenish yellow to light yellow. Winter Nelis predominantly russet.

Although winter pears soften more slowly on the tree than the Bartlett yet when held in 32° storage for 14 to 16 weeks they show a similar amount of softening. Table 15 shows an average decrease of 2.6 pounds in firmness between September and the last of December. The effects of a 10-day delay at 50° F before storing at 32° is also shown in table 15. During this 10-day period the fruit softened

nearly as much as it did in 14 weeks at 32°. Notwithstanding this fact, the differences in firmness of fruit stored immediately at 32° and that stored after a 10-day delay, averaged only 2 pounds. A comparison of Bartlett pears held under similar conditions has shown that the fruit held for 10 days at 50° F has a pressure test reading of only 3 to 5 pounds, and is either fully ripe or very close to prime eating condition.

TABLE 15

FIRMNESS OF WINTER NELIS PEARS, DECEMBER 29, 1930, FOLLOWING IMMEDIATE STORAGE AT 32° F AND STORAGE AFTER A 10-DAY SHIPPING PERIOD AT 50° F

Locality grown	Orchard No.	Date picked	Firmness, pounds		
			When picked	Following immediate storage at 32°	Following storage at 32° after 10 days at 50°
Placer County	1	September 17	15.5	12.9	9.7
	2	September 17	15.0	11.4	9.7
Santa Clara Valley	1	September 22	14.2	11.5	8.1
	2	September 22	13.1	10.7	9.0
	3	September 22	13.5	11.1	10.3
	4	September 22	14.0	10.8	9.3
	5	September 22	12.0	10.5	9.2
Average			13.9	11.3	9.3

Apples.—The Gravenstein variety, harvested in July, ripens relatively quickly, softening on the trees being about one-half that usually occurring in Bartlett pears. The rate of softening in the different orchards and in the two districts from which fruit was secured proved to be very similar. The two orchards in the Napa district, however, where the trees may at times have suffered for lack of available water, and growing under higher temperatures and lower humidity conditions, produced a slightly firmer fruit than that from the Sebastopol orchards (table 16).

Softening of the Yellow Bellflower and Yellow Newtown is similar to that of the Gravenstein, although in general, hardly so rapid.

During the first six days after picking, pressure tests of four separate samples of Gravensteins show, as with pears, that there is little difference in the rate of softening at 43° and 52° F (table 17). From the sixth to the twelfth day, softening became more rapid and the differences in firmness at the two temperatures became more marked, being 1.8 pounds at 43° as compared with 3 pounds at 52°. This difference, although small, was consistent in a large proportion

TABLE 16

COLOR CHANGES AND FIRMNESS OF APPLES PRECEDING AND DURING THE PERIOD OF HARVESTING

Variety	Locality grown	Number of orchards averaged	Date picked	Color*	Firmness, pounds	Average amount of softening in 10 days, pounds
Gravenstein	Sebastopol	3	June 11, 1926	1-2	20.7	
		3	June 18, 1926	2	18.8	
		4	June 25, 1926	2-3	18.3	
		4	July 2, 1926	2-3	17.4	
		4	July 8, 1926	2-3	17.0	
		4	July 22, 1926	2½-3½	14.9	
						1.4
Gravenstein	Sebastopol	6	July 10, 1929	2-2½	18.8	
		7	July 19, 1929	2-2½	17.1	
		7	July 27, 1929	2-2½	17.6	
		5	August 7, 1929	3-4	16.0	
						1.0
Gravenstein	Napa	2	July 10, 1929	1½-2	22.2	
		2	July 19, 1929	1½-2	19.2	
		2	July 27, 1929	2	18.8	
		2	August 7, 1929	3-3½	17.9	
						1.4
Yellow Bellflower	Watsonville	6	August 13, 1929	2-2½	21.4	
		6	August 21, 1929	2-2½	19.8	
		6	August 31, 1929	2-3	20.1	
		6	September 10, 1929	2-3	18.1	
		3	September 18, 1929	2-3	17.2	
		2	September 27, 1929	2-3	15.7	
						1.2
Yellow Newtown	Watsonville	2	August 30, 1928	1	21.8	
		3	September 13, 1928	1½-2	20.2	
		2	September 20, 1928	1½-2	20.0	
		3	October 4, 1928	2-3	18.0	
						1.1

* The colors corresponding to the numerical values are: 1. original green; 2. light green; 3. yellowish green; 4. greenish yellow to light yellow.

TABLE 17

FIRMNESS OF GRAVENSTEIN APPLES AFTER SIX AND AFTER TWELVE DAYS UNDER REFRIGERATOR CAR TEMPERATURES; 1926

Date picked	Number of orchards averaged	Firmness when picked	Firmness after 6 days*		Firmness after 12 days	
			At 43° F	At 52° F	At 43° F	At 52° F
		pounds	*pounds*	*pounds*	*pounds*	*pounds*
June 11	3	20.6	20.0	19.7	18.5	17 0
June 25	4	18.5	19.2	18.7	16.1	15.4
July 8	5	17.4	18.1	17.8	16.7	14.8
July 22	5	15.4	15.0	14.3	13.4	12.5
Average		17.9	18.1	17.6	16.1	14.9

* The apparent gain in firmness of two of the samples after 6 days at 43° is due to variation in sampling and perhaps also to a slight lack of turgidity of the fruit.

of the individual samples. After the 12-day period when the fruit at 43° had begun to soften appreciably the softening changes were about as rapid at 43° as they were at 52°. All samples were considered eating ripe on the twenty-first day following picking. In four out of five orchards the fruit held for 12 days at 52° had slightly higher color than that held at 43°.

Midseason pickings from five orchards, with an average pressure test of 17.8 pounds, showed a decrease of 2.8 pounds in 10 days storage at 50°, and 4.6 pounds in the same length of time at 70° F (table 18).

TABLE 18

FIRMNESS OF GRAVENSTEIN APPLES WHEN HELD FOR TEN DAYS AT 50° AND AT 70° F; 1930

Orchard No.	Date picked	Firmness when picked	Firmness after 10 days	
			At 50° F	At 70° F
		pounds	*pounds*	*pounds*
1	July 14	18.6	16.4	13.3
2	July 14	16.9	14.2	11.2
3	July 21	17.6	16.9	14.4
4	July 21	17.9	15.2	12.9
5	July 21	18.2	16.6	14.2
Average		17.8	15.0	13.2

CHANGES IN SOLUBLE SOLIDS

In extracting the fruit juices for soluble solid determinations the usual method was to run the samples of fruit through an Enterprise fruit press and then filter the juice and pulp through several folds of cheesecloth. With some of the more juicy varieties of peaches and plums, grinding was unnecessary. With other varieties of plums and also Beurre Bosc and Winter Nelis pears, considerable difficulty was encountered in extraction owing to the fact that when pressed the individual fruit cells would break apart rather than rupture, resulting in a very thick sap or pulp butter. Centrifuging the material was of some value but not always satisfactory. In order to secure readings with relatively small quantities of juice and to have a relatively large reading scale, two 6-inch Balling hydrometers were used, one reading from 0 to 10 per cent and one from 10 to 20 per cent. The usual corrections were made for variations in temperature.

Plums.—Soluble solids of plums immediately preceding and during the time of harvest were found to run from 8.1 to 16.3 per cent

(table 19). Samples of fruit of different color stages picked concurrently show that soluble solids, as well as sugars and acid, are closely associated with color development. Previous to and during the early stages of color development, soluble solids increase rather slowly while, after the characteristic overcolor of the fruit begins to appear, the increase is rapid. The quantity of soluble solids is approximately twice that of the total sugars and the percentage increase between that in very early-picked fruit and that in fruit of full color has been found to be as much as 15 to 25 per cent. After harvesting and until ripe, the soluble solids remain practically constant.[2]

Peaches.—Hydrometer readings of the juice of six varieties of peaches listed in table 20 show the soluble solids to fluctuate within a relatively narrow range around 12.0 per cent, with a minimum of 10.5 and a maximum of 14.5 per cent. In general the soluble solids tend to increase with the coloring and the softening of the fruit although the changes during this period are not always consistent and the differences are much less marked than with plums. Thompson and Whittier[37] have shown that soluble solids increase over the entire development period of the peach.

In the majority of samples there appears to be a slight gain in the soluble solids after picking. This is in agreement with the data of Culpepper and Caldwell[7] and is, as they state, doubtless due in large part at least to a loss in moisture from the fruit during ripening in storage. Similar gains were also noted in total sugars, which would tend to substantiate this explanation.

Pears.—Hydrometer readings on the juice of Bartlett pears, table 21, show a gradual increase in soluble solids with increase in color and with softening of the fruit, this increase continuing after harvesting until the fruit is ripe. Loss of moisture may account for a small amount of this increase but as all fruits were individually wrapped the greater part of the gain in solids and sugars is ascribed to the hydrolysis of starch.

Apples.—No determinations were made with apples to ascertain the changes in soluble solids immediately preceding and during harvest. Thompson and Whittier,[37] however, found late apples to increase in soluble solids throughout their development period.

CHANGES IN SUGAR CONTENT

For the purpose of analysis, small longitudinal slices, extending from the surface to the core and totaling 50 grams in weight, were cut from 10–20 fruits and placed in a 250 cc Erlenmeyer flask. The sample of fresh fruit was then covered with 150 cc of 95 per cent alcohol and brought to a brisk boil. For convenience the material was stored at this point. Further extraction of the fruit tissue, using approximately 100 cc of 95 per cent alcohol was carried out in Soxhlet thimbles, extracting for 8 hours. The alcohol used for extracting, together with that in which the sample was originally put up, was transferred into a 500 cc volumetric flask and made up to volume.

Aliquots of from 75 to 100 cc were placed in 300 cc Erlenmeyer flasks and the solution evaporated to dryness under a vacuum on a water bath at not over 60° C. The residue was taken up in water, cleared with neutral lead acetate and centrifuged. The clear liquid was then deleaded with potassium oxalate and the sugars determined by the Shaffer-Hartmann modification of the Munson-Walker method.[33]

Plums.—Representative data giving the development of sugars and their association with color development are shown in table 19. All ten varieties previously reported showed a marked increase in sugar content as the fruit ripened on the tree, the increase being 10 to 15 per cent for each commercial picking stage. The sugar content increases at a relatively uniform rate from the early picking stages until the fruit is of full color. As previously mentioned, soluble solids increase slowly during the early maturity stages of the fruit; hence, the ratio between soluble solids and sugar is not constant. In well colored fruit the percentages of sugars are usually slightly more than half the hydrometer readings, while in earlier picked fruit the sugars may be slightly less than half that of the soluble solids. Reducing sugars are relatively stable in quantity throughout the ripening period but usually increase slightly. Sucrose has been found to be approximately twice as great in late-picked samples as in those picked early.[2] Different varieties vary in the proportion of sucrose to total sugars which they contain. After harvesting and until fully ripe, there is little change in either the amount or relative proportions of the sucrose and reducing sugars.

