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CHANGES IN COMPOSITION DURING RIPENING AND STORAGE OF MELONS

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The shipment of various kinds of melons from the western states to eastern cities has become an important item in the produce industry during recent years. Because of the distance from producing regions to the larger markets, most of these melons are harvested and shipped in a more or less immature condition. Practices in harvesting and shipping should be established to yield the most satisfactory results from the standpoint of both shipper and consumer. Aside from some investigations with cantaloupes, little work has yet been done to establish rational methods for harvesting and handling of melons. Hence a detailed study has been undertaken at the University Farm, Davis, of the changes in composition and in quality of the leading types of melons, both in fruit ripening naturally on the plant, and in fruit harvested more or less immature and stored under different conditions.

Of the factors influencing quality of melons from the consumer's point of view, sweetness is probably most important. This may be affected both by the amount of sugars present, and by the kinds of sugars. The texture is also important, for palatability is partly determined by the degree of softness and the juciness of the flesh. From the shipper's standpoint, firmness is most important, for it determines the physical limits of shipping range and market handling.

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[1] Associate Professor of Truck Crops and Associate Plant Breeder in the Experiment Station. Died August 8.

[2] The writer was assisted by Miss Eleanor Joness in carrying on the work reported in this paper. The levulose determinations were very kindly made by Mr. O. Lilliland and Mrs. L. V. Davis.

CHANGES DURING RIPENING ON THE PLANT

The various classes of sugars, which chiefly affect flavor and sweetness, were determined in fruit at different stages of growth. Determinations of the pectic substances in the fruit-flesh at successive stages of development indicated the changes in composition connected with softening of the fruit. Strains which had been inbred for one or more years were used, to obtain greater uniformity of material.

Selection of Sample Material.—For the work with cantaloupes, fruit of the Salmon Tint variety, grown at Davis, was used. Flowers were tagged on June 28, 1926. Under midsummer conditions at Davis, this variety attains the full-ripe condition in 40 to 45 days after the fruit is set. The tagged fruit furnished material of uniform age for the chemical and storage experiments. Beginning 25 days after the fruit set, samples were picked every three days, until the full or field-ripe stage was reached.

For studies on the Honey Dew melons, flowers were tagged July 20, 1927. This variety requires about 55 days to reach commercial maturity, at which stage the fruits are still firm but the flesh is edible. For about 10 days following this, the ripening process continues to the full ripe condition, then deterioration commences if the fruit is left in the field. Samples were taken for analyses at intervals during the last three weeks of the ripening period.

Flowers of the Golden Beauty Casaba were tagged on July 24, 1927. This variety attains commercial maturity in about the same time as the Honey Dew, but its later stages of ripening proceed more slowly. Samples were taken of Casaba during the last five weeks of the ripening period.

Preparation of Samples.—Six melons of the same age, of about the same degree of maturity externally, but of somewhat varying sizes, were used for each sample. The number of fruits is considered sufficient to give reliable results in the measurement of the rather large differences between successive samples which were involved in most of this work.

A longitudinal segment was taken from each fruit, the seeds and placenta were removed, and a layer about one-eighth of an inch thick (including the rind) was pared from the outside and discarded. The flesh was ground in a food chopper, mixed well, and 300-gram samples were weighed out for sugar analysis. The samples were placed in large flasks at once, covered with 600 cc of hot 95 per cent alcohol, and boiled for 2 or 3 minutes. Calcium carbonate was added to the sugar samples. The samples were stored about 3 months before extraction.

Methods of Analysis.—Duplicate samples of the pulp were weighed out for determination of total solids. These were evaporated on the waterbath, then dried in the oven at 80° C. Three weeks or longer were required for the dried pulp to reach approximately constant weight. It is realized that there may be some loss of solids during this prolonged drying, so that the "total solids" reported may be a little low.

The juice was expressed from the remainder of the pulp for determination of specific gravity with the Brix spindle.

The sugars were completely extracted from the stored sample with 55 per cent alcohol. Starch and other hydrolyzable polysaccharides were determined on the residue, while the extract was used, after clarification with basic lead acetate, for reducing sugars and sucrose determination. The sucrose was inverted by digestion for about two hours with 1 cc of technical invertase (Wallerstein Laboratories, New York) to 100 cc of sugar solution. Sugars were determined by the combined Munson-Walker and Schaffer-Hartman methods. Reducing and total sugars are calculated as "invert sugars," and the difference between them $\times$ .95 is taken to be sucrose. Levulose was determined on the alcohol extract by the Nyn's method. The polysaccharides given in the last column of table 1 were determined after hydrolysis of the alcohol-insoluble residue with 5 per cent HCL.