Peaches.—With slight fluctuations when picked at intermediate stages of ripeness, total sugars in peaches between the earliest and latest dates show a relative increase in sugar of from 10 to 17 per cent.

Table 20 gives the actual increase at different stages of color and firmness of the fruit. The later ripening varieties of cling peaches contain a somewhat higher percentage of sugars than earlier varieties. Reducing sugars were found to show either a slight increase or decrease between individual pickings with no very definite tendency in either direction. Culpepper and Caldwell[7] report a general decrease, followed in some samples by a slight increase when the fruit becomes very soft. This increase in the riper fruit is noted in some of the samples. In all samples the differences between the reducing sugars and total sugar become larger as the fruit ripens. There is therefore a distinct gain in the sucrose content of the fruit. Culpepper and Caldwell report considerable variation in the sugar content in different seasons.

Following harvest, the quantity of sugars averages slightly higher than when picked, the apparent gain in total sugars again being attributed primarily to water loss.

Apricots.—Analyses were run on only a few samples of apricots and are given in table 22. The data show a marked and consistent increase in both reducing and total sugars as the fruit matures. Increase in sucrose is particularly marked between the first and second color stages of early-picked fruit. Only slight changes in any of the sugars were apparent after the fruit had been held at 50° for 10 days at which time the more mature samples were near prime eating condition.

Pears.—Bartlett pears make a material gain in sugars both as they ripen on the tree and after picking (table 21). Early-picked samples fail to develop as much sugar when ripe as do those picked late. The actual increase after picking in the early-picked fruit may, however, be as great as, if not greater than, in that picked later. As reported by Magness[21] increase in sugars, particularly early in the season, is primarily due to the increase in reducing sugars, which according to Thompson and Whittier,[36, 37] are largely levulose. At the time of commercial harvesting, sucrose is present in small amounts. As the fruit ripens at 70° F following harvest, the increase in sugar present is the result of an increase in both sucrose and reducing sugars. The amount of sucrose tends to be somewhat greater in fruit well matured before harvesting although some of the earlier samples show as much as those picked later.

Apples.—Data presented in table 23 on sugar changes in Gravenstein apples are in conformity with the general findings of Magness and Diehl,[22] St. John and Morris,[35] of Plagge, Maney and Gerhardt[32] and of other earlier investigators. With the decrease of

TABLE 19

SOLUBLE SOLIDS, SUGARS, AND ACID CONTENT OF PLUMS IN RELATION TO COLOR DEVELOPMENT; 1926

Variety	Date picked	Color stage	Soluble solids	Reducing sugars	Total sugar	Malic acid in juice	Malic acid in fruit
			per cent Balling	*per cent*	*per cent*	*per cent*	*per cent*
Beauty	June 2	Straw to slight pink tip	11.3	3.80	4.34	1.43	.....
		Pink tip to ⅛ red	11.8	5.80	6.20	1.02	.....
	June 12	Greenish yellow to red tip	11.5	6.01	.....	1.10	2.03
		⅔ to full red	13.4	6.34	.....	0.94	2.29
Burbank	June 25	Straw to yellow	14.5	3.87	9.12	1.55	1.79
		Straw with red tip	14.2	3.81	9.17	1.36	1.73
	July 6	Yellow, slight red	16.3	3.49	10.37	1.04	1.46
		Yellow, ½ red	16.2	3.70	11.06	0.92	1.41
	July 9	Yellow	14.1	2.94	8.46	1.05	1.68
		Yellow, ¼ red	14.0	3.07	9.27	1.04	1.64
Climax	June 13	Greenish yellow to full straw	10.1	4.58	.....	1.84	2.12
		Greenish yellow, red tip	11.5	4.84	.....	1.75	2.42
	June 16	Green with faint straw tip	10.2	4.76	.....	2.37	2.31
		Green with slight red tip	11.0	5.06	.....	1.81	2.46
Diamond	July 7	Green to slight purple	10.8	4.32	5.62	.....	2.60
		½ to ⅔ purple	12.7	4.35	7.09	2.51	2.50
	July 7	Green to ¼ purple	12.5	.....	5.10	.....	.....
		⅔ purple	14.2	.....	6.20	.....	.....
Duarte	July 3	Yellowish green, slight dull red	12.4	4.26	6.53	1.62	1.45
		½ to ⅔ light red	13.4	3.94	7.26	0.80	1.31
	July 9	Greenish yellow, slight red	11.5	4.32	6.61	1.35	1.61
		½ to ⅔ red	14.6	4.12	8.10	0.99	1.48
Formosa	June 3	Green to light straw	8.1	3.54	4.30	0.94	.....
		Straw to faint pink tip	10.3	4.50	5.70	0.57	.....
Santa Rosa	June 11	Pink tip	13.6	5.52	6.70	1.48	1.83
		⅛ to ½ light red	14.4	5.30	6.96	1.41	1.95
	June 11	Greenish yellow, red tip	11.7	5.15	6.24	2.19	2.85
		¼ to ¾ red	13.1	5.27	6.56	2.07	2.77
	June 13	Greenish yellow, slight red	11.1	4.50	.....	2.34	2.74
		¼ to ½ red	12.1	4.45	.....	2.25	2.74

TABLE 20

Maturity Changes in Peaches During the Period of Harvesting

Orchard No.	Date picked	Color stage	Firmness	Soluble solids		Reducing sugars		Total sugar		Acid as malic	
				When picked	When ripe	When picked	When ripe	When picked	When ripe	When picked	When ripe
		Early Crawford	*pounds*	*per cent Balling*	*per cent Balling*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1	July 14, 1925	Yellowish green, slight blush	20.0	12.2	12.1	2.40	2.75	8.06	8.97	.....	0.84
	July 20, 1925	Greenish yellow, ¼ red	16.4	12.3	12.6	2.45	2.63	9.15	9.24	0.70	0.69
	August 6, 1925	Full yellow, ¼ to ½ red	12.5	12.5	12.7	2.39	2.57	9.24	9.36	0.71	0.72
2	July 14, 1925	Yellowish green	13.8	11.5	11.9	2.43	2.46	8.12	8.36	0.96	0.97
	July 14, 1925	Light yellow, ¼ red	11.5	12.5	12.2	2.64	2.73	8.48	8.57	0.82	0.65
	July 20, 1925	Full yellow, ¼ to ½ red	11.1	12.6	14.4	2.49	2.78	9.35	10.08	0.59	0.61
3	July 1, 1926	Light green	18.7	13.5	14.0	2.50	3.00	7.06	8.00	0.70	0.74
	July 7, 1926	Greenish yellow, slight blush	14.2	14.4	13.7	2.42	2.34	8.66	8.10	0.83	0.63
	July 12, 1926	Yellow, slight to ⅓ red	10.0	14.5	14.4	2.06	2.56	9.34	10.08	0.65	0.62
		Average	.....	*12.9*	*13.1*	*2.42*	*2.64*	*8.60*	*8.97*	*0.74*	*0.72*
		Elberta									
1	July 20, 1925	Yellowish green	17.6	11.7	12.7	2.73	3.00	8.47	8.47	0.63	0.79
	July 30, 1925	Greenish yellow to light yellow	12.4	12.1	12.8	2.72	2.94	8.30	9.09	0.62	0.53
	August 6, 1925	Full yellow, ⅓ to ½ red	3.7	13.1	13.0	2.94	2.94	9.66	10.21	0.49	0.44
2	July 23, 1925	Greenish yellow	17.8	12.0	12.3	3.00	3.04	7.56	8.15	0.66	0.63
	July 30, 1925	Greenish yellow to light yellow	13.2	11.3	11.0	3.05	3.04	7.86	8.18	.....	0.53
3	July 13, 1925	Light green to greenish yellow	16.5	12.6	13.6	2.96	3.10	7.86	.....	0.56	0.50
	July 23, 1926	Greenish yellow, ¼ red	12.7	11.6	14.4	2.60	2.56	7.02	7.30	0.37	0.34
	July 23, 1926	Greenish yellow to yellow, ⅓ red	7.7	11.6	11.7	2.56	2.80	7.74	8.50	0.33	0.35
	July 27, 1926	Greenish yellow to yellow, ⅓ red	5.7	11.6	13.0	2.68	2.56	8.86	9.98	0.34	0.32
4	July 13, 1926	Green	16.6	12.7	14.3	3.10	3.26	7.86	8.66	0.52	.....
	July 23, 1926	Greenish yellow	12.3	12.1	12.7	3.10	3.40	8.50	8.10	0.41	.....
	July 23, 1926	Greenish yellow to yellow, ¼ red	6.1	12.0	12.6	3.26	3.26	8.26	8.66	0.36	.....
	July 27, 1926	Yellow, ⅓ red	6.2	13.6	13.2	3.10	3.48	9.20	9.26	0.40	.....
		Average	.....	*12.1*	*12.8*	*2.91*	*3.03*	*8.24*	*8.71*	*0.47*	*0.49*

TABLE 20—*Continued*

Orchard No.	Date picked	Color stage	Firmness	Soluble solids		Reducing sugars		Total sugar		Acid as malic	
				When picked	When ripe	When picked	When ripe	When picked	When ripe	When picked	When ripe
			pounds	*per cent Balling*	*per cent Balling*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
		Triumph									
1	June 5, 1925	Greenish white	14.8	11.3	10.5	1.54	1.58	6.98	7.91	0.84	0.74
	June 11, 1925	Yellowish green, ½ red	10.3	12.0	10.7	1.55	1.76	8.33	8.12	0.96	0.71
2	June 4, 1926	Yellowish green, ⅓ red	13.3	11.9	11.6	2.20	2.00	7.90	7.40	0.47	0.33
	June 9, 1926	Greenish yellow, ⅔ red	13.8	11.3	10.7	1.70	1.70	7.64	6.40	0.36	0.28
	June 16, 1926	Yellow, ¾ to full red	4.7	11.9	11.2	1.60	1.82	8.90	8.66	0.36	0.30
		Average	.....	*11.7*	*10.9*	*1.72*	*1.77*	*7.95*	*7.30*	*0.60*	*0.47*
		Tuskena									
1	July 3, 1925	Greenish yellow, slightly red	20.3	11.4	12.6	2.43	2.85	7.32	8.00	0.96	.....
	July 9, 1925	Greenish yellow to full yellow, ¼ red	12.9	11.7	12.7	2.18	2.48	7.81	8.30	1.00	0.96
	July 13, 1925	Full yellow, ½ red	10.5	11.6	12.4	2.12	2.31	7.93	7.90	0.98	0.90
	July 17, 1925	Full yellow, ½ to ¾ red	9.6	12.3	12.7	2.43	2.52	8.87	8.82	0.92	0.90
2	July 17, 1925	Greenish yellow, slight to ¼ red	13.5	11.9	11.9	2.24	2.51	7.47	7.63	1.08	0.97
	July 20, 1925	Greenish yellow to full yellow, ½ to ¾ red	10.5	12.0	12.3	2.29	2.35	8.20	8.18	0.78	0.83
	July 27, 1925	Yellowish red	7.5	12.0	13.2	2.17	2.04	8.08	8.12	0.88	0.87
3	July 6, 1926	Greenish yellow, slight red	13.5	12.9	13.2	2.24	2.34	8.00	8.04	1.00	0.80
	July 6, 1926	Yellow, ⅓ red	11.9	13.7	12.8	2.10	2.10	8.74	8.40	0.76	0.66
	July 12, 1926	Yellow, ½ dark red	10.2	13.0	13.6	2.18	2.24	9.90	9.46	0.60	0.62
	July 16, 1926	Yellowish red	8.8	13.2	14.0	2.24	2.18	9.40	9.32	0.47	0.44
		Average	.....	*12.3*	*12.9*	*2.24*	*2.35*	*8.34*	*8.38*	*0.86*	*0.79*
		Levy									
1	September 2, 1925.	Light green	13.6	10.5	13.2	2.39	2.49	9.18	9.73	0.69	0.49
	September 15, 1925.	Greenish yellow, ¼ red	7.9	10.8	11.2	2.31	2.52	9.54	10.22	0.68	0.39
	September 15, 1925.	Golden yellow, ½ red	6.7	12.5	14.2	2.43	2.76	10.40	11.28	0.39	0.36
		Phillips Cling									
1	August 17, 1925	Greenish yellow to yellow	12.0	11.5	12.1	2.15	2.15	8.39	8.56	0.77	0.70
	August 25, 1925	Yellow, ¼ to ½ red	8.8	12.4	12.7	2.40	2.52	9.82	10.10	0.63	0.56
	September 2, 1925	Golden yellow, ¼ to ¾ red	8.4	12.6	13.1	2.40	2.63	10.22	10.73	0.57	0.45

TABLE 21

MATURITY CHANGES IN BARTLETT PEARS DURING THE PERIOD OF HARVEST

Locality	Orchard	Date picked	Color	Firmness	Soluble solids		Reducing sugars		Total sugar		Acid, as malic	
					When picked	When ripe	When picked	When ripe	When picked	When ripe	When picked	When ripe
				pounds	*per cent Balling*	*per cent Balling*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Sacramento River district	1	June 24, 1925	1	24.5	.....	12.6	5.32	6.20	5.53	7.00	0.52	0.39
		July 6, 1925	1	22.0	11.6	12.8	5.31	6.31	5.76	7.38	0.49	0.51
		July 16, 1925	2	19.9	11.7	12.7	6.08	6.81	6.69	7.81	0.48	0.45
		July 25, 1925	2	19.2	12.3	12.7	6.02	7.81	7.81	8.11	0.40	0.44
		August 4, 1925	2	19.3	14.7	15.5	7.01	7.42	8.22	9.64	0.51	0.45
	2	June 29, 1925	1	22.6	11.7	13.0	5.38	6.50	.....	7.11	0.55	0.46
		July 10, 1925	1½	21.3	12.0	14.0	5.83	6.93	6.17	7.84	0.51	0.46
		July 20, 1925	2	19.9	13.9	14.9	7.72	7.51	8.33	8.45	0.43	0.47
		July 31, 1925	2	18.9	14.8	15.6	7.72	8.18	8.07	9.42	0.41	0.47
	3	June 8, 1926	1	26.5	11.9	13.8	4.84	6.90	4.90	7.30	0.16	0.16
		June 14, 1926	1½–2	23.9	12.0	12.4	5.14	6.40	5.44	6.90	0.12	0.13
		June 21, 1926	1½–2	21.6	12.4	13.4	5.90	5.26	6.20	7.60	0.16	0.21
		June 28, 1926	1½–2	19.7	12.1	13.3	5.66	5.66	5.94	6.30	0.17	0.19
		July 7, 1926	2–2½	19.2	12.9	13.6	5.08	7.02	5.34	7.86	0.17	0.18
		July 20, 1926	2–2½	18.9	13.6	14.8	5.94	7.38	6.62	8.70	0.16	0.17
Average					*12.7*	*13.7*	*5.93*	*6.82*	*6.50*	*7.83*	*0.35*	*0.34*
Placer County	4	July 3, 1925	1	24.3	13.0	13.4	5.65	6.96	6.74	7.93	0.62	0.63
		July 13, 1925	1–2	20.7	12.6	14.3	6.01	6.93	6.50	8.14	0.54	0.55
		July 23, 1925	2	21.2	12.6	13.9	6.05	6.93	6.81	8.21	0.76	0.50
		August 3, 1925	2	21.3	13.6	14.3	6.01	7.63	6.56	9.43	0.71	0.61
	5	July 2, 1925	1	23.6	13.0	14.1	5.77	7.26	6.00	8.51	0.66	0.74
		July 13, 1925	1–2	19.2	12.4	13.9	6.01	7.11	6.50	8.60	0.70	0.69
		July 23, 1925	2	19.2	13.0	14.5	6.32	7.20	6.81	8.42	0.71	0.68
		August 3, 1925	3	18.8	13.4	14.5	6.63	6.63	7.32	9.49	0.75	0.71
		August 12, 1925	3	17.1	13.5	14.9	6.25	7.11	7.23	9.50	0.79	0.62
	6	June 25, 1926	2	23.1	14.7	15.9	6.46	7.86	6.54	9.00	0.20	0.36
		July 2, 1926	2	19.9	13.6	14.4	5.90	7.94	6.26	8.70	0.21	0.27
		July 9, 1926	1½–2	18.3	14.7	15.0	6.54	7.80	6.86	8.86	0.28	0.28
		July 16, 1926	2–2½	17.5	15.1	16.0	7.86	8.34	8.46	9.40	0.30	0.24
		July 23, 1926	2½	17.2	15.6	17.2	6.86	8.40	7.20	9.58	0.34	0.19
		July 30, 1926	2½–3	16.0	16.3	16.3	6.92	8.58	7.52	9.94	0.30	0.24
Average					*13.8*	*14.8*	*6.35*	*7.51*	*6.88*	*8.91*	*0.52*	*0.49*

starch accompanying maturity there is a rather marked and consistent increase in sugars, the increase being due to greater amounts of both sucrose and reducing sugar. With the early season of ripening of the Gravenstein these changes continue with considerable rapidity during a 10-day holding period at 50° and at 70° F. Starch almost disappears at the higher temperature while the sugars show an average relative increase of approximately 20 per cent.

TABLE 22

SUGAR AND ACID CHANGES IN APRICOTS DURING THE PERIOD OF HARVEST; 1930

Orchard No.	Variety	Date picked	Reducing sugars	Total sugar	Acid, as malic
			per cent	*per cent*	*per cent*
1	Derby Royal	June 2	1.58	5.30	1.40
		June 7	1.91	7.34	1.29
		June 12	2.42	7.82	1.06
1	Royal	June 2	2.25	5.59	1.59
		June 7	2.26	8.02	1.47
		June 12	2.63	8.62	1.16
2	Royal	June 17	1.77	5.47	1.41
		June 17	2.36	8.09	1.19
3	Royal	June 18	2.25	6.36	1.24
		June 18	3.00	8.65	1.03
		June 23	2.50	7.50	1.20
		June 23	2.75	8.46	1.05
		June 23	3.35	9.86	0.77

ACID CONTENT

Previous to 1930, acid determinations were made either on the extracted juice or the flesh of the fruit. Where the latter was used, 50 grams of the fruit tissue was extracted for several weeks in water covered with toluene and the solution titrated against N/10 sodium hydroxide using phenolpthalein. The method employed during 1930 was essentially the same as used previously except for the fact that an aliquot portion of the alcohol solution, remaining after the sugar extraction, was used. The results secured from this method may be slightly lower than those secured from the samples put up in water but they check with a high degree of accuracy. Table 24 gives the results on Gravenstein apples. Those secured from pears were very similar to those secured with apples. It would therefore seem unnecessary to put up the extra water sample for acid determinations.

TABLE 23

STARCH, SUGAR, AND ACID CHANGES IN GRAVENSTEIN APPLES DURING THE PERIOD OF HARVEST, HEALDSBURG-SEBASTOPOL DISTRICT; 1930

Orchard No.	Date picked	Starch			Reducing sugars			Total sugar			Acid		
		When picked	After 10 days at		When picked	After 10 days at		When picked	After 10 days at		When picked	After 10 days at	
			50° F	70° F		50° F	70° F		50° F	70° F		50° F	70° F
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1	June 30	1.16	0.48	0.10	6.07	6.68	7.28	6.92	7.86	8.56	0.96	0.86	0.74
	July 14	1.12	0.46	0.21	6.63	6.74	8.54	7.60	8.42	10.27	0.80	0.77	0.73
	July 29	1.31	0.74	0.24	6.76	7.11	7.60	8.50	9.34	10.45	0.82	0.76	0.68
2	July 7	1.49	0.74	0.36	6.59	6.80	7.64	7.90	8.44	9.30	0.77	0.79	0.76
	July 28	1.00	0.32	0.26	7.25	7.69	8.44	9.70	10.07	10.62	0.76	0.68	0.66
3	July 7	1.40	0.52	0.30	5.98	6.77	7.42	7.29	8.34	8.78	0.82	0.77	0.70
	July 21	1.33	0.58	0.25	6.29	6.97	8.14	8.18	8.89	9.68	0.80	0.72	0.69
4	July 7	1.69	0.90	0.44	6.41	7.12	9.20	7.39	8.60	10.75	0.94	0.91	0.73
	July 21	1.33	0.56	.....	7.78	8.76	.....	9.56	10.78	.....	0.78	0.77	.....
5	July 14	1.16	0.30	0.11	6.46	6.70	7.04	7.82	7.92	8.64	0.86	0.74	0.68
6	July 9	1.23	0.62	0.11	6.72	7.43	7.54	8.07	9.41	9.31	0.87	0.80	0.69
Averages, July 21 to July 29		1.24	0.55	0.25	7.02	7.63	8.06	8.98	9.77	10.25	0.79	0.73	0.68
Averages, June 30 to July 7		1.43	0.88	0.30	6.26	6.84	7.88	7.37	8.31	9.35	0.87	0.83	0.73
Average loss or gain between pickings		−0.19			+0.76			+1.61			−0.08		