Sugars in Cantaloupes.—An extensive study of the sugar content as determined on the juice of immature, half-slip, full-slip and field ripe cantaloupes has been reported by Chase, Church and Denny.[6] The differences reported by these workers between the foregoing classes of melons were not as great as when the melons were classed according to edibility. In general their data show more total sugars in high quality melons than in those of low quality. The soluble solids, as determined by the Brix spindle, were higher in the high quality melons. As a result of the latter work, Chase, Church and Denny were able to conclude that melons whose juice gave a Brix reading of 10 or above were likely to be of good quality, those between 9 and 10 were of doubtful quality, and those below 9 were of poor quality.

Table 1 gives the results obtained with the 1926 series of cantaloupes at Davis. The results here were obtained by analysis of the whole flesh, as described, rather than of the juice alone, as was done by Chase, Church and Denny. Marked correlation between the changes in the different constituents and the age of the fruit, is to be observed.

TABLE 1

CHANGES IN COMPOSITION OF CANTALOUPE MELONS DURING GROWTH AND RIPENING, IN PER CENT OF FRESH WEIGHT OF FLESH. HARVESTED JULY 23 TO AUGUST 10, 1926

Number of days after fruit-setting	Conditions of fruit	Total solids	Brix reading on juice	Reducing sugars	Levulose	Sucrose	Total sugar	Hydrolyzable polysaccharides
25	Inedible, flesh white	6.00	5.9	3.01	1.56	0.17	3.29	0.53
28	Inedible, flesh faint pink	7.25	7.1	3.40	1.84	0.83	4.27	0.51
31	Hard but distinctly sweet, flesh medium pink	9.70	9.3	3.31	1.77	2.74	6.19	0.50
34	Barely edible, flesh pink	9.82	9.6	3.10	1.77	3.21	6.48	0.48
37	Forced slip, edible, flesh pink	10.74	10.8	2.83	1.56	4.37	7.43	0.45
40	Half slip	12.19	11.5	2.43	1.21	5.52	8.24	0.32
43	Full slip	12.16	11.8	2.05	0.94	5.68	8.03	0.28

The cantaloupe fruit increases slightly in average weight and gains steadily in per cent of total solids throughout the latter part of the growth period, the maximum being reached at the half-slip stage. The increase in per cent of solids is primarily due to the increase in sugars and not to loss of water. At the 25-day stage, 52 per cent of the total solids consists of sugar, but at the half-slip stage they constitute 66 per cent of the total. The soluble solids in the juice as shown by the Brix reading show a fairly close agreement with the total sugar content of the flesh.

A marked change takes place in the form in which the sugars occur at different stages of maturity. Up to the time the fruit reaches the "barely edible" stage, at 34 days after setting, the per cent of reducing sugars remains about constant, but thereafter these sugars decrease until the fruit is fully ripe. On the other hand, the per cent of sucrose increases rapidly, from almost zero at the 25-day stage, until the fruit reaches the full-slip condition. Figure 1 shows the changes in composition of cantaloupes, in relation to the age of the fruit. The amount of total solids and total sugars increases in almost a straight-line graph, up to the half-slip stage on August 7, with little increase beyond that stage. The increase of sucrose is more rapid than that of the total sugars; it is largely through fresh accretions of sugar to the fruit during the latter part of its growth period, but judging from the storage experiments, to be presented later, sucrose also increases during ripening partly at the expense of the reducing sugars.

The changes in proportion of the different sugars are important from the standpoint of flavor. Beister, Wood and Wahlin[2], give the following ratings from the standpoint of sweetness: Sucrose, 100;