TABLE 24

COMPARATIVE DATA ON ALCOHOLIC AND WATER EXTRACTIONS FOR THE DETERMINATION OF ACID IN GRAVENSTEIN APPLES

Sample No.	Alcohol extraction	Water extraction	Difference
	per cent, malic	*per cent, malic*	*per cent*
1	0.76	0.77	0.01
2	0.77	0.77	0.00
3	0.79	0.82	0.03
4	0.75	0.75	0.00
5	0.74	0.76	0.02
6	0.94	0.94	0.00
7	0.91	0.93	0.02
8	0.73	0.74	0.01
9	0.62	0.64	0.02

Plums.—Plums contain from 0.5 to 2.0 or 3.0 per cent of acid depending upon the variety, the time of harvesting, and whether the determination is made upon the expressed juice or upon the flesh. In most cases there is a distinct decrease in the acidity of the fruit as it ripens, either previous to or following harvest. When computed upon the juice, the acidity decrease may be as much as 50 per cent of the total acid present. Analyses of the flesh may or may not show any acid decrease. The decrease in acid varies rather markedly with different varieties. Diamond shows a small acid change, both before and after harvesting, while Beauty and Wickson show a marked decrease in the acidity of the juice but a relatively small amount in the flesh. This is apparently due to the fact that the acid becomes localized in the flesh near the skin and around the pit, and the juice coming from the main portion of the flesh contains relatively much less acid. This condition is more noticeable as the fruit approaches full maturity on the tree or as it ripens following harvest.

Peaches.—The percentage of acid in the flesh of peaches usually varied between 0.5 and 1.0 per cent. Of the six varieties analyzed, Elberta gave the lowest average and Tuskena the highest. Nightingale, Addoms and Blake,[30] working with Elberta and Shipper Cling peaches, report an increase in acidity with development until the fruit reaches the soft-ripe stage. The data presented in table 20 show this was true in some of the earlier-picked samples but that in most cases there was a gradual decrease in acidity with maturity. Generally speaking it would appear that there is little significant change in the acid content. A small decrease continues following harvest but this does not reach its minimum until the fruit has passed its prime eating condition.

Apricots.—The acidity of apricots is greater than that found in peaches and is similar in amount to that of most varieties of plums. There is a gradual and consistent decrease in acid content as the fruit matures on the tree (table 22) and a further decline, although somewhat less marked, after the fruit has been held for 10 days under a temperature of 50° F.

Pears.—Pears show a low percentage of acid which, according to table 21, varies rather widely between two successive years. Although the orchards from which the samples were taken in 1926 were not the same as those from which fruit was obtained the year previous, results of the analyses strongly suggest a considerable fluctuation in the acid content from year to year.

Changes in acidity slightly in advance of and during the commercial harvest season are confined within a narrow range. The fruit from the Sacramento River district behaved differently from that grown in the Sierra foothills, the former showing either no consistent change or a slight decrease in acid as the season advanced, while the latter shows a rather definite and consistent increase. Magness,[21] comparing samples from the Sacramento River district with those from Medford, Oregon, and Yakima, Washington, found fruit from the latter districts to show a slight gain in acids as the picking season advanced.

After ripening at 70° F samples from the Sacramento River showed a very slight change in acids with no consistent trend either up or down. Fruit from the Sierra foothills decreased slightly in acid content.

From the results thus obtained to date it would appear that the acid content and acid changes in pears are, within narrow limits, subject to considerable variation.

Apples.—Acidity in Gravenstein apples (table 23) shows a slight decrease within a two-weeks harvesting period and also a further decline after 10 days at 50° and at 70° F. Magness and Diehl[22] suggest that the decrease in acidity noted before harvesting is due to a dilution as the fruit increases in size (as illustrated in table 3). St. John and Morris,[35] as a result of several seasons' investigations with Jonathan apples state that the level of sugars, acids, and other fractions vary in different years and with the location of the individual fruits on the tree. In view of these variations they think it doubtful whether much significance can be attached to small changes in the quantity of acid.

Accepting these views as correct, the decrease in acid following removal of the fruit from the tree can scarcely be interpreted other than as an actual loss—the rate of decrease being greater after 10 days at 70° F than after the same period at 50°.

STARCH DETERMINATIONS

Determinations for starch were made only in the case of the apple. The residue from the alcohol extraction of the sugars was dried at 65° C for 24 hours, ground in a mortar, transferred to a drying dish, and returned to the vacuum oven at 65° C for 3 days. The samples were then transferred to ball-mill jars and ground for 20 to 22 hours. After adding 30 cc of distilled water the jars were placed in a water bath and held 30 minutes at 100° C. As soon as cool, 10 cc of taka-diastase solution (2 grams in 100 cc of water), 10 cc of sodium acetate buffer (pH 5.0), and 2 cc of toluene were added to each sample. Following incubation at 32° C for 18 hours the samples were washed from the ball-mill jars into centrifuge bottles, 5 cc of lead acetate added, and centrifuged. The lead was subsequently removed with a balanced amount of potassium oxalate, filtered and made up to 250 cc volume. From this, 100 cc samples were withdrawn and placed in 300 cc Erlenmeyer flasks, 10 cc of HCl (sp. gr. 1.125) added, and then refluxed on a steam bath for 2.5 hours. After neutralizing with 35 per cent NaOH and making up to 200 cc the samples were analyzed for glucose in the same manner as for reducing sugars. After subtracting the taka-diastase blank the amount of starch is expressed as glucose in percentage of fresh weight.

The starch content of Gravenstein apples is presented in connection with the data on sugars and acid in table 23. Except for one sample, starch showed a decrease as the picking season advanced while a very material reduction was noted after harvesting and holding the fruit for 10 days at 50° and at 70° F.

MATURITY CHANGES AS MEASURED BY ELECTRICAL CONDUCTIVITY

Winkler,[40] measuring permeability changes by recording the resistance of the tissues to the passage of a weak electric current, found that Yellow Newtown apples near the end of their storage period showed a marked increase in permeability. The flesh of the fruit beginning to show storage breakdown or internal browning had a much lower resistance than that still in normal condition. Unpublished work of Latimer[19] also shows that as the flesh of pears begins to break down there is a marked loss in resistance of the tissues. This, however, was preceded by an increase in resistance during development.

To further test the resistance of the flesh to an electrical current as a possible maturity index for harvesting Bartlett pears, samples of this fruit were collected at intervals from four orchards in widely separated districts and resistance determinations made at the time of harvesting, after a shipping period of 12 days at 50° F, and again when fully ripe.

Resistance measurements were taken in the usual manner with a Wheatstone bridge. The potential resistance of the bridge was balanced in the resistance box so as to have the bridge readings of equal sound intensity at 15–25 points each side of the center. The electrodes were frequently standardized in N/50 KCl solution at 25° C and all readings calculated as specific resistance at this temperature. Temperatures of some samples of fruit varied slightly from this mean but those run at comparable temperatures show that variations not due to temperature are many times those which may be caused by a fluctuation of several degrees.

Heavy platinum electrodes, 7.5 x 7.5 mm spaced 5 mm apart were suitably mounted so that readings could be made by inserting the electrodes directly into the flesh of the fruit. Readings were taken on opposite sides of each of ten specimens. Determinations were made (a) in the cortex area by forcing the electrodes through the skin of the fruit at the point of largest cross section diameter; (b) in the cortex area, forcing the electrodes into the flesh at right angles to the face of the cut cross section; and (c) in the pith area at right angles to the face of the cross section. A comparison of the readings secured in those positions is shown in table 25.

Readings (a) and (b) taken in the cortex area are very similar, the skin in most instances adding slightly to the resistance. Readings

in the pith area were found to be approximately only two-thirds those of the outer parts of the flesh. As pears first show physiological breakdown in this region these lower resistance readings might be construed as representing a more mature condition of the flesh in this part of the fruit. This, however, can scarcely be true since this differential, which remains fairly constant, exists previous to harvesting for commercial shipment. The readings do not increase with the later picked fruit which is considerably softer.

TABLE 25

SPECIFIC RESISTANCE OF THE FLESH OF BARTLETT PEARS; 1927

Locality	Date picked*	Specific resistance, ohms					
		When picked			After 12 days at 50° F		
		(a)†	(b)	(c)	(a)	(b)	(c)
Sacramento River district	June 20	5333	5340	3905	.....	.....	.....
	July 6	5714	5372	3454	6150	6051	4083
	July 19	5879	5198	3444	6736	6400	4000
	August 6	6912	6625	4575	7440	7099	4859
Newcastle	July 1	4957	4868	3250	5195	4814	3386
	July 20	5969	5297	3624	6808	6864	4096
	August 3	6802	5955	3660	6246	6584	4097
	August 25	5580	5490	3945	6182	6150	4025
Santa Clara	July 13	4896	4637	3612	6646	5947	4322
	July 27	6112	5490	4035	6826	6101	4266
	August 10	6858	6617	4701	6352	5235	3630
	August 23	5910	6165	4350	6930	6345	4425
Placerville	July 14	4447	4229	3223	6660	6375	4665
	August 3	6187	6045	3045	6681	6923	4347
	August 17	6304	6400	4144	6787	6280	4687
	September 1	6030	5820	3870	.....	.....	.....

* The four dates in each case represent respectively 14-20 days previous to commercial harvest; early commercial picking; midseason picking; and last of crop.

† Readings taken (a) in cortex area through the skin of the fruit; (b) in cortex area, cut cross section; (c) in pith area, cut cross section.

Further comparison between softening and specific resistance readings obtained at (a) on the same fruits at different dates previous to and during the commercial picking season are illustrated in figure 1. The resistance curves show a distinct rise throughout most of the picking season, with a slight lowering of resistance in late-picked fruit. While this lower resistance accompanies softening it is apparently independent of it as all samples picked at the end of the commercial harvest season had a higher resistance than comparable samples at the beginning of the season. This is in agreement with

the general idea of all permeability, in that changes in resistance are due to the solution of electrolytes within the cell rather than to changes in the cell walls, the latter being considered as offering little or no resistance to the passage of ions.

Latimer[19] states that, "during the growing period the resistance of the tissue increased gradually until the fruits reached their maximum size and were morphologically mature." Although it has been shown that the fruit continues to increase in size as long as usually allowed to remain on the tree the statement of Latimer is generally substantiated by the resistance curves in figure 1. A comparison of

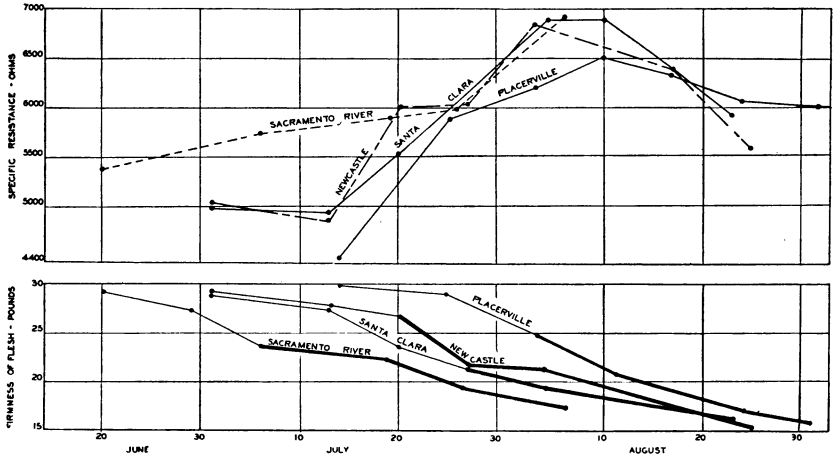

Fig. 1. Softening and specific resistance of Bartlett pears, 1927. Heavy lines represent period of commercial harvest.

the resistance curves with those of softening, show that, instead of any direct correlation existing between resistance and softening, up to full development of the fruit the two changes are to a certain extent inversely proportional. With late-picked fruit the resistance decreases and has a tendency to drop with the softening of the flesh.

Previous investigations have shown a general correlation between the quality of Bartlett pears and their firmness when picked. A pressure test of 22 pounds in the Santa Clara Valley and of 23 to 25 pounds in the interior valleys has been recommended as the maximum firmness at which the fruit should be harvested and expected to ripen with fair quality. To secure the *best* quality, harvesting in most sections should be delayed until the pressure drops to 20 pounds.

Noting the dates on the lower part of figure 1 when the fruit from each of the four districts had softened to these pressures, and then

observing the resistance of the fruit on the same days, it is seen that with a firmness of 22–23 pounds the resistance shown by the fruit from the different sections is rather variable (table 26). With a drop in firmness to 20 pounds, this variation becomes less in three out of the four samples and it might appear that a resistance of 6450 to 6600 ohms does mark the beginning of the period when pears from the Newcastle, Placerville, and Santa Clara Valley ripened with *good* quality.

TABLE 26

SPECIFIC RESISTANCE OF BARTLETT PEARS AT THE TIME OF COMMERCIAL HARVEST; 1927

Locality	Date testing 23 pounds pressure	Specific resistance, ohms	Date testing 20 pounds pressure	Specific resistance, ohms
Sacramento River district	July 11	5750	July 25	5950
Newcastle	July 25	6000	August 8	6650
Placerville	August 7	6400	August 13	6450
Santa Clara Valley	July 25	5950*	August 1	6600

* At a pressure of 22 pounds.

The dessert quality in the later pickings of fruit after the resistance readings had begun to drop were, however, as good if not superior to that in the fruit picked when showing its highest resistance.

Pears from the Sacramento River district possessed good quality considerably before reaching their maximum resistance and all fruit from the orchard under test was harvested before the resistance declined. While therefore the general rise in resistance may be correlated with general maturity it is too variable to be considered as a picking index.

The time of the initial commercial picking in each of the four orchards is shown in figure 1. In the Sacramento River district, at Newcastle, and at Placerville, harvesting began as soon as the fruit was 2¼ inches in diameter and from 3 to 5 days before it would meet a 23-pound pressure test. In the Santa Clara orchard the first picking of fruit was delayed until it tested 21 pounds and was 2½ inches or over in size.

The specific resistance of the fruit after storing for 12 days at 50° F, or what might be considered the time the fruit is in transit to eastern markets is, in most cases, slightly higher than when harvested. However, measurements taken on late-picked fruit from the Santa Clara Valley may show a marked decrease in resistance (fig. 2).

After removing to a temperature of 70° F following a 12-day period at 50°, Bartlett pears reach prime eating condition in from

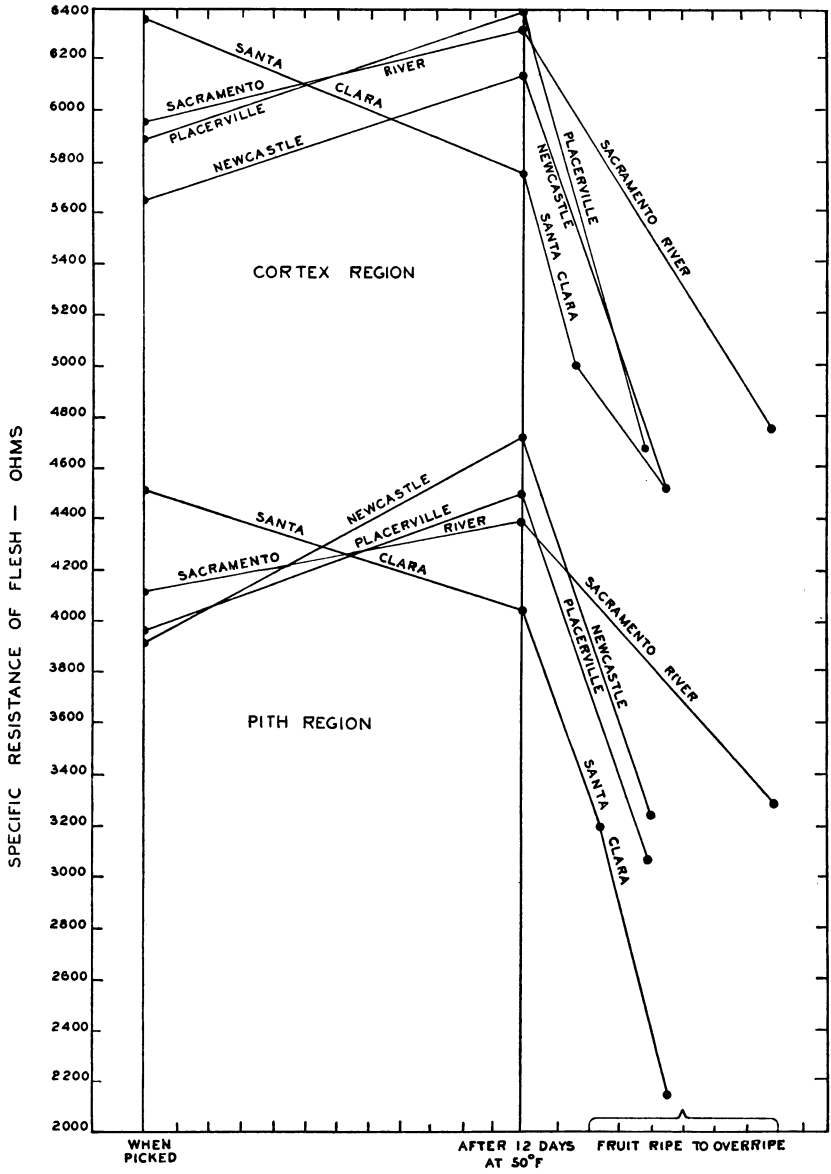

Fig. 2. Specific resistance readings of the flesh of late-picked Bartlett pears from the time of harvesting until ripe. Top, cortex region; bottom, pith region.

2 to 5 days. During this ripening period, and as the fruit becomes overripe and shows evidence of physiological decay, the resistance of the tissues falls very rapidly. Figure 2 illustrates these changes as measured in both the cortex and pith areas of certain samples of late-picked fruit.

The results are in agreement with those of Winkler[40] and of Latimer,[19] and indicate rather clearly that in most instances the resistance of Bartlett pears maintains an upward trend until the fruit approaches edible condition and then decreases rapidly as the flesh becomes soft.

INFLUENCE OF ETHYLENE GAS ON THE RIPENING OF GRAVENSTEIN APPLES

The Gravenstein apple is the earliest commercial variety grown in California for eating out of hand but as harvested in this state it arrives on the eastern markets considerably in advance of the time when it is most attractive as a dessert apple. The success which has been attained by a number of investigators in hastening the coloring and ripening of certain fruits and vegetables by the use of ethylene gas suggested its possibilities in hastening the ripening of the Gravenstein apple and also of a number of varieties of fall and winter pears.

Box lots of apples were secured from six different orchards in the Sebastopol section, pickings being made early in the shipping season and again two to four weeks later. All fruit was brought to Davis the second day following harvest and immediately treated or placed under storage conditions. Ethylene gas was used at a strength of 1–1000, the fruit being placed in tight chambers of 20–25-box capacities and under temperatures of 50° and 70° F. Runs extended for 4 and for 10 days, the chambers being opened and regassed each second day. Following the period of treatment the samples were exposed to a temperature of 65°–75° F for ripening.

Influence on Color.—Notations on color were made at the time of picking and also after treating by comparing the ground color of the fruit with a color chart showing different shades of green to yellow.[2] Although color changes were not always consistent, there is no doubt but that the treatment influenced some samples, changing the color

[2] The chart used is that adopted by the California State Department of Agriculture in the shipping of Bartlett pears, reproduced in California Experiment Station Bulletin 470, "Maturity Standards for Harvesting Bartlett Pears for Eastern Shipment," and similar to that used by Magness and others in U. S. D. A. Dept. Bul. 1406, "The Ripening, Storage and Handling of Apples."

of the skin from a decided light green to a greenish yellow. This change, however, was apparent in only 35 per cent of the samples held at 50° F and in a little over 50 per cent of those held at 70° F. Early-picked fruit responded in a greater number of cases than did that picked later.

In certain instances the changes were practically as marked after 4 days of treatment, at 70° F plus 6 days ripening in air, as they were after 10 days gas treatment at the same temperature. As was anticipated, temperature had a decided influence on the rate of yellowing. In no instance was there any effect upon the red color. Fruit wrapped and packed showed practically the same color change as that unwrapped.