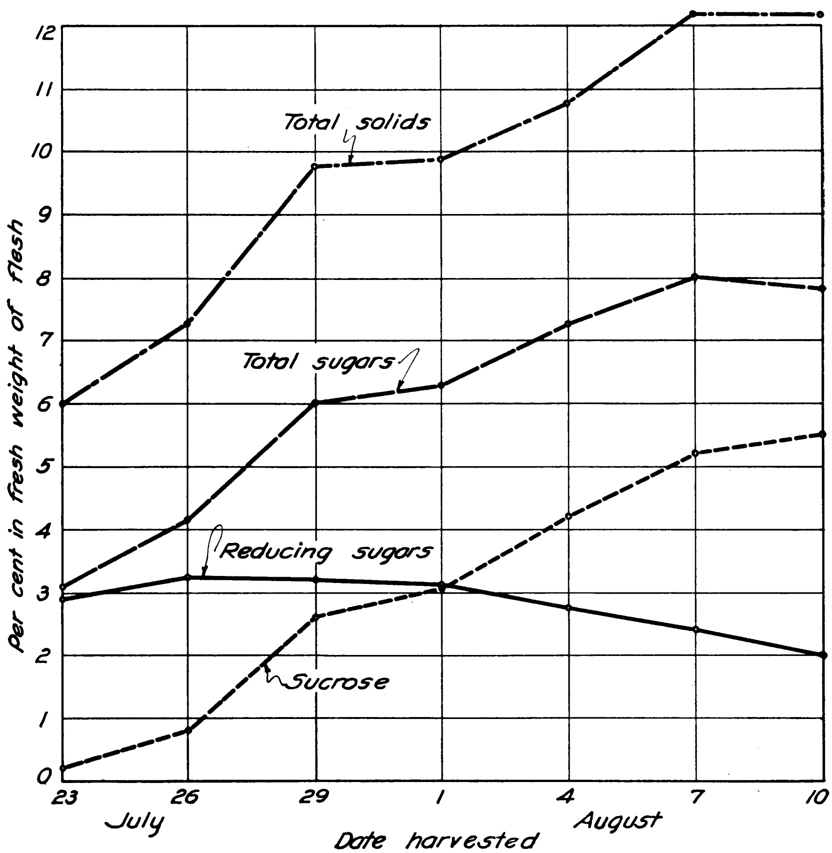

Fig. 1.—Content of sugars and solids in cantaloupe harvested at successive intervals after setting. (Compare with table 1.)

dextrose, 74; levulose, 173, and mixtures of equal parts dextrose and levulose, 130. Table 1 shows that about one-half of the reducing sugars in cantaloupes are levulose, the rest presumably being dextrose. The ratio of levulose to reducing sugars varies only slightly during ripening. Thus, while the fruit loses slightly in sweetness because of the loss of some levulose, it gains much more through the large increases in sucrose.

It was found that about half of the hydrolyzable polysaccharides consisted of starch (or dextrin) in the immature fruit, but that even this small amount of starch disappeared by the time the fruit approached ripeness. The balance probably consists of pectic substances. It is evident that the cantaloupe contains no extensive reserves of insoluble carbohydrates that might be expected to change to sugar after the fruit is picked.

Sugars in Other Melons.—The first sample of Honey Dew melons was picked September 3, which was 44 days after the fruit had set. While the fruits were approximately full grown at this time, the flesh was hard, and lacked sweetness and flavor. The rind was a glistening greenish white color. When the fruits were 5 days older, the appearance had not changed but the flesh was noticeably sweeter. On September 15, when the fruits were 56 days old, they were in a condition that might be termed "commercially mature." The rinds while still perfectly hard, were showing a slight tinge of yellow, and while the flesh was still too hard to be palatable, it was distinctly sweet and well flavored. Fruit harvested in this stage may be expected to ripen subsequently in storage, with resulting good quality. The last picking, at the age of 63 days, yielded fruit which was slightly soft and distinctly yellow externally, while the flesh was soft and juicy; the fruit was ready for immediate use.

The first sample of Casabas, picked August 29, or 38 days after the fruit set, was hard, green and inedible. Not until the fourth sampling, on September 15, when the fruit was 54 days old, was it ripe enough for commercial harvesting. At this time the rind was still perfectly hard, but it was turning yellow at the blossom end, whereas the whole surface was overspread with green in the earlier stages. The flesh, while still hard, was of fair flavor, and such fruit was found to be of excellent quality when picked and allowed to ripen in storage. The fruit picked at the two subsequent periods, on September 22 and October 6, showed progressive ripening changes. At the last date, the fruit was of light orange color over nearly the whole surface and was soft at the blossom end, while the flesh was soft, juicy, and ready for immediate use.

The watermelons used for analysis were of the Black Seeded Angeleno variety and the different samples with reference to maturity were selected on the basis of flesh color. The sample designated "ripe," was of fruit about 50 days old. Many individual fruit records show that watermelons of the Angeleno and Klondyke varieties attain good edible condition in from 45 to 50 days after the fruit sets. The portion of the watermelon fruit used for analysis was the heart flesh, inside of the seed cavities.

Table 2 gives the analyses of the three foregoing varieties of melons, harvested at different ages from time of fruit setting, and therefore in different stages of maturity.

TABLE 2

SOLIDS AND SUGAR CONTENT OF MELONS PICKED FROM THE PLANT AT SUCCESSIVE STAGES OF DEVELOPMENT. EXPRESSED IN PER CENT OF THE FRESH WEIGHT OF FLESH