TABLE 27

INFLUENCE OF ETHYLENE GAS UPON THE SOFTENING OF GRAVENSTEIN APPLES; 1930

Orchard No.	Date picked	Firmness when picked	Firmness of fruit after 10 days at			
			50° F		70° F	
			Check	Treated	Check	Treated
		pounds	*pounds*	*pounds*	*pounds*	*pounds*
1	June 30	19.7	.....	.....	13.9	10.6
	July 29	19.5	16.6	16.3	14.0	12.4
2	June 30	17.3	.....	.....	11.1	9.9
	July 21	15.4	13.7	13.4	13.5	11.1
3	July 7	17.0	17.8	16.2	17.3	11.0
	July 21	17.6	16.9	16.2	14.4	12.4
4	July 8	17.0	17.2	15.4	13.5	11.1
	July 21	17.8	15.6	14.3	15.6	9.5
5	July 7	17.4	17.8	17.4	16.4	12.1
	July 28	17.9	15.2	14.4	12.9	12.5
6	July 8	16.7	19.0	16.1	15.2	11.4
	July 21	18.2	16.6	16.0	14.2	13.8
Average		.....	16.6	15.5	14.6	11.5
Average decrease		.....	.....	1.1	.....	3.1

Influence on Softening.—Pressure tests taken when the fruit was picked and after it had been held 10 days at 50° F showed a difference of only 1 pound between the treated and untreated samples. When held at 70° F the difference averaged 3 pounds and was the most outstanding effect of the treatment (table 27). A rearrangement of the data in table 27 is presented in table 28 and gives more clearly the comparative differences between the softening of early and of

TABLE 28

INFLUENCE OF ETHYLENE GAS UPON THE SOFTENING AND RIPENING OF EARLY AND OF LATE-PICKED GRAVENSTEIN APPLES; 1930

Orchard No.	Date picked	Temperature at which the fruit was held, degrees Fahrenheit	Average firmness after 10 days, pounds		Additional number of days to ripen after 10 days' treatment or holding	
			Check	Treated	Check	Treated
		Early pickings				
1	June 30	50	.....	.....	14	13
		70	13.9	10.6	9	9
2	June 30	50	.....	.....	13	12
		70	11.1	9.9	9	9
3	July 7	50	17.8	16.2	10	9
		70	17.3	11.0	5	4
4	July 8	50	19.7	15.4	10	7
		70	13.5	11.1	6	5
5	July 7	50	17.8	17.4	10	8
		70	16.4	12.1	6	5
6	July 8	50	19.0	16.1	12	11
		70	15.2	11.4	6	4
Average		.....	16.1	13.1	9.2	8.0
Average decrease		.....	.....	3.0	.....	1.2
		Late pickings				
1	July 29	50	16.6	16.3	2	1
		70	14.0	12.4	2	2
2	July 21	50	13.7	13.4	8	8
		70	13.5	11.1	1	1
3	July 21	50	16.9	16.2	9	9
		70	14.4	12.4	9	9
4	July 21	50	15.6	14.3	8	8
		70	15.6	9.5	2	1
5	July 28	50	15.2	14.4	6	6
		70	12.9	12.5	3	3
6	July 21	50	16.6	16.0	9	9
		70	14.2	13.8	2	2
Average		.....	14.9	13.5	5.1	4.9
Average decrease		.....	.....	1.4	.....	0.2

TABLE 29

INFLUENCE OF ETHYLENE GAS UPON THE STARCH, SUGAR, AND ACID CONTENT OF GRAVENSTEIN APPLES; 1930

Orchard No.	Date picked	When picked				Treatment	After 10 days at 50° F				After 10 days at 70° F			
		Starch as glucose	Reducing sugars	Total sugar	Acid, as malic		Starch as glucose	Reducing sugars	Total sugar	Acid, as malic	Starch as glucose	Reducing sugars	Total sugar	Acid, as malic
		Figures in per cent					*Figures in per cent*				*Figures in per cent*			
1	July 7	1.49	6.59	7.90	0.77	Check	0.74	6.80	8.44	0.79	0.32	7.64	9.30	0.76
						Treated	0.53	7.26	8.95	0.78	0.20	8.38	9.56	0.68
2	July 28	1.00	7.25	9.70	0.76	Check	0.36	7.69	10.07	0.68	0.26	8.44	10.62	0.66
						Treated	0.34	8.02	10.20	0.66	0.23	8.18	9.92	0.63
3	July 7	1.69	6.41	7.39	0.94	Check	0.90	7.12	8.60	0.91	0.44	9.20	10.75	0.73
						Treated	.....	8.24	9.66	0.79	0.25	7.97	8.82	0.66
4	July 21	1.33	7.78	9.56	0.78	Check	0.56	8.76	10.78	0.77	.....	.....	.....	.....
						Treated	0.45	8.82	10.83	0.70	0.27	8.48	10.07	0.62
5	July 14	1.16	6.46	7.82	0.86	Check	0.30	6.70	7.92	0.74	0.11	7.04	8.64	0.68
						Treated	0.28	6.89	8.56	0.72	0.11	7.25	8.58	0.61
6	July 9	1.23	6.72	8.07	0.87	Check	0.62	7.43	9.41	0.80	0.11	7.54	9.31	0.69
						Treated	0.28	7.48	9.44	0.72	0.10	7.69	9.19	0.60
7	June 30	1.16	6.07	6.92	0.96	Check	0.48	6.68	7.86	0.86	0.10	7.28	8.56	0.74
						Treated	0.25	7.26	8.64	0.79	0.09	7.04	7.51	0.78
8	July 14	1.12	6.63	7.60	0.80	Check	0.46	6.74	8.42	0.77	0.21	8.54	10.27	0.73
						Treated	0.36	6.92	8.52	0.74	0.17	9.08	11.30	0.72
9	July 29	1.31	6.76	8.50	0.82	Check	0.74	7.11	9.34	0.76	0.24	7.60	10.45	0.68
						Treated	0.65	7.30	9.50	0.72	0.24	7.35	10.20	0.68
10	July 7	1.40	5.98	7.29	0.82	Check	0.52	6.77	8.34	0.77	0.30	7.42	8.78	0.70
						Treated	0.43	6.88	8.36	0.75	0.19	7.80	8.60	0.67
11	July 21	1.33	6.29	8.18	0.80	Check	0.58	6.97	8.89	0.72	0.25	8.14	9.68	0.69
						Treated	0.39	7.06	9.34	0.71	0.17	7.68	9.30	0.62
Average	.....	1.29	6.63	8.08	0.83	Check	0.57	7.16	8.91	0.78	0.23	7.88	9.63	0.70
						Treated	0.39	7.46	9.27	0.73	0.18	7.90	9.37	0.66

late-picked fruit. With the former the average difference between the treated and check samples was 3 pounds while with the latter it was only 1.4 pounds. This softening is reflected in the time required for each sample to reach its prime eating condition. In each case the number of days recorded represents the first day when the fruit seemed to have reached its best quality. Obviously, the recording of such data presents opportunity for error and is less satisfactory than where possible to use a definite standard of measurement. On the average, however, the early-picked fruit which was treated ripened one day ahead of that not treated. Late-picked samples showed no difference in this respect.

Influence on Dessert Quality and Chemical Composition.—Critical sampling for dessert quality seems to justify the statement that in two or three lots only, was the treated fruit noticeably sweeter and more mellow in texture than that of the untreated. Results of chemical analysis of treated and untreated samples are given in table 29. These data show the normal changes in starch, sugars, and acids during a ripening period of ten days at 50° and at 70° F, and also the changes induced by the ethylene gas treatment. All samples of fruit treated at 50° showed a slight increase in sugars and a decrease in acid and in starch over the check samples. Comparable lots treated at 70° F likewise showed a decrease in starch and in acids in 8 out of 11 samples. In most cases there was no increase in sugars. In fact most treated samples showed a decrease, possibly due to the use of these materials in a more rapid metabolism of the tissues.

Using the averages for starch, sugars, and acids given in table 29 as a basis, the per cent loss or gain in these substances is illustrated in figure 3. From this it is readily apparent that the greatest loss or gain was with the fruit held at 70° F but that the greatest differences between the treated and check samples occurred at 50°. At this temperature the percentage increase in total sugar averaged 4.5 per cent while the decrease in acid and starch was 6.0 and 13.8 per cent, respectively.

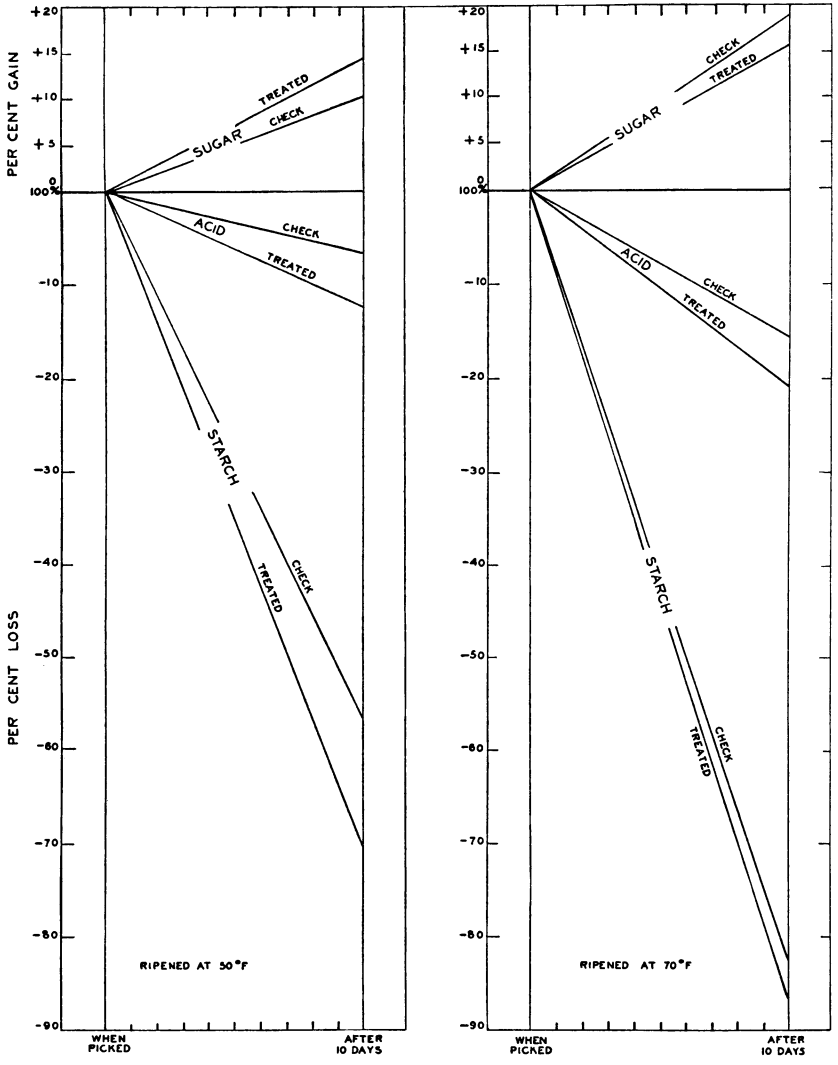

Fig. 3. Gain or loss in starch, sugar, and acid in Gravenstein apples after ten days ripening at 50° and 70° F. Figures are in percentage of the amounts present when the fruit was harvested.

INFLUENCE OF ETHYLENE GAS ON THE RIPENING OF PEARS

Methods of handling Anjou, Beurre Bosc, Beurre Clairgeau, Comice, Glou Morceau, Winter Nelis, Easter Beurre, and Kieffer pears were similar to those with apples. All samples, however, were held at 70° F during treatment and the duration of the treatment was reduced in most instances to a period of 3 or days. A few samples were treated immediately after harvesting, but in most cases the treatments followed a 10-day 'in transit' period during which time the fruit was held at 50° F. With the more important varieties, tests were also run after a storage period of from 12 to 18 weeks at 32° F.

Fruit was obtained primarily from the Santa Clara Valley with some samples from the Sacramento River and Sierra foothill districts. Influences of the gas on rate of ripening were confined to recording color changes, the number of days required for each sample to reach prime eating condition and its period of marketability. Chemical analyses were run on a number of samples of the Beurre Bosc and Winter Nelis varieties.

Anjou.—The influence of ethylene gas upon the ripening of Anjou pears is shown in table 30. When the fruit was held continuously at 70° following harvest the ethylene treatment reduced the period of ripening in the two samples from 17 and 26 days to 10 days. Comparable samples from both Newcastle and Davis held at 50° for 10 days and then treated showed an average difference in ripening of 1.3 days. Samples stored for 12 weeks at 32° F previous to treatment showed the same difference.

Untreated pears from the Santa Clara Valley were exceedingly slow in reaching a ripe condition; in fact the flesh became tough and ripened only imperfectly after 3 to 5 weeks. Treated samples ripened very satisfactorily in 9 to 11 days and with better quality than the untreated samples. Slight to rather marked differences in color were noted in about half of the samples treated. These differences were noticeable in from 4 to 8 days.

Beurre Bosc.—Samples of Beurre Bosc pears from two orchards in the Santa Clara Valley and in the Sacramento River district were treated and held at 70° F immediately following harvest. Fruit from the Santa Clara Valley ripened somewhat slower than that from the River district. In both instances, however, the ethylene treatment

hastened the process, the treated samples from the former section ripening in 11.3 days or 8 days previous to that of the untreated samples. In the latter district the time was 11.5 and 14.5 days (table

TABLE 30

INFLUENCE OF ETHYLENE GAS UPON THE RIPENING OF ANJOU PEARS; 1930

Locality	Orchard No.	Date picked	Time treated	Days to ripen, including days treated	Color and quality when ripe
Treated as soon as harvested					
Newcastle	1	August 15	Treated 2 days	10	Yellow, good
			Check	26	Greenish yellow, poor, shriveled
	2	August 15	Treated 2 days	10	Greenish yellow, fair to good
			Check	17	Greenish yellow, fair to good
Treated after storing 10 days at 50° F					
Newcastle	1	August 15	Treated 2 days	6	Yellow, good
			Check	6	Yellow, good
	2	August 15	Treated 2.5dys.	5	Yellow, fair to good
			Check	7	Yellow, fair to good
Davis		August 15	Treated 3 days	11	Yellow, good
			Check	13	Greenish yellow, good
Santa Clara	1	August 22	Treated 3 days	11	Greenish yellow, good
			Check	33	Greenish yellow, poor, shriveled
	2	August 30	Treated 4 days	9	Yellow, very good
			Check	25	Greenish yellow, good, but fruit slightly shriveled
	3	August 30	Treated 4 days	10	Yellow, good
			Check	35	Light yellow, fair to good
Treated after storing 12 weeks at 32° F					
Newcastle	1	August 15	Treated 3 days	10	Greenish yellow, good
			Check	11	Greenish yellow, fair, insipid
	2	August 15	Treated 4 days	12	Greenish yellow to yellow, good
			Check	13	Greenish yellow to yellow, good
Davis		August 15	Treated 3 days	11	Yellow, good
			Check	13	Greenish yellow, good

31). Color in each of the five treated samples was either developed or hastened by the use of the ethylene. The flesh of two untreated samples became somewhat tough and shriveled previous to ripening and the quality was not good. In the other two samples no difference in quality could be detected.

TABLE 31

INFLUENCE OF ETHYLENE GAS UPON THE RIPENING OF BEURRE BOSC PEARS; 1930

Locality	Orchard No.	Date picked	Time treated	Days to ripen, including days treated	Color changes
Treated as soon as harvested					
Santa Clara Valley	1	August 29	Treated 4 days	13	Color changing from olive green to greenish yellow after 6 days
			Check	20	Color remained olive green, fruit shriveled
	2	August 30	Treated 3 days	11	Golden yellow when ripe
			Check	16	Green after 11 days, becoming golden yellow when ripe
	3	August 29	Treated 3 days	10	Noticeable change in 3 days, golden yellow in 10 days
			Check	22	Green after 10 days
Sacramento River district	1	August 4	Treated 4 days	9	Fruit yellow when ripe
			Check	11	Fruit green and slightly shriveled when ripe
	2	August 4	Treated 4 days	14	Golden russet when ripe
			Check	18	Light yellow, russet, ripening unevenly and slightly shriveled on neck of the fruit
Treated after storing for 10 days at 50° F					
Santa Clara Valley	1	August 22	Treated 3 days	5	No apparent increase
			Check	5	
		August 30	Treated 4 days	9	No apparent increase
			Check	10	
	2	August 22	Treated 3 days	9	Noticeably more yellow after [3–4 days
			Check	10	
		August 30	Treated 4 days	11	Noticeably more yellow after [3–4 days
			Check	11	
	3	August 22	Treated 3 days	9	Noticeably more yellow after [3 days
			Check	12	
		August 30	Treated 4 days	11	No apparent increase
			Check	11	
	4	August 22	Treated 3 days	8	Noticeably more yellow after [3 days
			Check	10	
		August 30	Treated 4 days	10	No apparent increase
			Check	12	
	5	August 22	Treated 3 days	8	Noticeably more yellow after [3 days
			Check	10	
	6	August 22	Treated 3 days	8	No apparent increase
			Check	10	
Sacramento River district	1	August 13	Treated 2.5 d's	7	Possibly more yellow
			Check	7	
	2	August 13	Treated 2.5 d's	6	No apparent increase
			Check	6	
	3	August 13	Treated 2.5 d's	7	Noticeably more yellow after [3 days
			Check	7	
Penryn	—	August 15	Treated 2.5 d's	4	No apparent increase
			Check	4	
Newcastle	—	August 15	Treated 3 days	5	No apparent increase
			Check	5	
Auburn	—	September 3	Treated 4 days	6	No apparent increase
			Check	6	
Davis	—	August 29	Treated 4 days	10	Noticeably more yellow after [4 days
			Check	11	

Fruit from a larger number of orchards was treated after an initial storage period of 10 days at 50° F. Samples from the Santa Clara Valley again responded to the ethylene treatment but in a less degree than when treated as soon as harvested. Early-picked fruit showed a more uniform, or in some cases a greater response both in time of ripening and in coloring than did that picked a week following. Average differences in the time of ripening for the treated samples harvested August 22 (table 31) were 1.7 days. Only 1 of the 6 samples failed to show a noticeable difference in time of ripening. Increased color development was apparent in 4 out of 6 samples. No difference could be detected in quality.

Pears harvested August 30 from four of the above orchards failed to show consistent results, only 2, or half of the treated samples, showing a difference in rate of ripening with an average increase of 0.8 days. Only one sample showed any noticeable increase in color. No difference could be detected in quality.

Samples of Beurre Bosc from three orchards in the Sacramento River district and from a like number in the Sierra foothills failed to show any influence of the ethylene on the rate of ripening. All samples ripened within a week. Color differences were likewise noticed in only one or two cases, due in part at least to slightly more color development and a greater amount of russet on the fruit when harvested. A single sample of treated fruit from the University Farm at Davis ripened one day in advance of the untreated sample and showed more rapid color development.

Nine samples of Beurre Bosc from the Santa Clara Valley, one from the Sierra foothills and one from Davis, were also placed in 32° storage and held 10 weeks previous to exposure of ethylene gas. Treatment for 4 days increased the rate of ripening one day in 5 of the samples, the other showing no influence of the gas. Color differences were noted in 4 samples.

From the data secured it appears that ethylene is capable of hastening both softening and coloring of Beurre Bosc, as well as Anjou, but that its influence is greatest with early-picked fruit and that treated previous to storage. Except where the fruit was ripened immediately without the usual period of storage, there were only one or two cases where possibly the quality was improved by the use of ethylene.

Beurre Clairgeau.—Results with Beurre Clairgeau pears were again rather marked where the samples were treated immediately following harvest. Fruit treated after being stored for 10 days at

50° F showed a slight effect of the ethylene on two of the samples while the average difference in ripening with the fruit previously held at 32° was practically negligible. Slightly better flavor was noted in samples ripened immediately and in two of those ripened after the 10-day holding period. As Beurre Clairgeau is usually of a light greenish yellow to yellow color when harvested little color difference due to ethylene was noted.

Comice.—Only one sample of Comice grown in the Santa Clara Valley was subjected to the ethylene treatment. Treatment was given for 4 days following storage for 10 days at 50° F. The treated sample ripened in 8 days and the check sample in 10 days. At the end of the treatment period the treated sample was turning yellow while only a slight change of color had occurred in the check sample.

Glou Morceau.—This variety requires a relatively long ripening season and attempts to ripen two samples picked August 30 without holding in storage resulted in the fruit becoming tough and shriveled and with little change in color after 30 days. Concomitant lots treated with ethylene ripened rather imperfectly after 21 and 25 days and were of yellow color. Development of color was noticeable in 12 days. Two samples ripened after 10 days at 50° F showed practically no difference either in softening or color as a result of 6 days' treatment. Of five samples held at 32° for 16 weeks previous to 6 days' treatment only two ripened one day in advance of the checks. Both of these samples showed a noticeable increase in color.

Easter Beurre.—Attempts were made to ripen three samples of Easter Beurre immediately after harvesting, three samples after holding the fruit for 10 days at 50° F and two samples after holding for 18 weeks at 32° F. After being in storage at 32° the fruit required 10 and 20 days to ripen, the difference being due to its maturity when picked. Ethylene treatment for 4 days after removal from storage did not hasten ripening or produce any noticeable difference in color. The fruit which was not stored, as well as that stored for only 10 days, either failed to ripen or ripened very imperfectly, all specimens becoming shriveled and spongy with only slight change in color. Easter Beurre, which has excellent keeping quality in storage, also ripened very slowly when placed under ripening temperatures, and longer periods of treatment will be necessary to demonstrate the influence of ethylene with this variety.

Winter Nelis.—Untreated samples of Winter Nelis responded similarly to the Easter Beurre variety in that all attempts to ripen the fruit as soon as harvested resulted in failure. Comparable lots which

were treated ripened fairly satisfactorily. Of the three lots held 10 days at 50° F before being treated one sample showed no influence of ethylene, one treated sample ripened two days in advance of the check, while the third ripened six days earlier. After 15 weeks at a

TABLE 32

INFLUENCE OF ETHYLENE GAS UPON THE RIPENING OF WINTER NELIS PEARS; 1930

Locality	Date picked	Time treated	Days to ripen, including days treated	Color and quality when ripe
Treated as soon as harvested				
Santa Clara	August 22	Treated 2.5 d's	13	Fair quality
		Check	—*	
	August 30	Treated 3 days	12	Fair to good quality, yellow color
		Check	—*	Green and spongy
	August 30	Treated 3 days	12	Fair quality
		Check	—*	Green and spongy
	August 30	Treated 3 days	12	Fair quality
		Check	—*	
Davis	August 29	Treated 3 days	12	Fair to good quality, greenish yellow
		Check	—*	Green and spongy [color
Treated after storing for 10 days at 50° F				
Santa Clara	August 30	Treated 4 days	11	No apparent increase, fair quality
		Check	11	
Davis	August 29	Treated 4 days	11	No apparent increase in color
		Check	17	
	September 9	Treated 4 days	9	No apparent increase in color
		Check	11	
Treated after storing for 15 weeks at 32° F				
Santa Clara	August 30	Treated 4 days	12	No apparent increase in color or firm-
		Check	12	[ness, fair quality
Davis	August 29	Treated 4 days	12	No apparent increase in color or firm-
		Check	12	[ness, fair quality

* Fruit failed to ripen in 30 days.

temperature of 32° all samples ripened in 12 days. The data are presented in table 32 and seem to justify the conclusion that ethylene is capable of ripening Winter Nelis within two weeks after harvesting. Untreated samples have subsequently been ripened successfully in 30 days under a temperature of 50° F.

Kieffer.—Only three samples of Kieffer were secured but the results obtained indicate that this variety responds readily to the use of ethylene gas. Although all samples, when fully ripe, had a very clear, deep yellow color, the rate of development of this color was markedly influenced by the ethylene treatments. Softening of the flesh was not marked as the variety attains its characteristic color, flavor, and aroma while still firm. However, differences in ripening were noted as shown in table 33. The quality of the early-picked samples was superior in the treated samples, the flesh being sweeter, more juicy and more aromatic.

TABLE 33

INFLUENCE OF ETHYLENE GAS UPON THE RIPENING OF KIEFFER PEARS; DAVIS, 1930

Date picked	Color when picked	Time treated	Days to ripen, including days treated	Color changes
Treated as soon as harvested				
August 29	Green	Treated 4 days	15	Yellowish green to light yellow after 4 days, yellow after 9 days
		Check	19	Yellowish green after 4 days, greenish yellow after 9 days
Treated after storing for 10 days at 50° F				
August 29	Green	Treated 4 days	9	Yellow after 4 days, golden yellow after 11 days
		Check	11	Light yellow after 4 days, yellow after 11 days
September 9	Yellowish green	Treated 4 days	7	Yellow after 4 days
		Check	8	Light yellow after 4 days

Influence of Ethylene Gas on Dessert Quality and Chemical Composition of Pears.—In some cases, as previously noted, treated samples of fruit were of slightly better quality than the untreated samples. Generally speaking, however, when the check samples ripened in a normal manner their quality was the same as that of the treated lots. A rather limited number of chemical analyses for sugars and acid show little difference as a result of the ethylene treatment. The averages shown in table 34 are the results of analyses on samples treated 4 days after the fruit had previously been in storage for 10 and 15 weeks. In view of the results on softening and color, it would appear that greater differences in chemical composition might have been found had samples been analyzed within a short time after harvesting.

TABLE 34

SUGAR AND ACID CONTENT OF TREATED AND UNTREATED BEURRE BOSC AND WINTER NELIS PEARS AFTER STORAGE PERIOD OF 10 AND 15 WEEKS, RESPECTIVELY, AT 32° F

Variety	Date picked	Reducing sugars		Total sugar		Acid, as malic	
		Treated	Check	Treated	Check	Treated	Check
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Beurre Bosc	August 22, 1930	6.13	6.13	8.23	8.29	0.22	0.22
	September 12, 1930	5.55	5.42	8.69	8.51	0.14	0.14
Winter Nelis	August 30, 1930	9.25	9.10	10.55	10.29	0.22	0.22

SUMMARY AND CONCLUSIONS

Measurements made on several varieties of plums, peaches, pears, and on Gravenstein apples show that these fruits continue to increase in size until more mature than they are allowed to become before harvesting for eastern shipment and that early harvesting for commercial shipment frequently results in a considerable loss of tonnage.

Although light may hasten their coloring, plums are able to develop their characteristic overcolor when sunlight is excluded. Plums showing only slight red or blue color when harvested may thus develop their full color while in transit to eastern markets, the extent and rapidity of the coloring being dependent upon the temperatures in transit.

Apples, peaches, pears, and apricots generally require sunlight for the development of their red color. Red color on these fruits therefore does not develop under storage conditions but may appear more noticeable after storage than when the fruit was harvested because of the change in ground color. This change from green to yellow may require only a few days in the case of the stone fruits, to a period of several weeks or months with late varieties of pears and apples stored under low temperatures.

Plums are a striking example of a fruit which may be harvested when showing only a trace of their overcolor and yet subsequently assume their full blue or red color after harvesting and while under transit or storage conditions.

Softening of the flesh is one of the most important ripening changes taking place in deciduous fruits and with the use of mechanical pressure testers can now be successfully measured. Fruits not only soften rapidly after beginnnig to change color, but tests with Bartlett pears have shown that softening may begin at a time when the fruit has attained less than half its full size.

When measured by a mechanical pressure tester different varieties of the same fruit show considerable variation in firmness of flesh and in its rate of softening. Climatic conditions and the type of rootstock upon which the tree is worked also have been found to be important factors in the softening of Bartlett pears. In general, however, the rate of softening immediately preceding and during harvest is from ½ to 1 pound per day with plums, peaches, and apricots; apples and fall pears ½ to 1½ pounds in ten days; and Bartlett pears 2 to 3 pounds in ten days.

As with coloring, softening of the fruit following its removal from the tree is primarily dependent upon the temperature at which it is held. Plums held at 43° F for 12 days softened approximately as much as comparable samples held at 52° F for only 6 days. Bartlett pears soften only 1 to 2 pounds in several months at 32° F, while they will ripen from two to three times as rapidly at 36° F. Somewhat similar differences were found with peaches and Gravenstein apples.

Plums, peaches, and pears all show an increase in soluble solids as the fruit ripens on the tree. The quantity of soluble solids is roughly twice that of the total sugars.

All of the fruits analyzed made a material gain in sugar content as the fruit colored on the tree. The stone fruits made a distinct gain in sucrose sugar, apples in both sucrose and reducing sugars, and pears primarily in reducing sugars. Apples and pears—usually harvested sometime in advance of eating ripe condition—show a decrease in starch and a marked gain in sugar content after picking.

Plums show an acid content of from 0.5 to 3.0 per cent, apricots approximately 1.0 per cent, peaches and apples 0.5 to 1.0 per cent, and pears 0.25 to 0.75 per cent. During maturity on the tree the acid of apricots, apples, and most plums and peaches shows a decrease. With some peaches and with Barlett pears from the Sierra foothill districts there may be an increase. The acid changes in peaches, Gravenstein apples, and pears are much less than in plums or apricots.

A comparison of the softening of Bartlett pears with the resistance of the tissues to the passage of an electrical current shows that while the fruit is maturing and softening on the tree, the specific resistance continues to show a distinct rise until late in the picking season. The samples tested show considerable variation in their resistance readings. While highest dessert quality is associated with high electrical resistance, additional work is considered necessary before the exact value of resistance readings as a picking index can be stated.

Specific resistance readings taken in the pith area of the pears were approximately only two-thirds as high as those secured in the cortex region.

After harvesting there is usually a continued rise in the resistance of the fruit until the flesh becomes overripe or shows signs of physiological decay. The resistance then drops rapidly.

Treating Gravenstein apples with ethylene gas can scarcely be recommended for commercial shipments although it resulted in hastening the softening and in increasing the yellow color of some samples. The difference in softening and coloring between the treated and untreated lots was most marked in the early-picked fruit and in those samples treated at a temperature of 70° F. When treated under a temperature of 50° F rather noticeable differences were also found in the starch, sugar, and acid content of the fruit.

Ethylene is also capable of both increasing the color and hastening the ripening of pears. The results, however, vary with different varieties and were not entirely consistent with all samples of the same variety. Early-picked fruit and that treated previous to storage showed the most striking differences.

Although a few of the treated samples of both apples and pears were judged as being of better dessert quality than the check lots, it was usually difficult to detect differences in flavor between the treated and the untreated lots. Chemical analyses of Gravenstein apple samples show that fruit which was treated with ethylene contained somewhat less starch and acid than that not treated. There was a slight increase of sugar in the samples treated under a refrigerator car temperature of 50° but slightly less sugar in most samples when treated under a temperature of 70° F. A limited number of analyses of Beurre Bosc and Winter Nelis pears show the ethylene treatment to have had practically no effect upon the sugar or acid content of the fruit.

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