Variety	Date picked	Quality	Total solids	Soluble solids*	Reducing sugars	Sucrose	Total sugars
HONEY DEW	Sept. 3	Hard, inedible	8.38	78.8	5.48	0.86	6.38
	Sept. 8	Hard, barely edible	10.67		4.38	4.53	9.15
	Sept. 15	Rind hard, flesh firm, edible	11.27	86.8	4.32	5.40	10.00
	Sept. 22	Soft, excellent eating quality	12.53	87.4	3.33	7.39	11.11
CASABA	Aug. 29	Green, hard, inedible	7.12	73.8	4.66	0.41	5.11
	Sept. 3	Rind hard, greenish. Flesh hard, inedible	7.45	74.4	4.58	0.78	5.40
	Sept. 8	Rind hard, greenish. Inner flesh barely edible	8.27	79.7	4.32	1.94	6.36
	Sept. 15	Rind hard, partly yellow. Flesh hard, edible	8.90	82.4	4.10	3.13	7.40
	Sept. 22	Rind hard, mostly yellow. Flesh firm, fairly edible	9.55	82.2	3.97	4.17	8.36
	Oct. 6	Rind hard, light orange. Flesh soft, juicy, sweet	10.81	84.1	2.76	6.24	9.32
WATERMELON	Very immature	Flesh yellowish	6.05	90.6	5.30	0.21	5.58
	Immature	Flesh pale pink	7.51	93.7	5.60	1.30	6.97
	Ripe	Flesh red, firm	8.65	93.3	3.78	3.91	7.89
	Overripe	Flesh red, mealy	8.69	92.4	2.90	4.85	8.00

* As per cent of total solids.

The three kinds of melons discussed in table 2 show similar changes during maturation while the fruit remains attached to the plant. The total solids (per cent of dry matter) increases steadily, throughout the period under consideration. However, the proportion of these solids occurring in soluble form also increases, which is one reason for the apparent increase in juiciness as the fruit ripens. Soluble solids are lowest at all stages in the Casaba, and are highest in the watermelons. The soluble solids given in table 2 represent that portion of the fruit's solids which were dissolved in 55 per cent alcohol and consist mainly of the various sugars.

The reducing sugars, about constant in amount during the late growth phase, decrease rapidly as ripening commences, in these three types of melons. Levulose was determined only on the Honey Dew melons and is not included in the table. It constitutes about one-half of the reducing sugars throughout the whole series, as was the case in

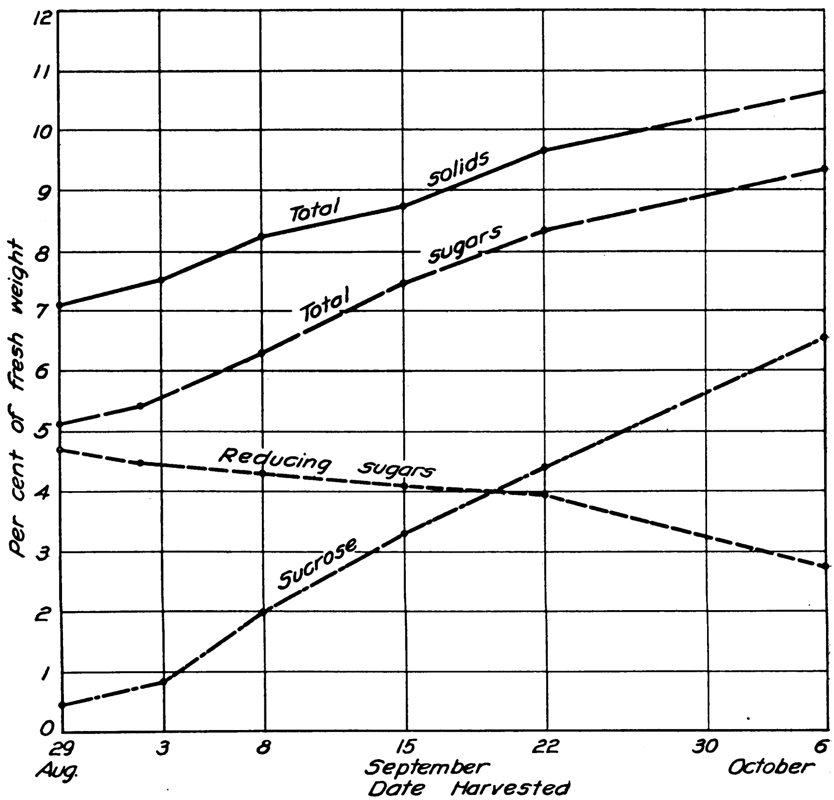

Fig. 2.—Changes in the amount of sugars and solids in Casaba melons, in fruit picked at different ages. (Compare with table 2.)

cantaloupes. Sucrose increases rapidly, from practically none in immature fruit, until it constitutes well over two-thirds of the total sugar content in ripe fruit. The total sugar also increases, although at a more moderate rate, throughout the late-growth and maturation phases of the fruit. Maximum sugar content is not reached until the fruit is in the stage fit for immediate consumption. Fig. 2 shows the changes in sugar content, in relation to age of the fruit, in the Casaba melon.

Pectic Substances.—Investigations on various fruits have indicated that there are three main classes of pectic substances. They are associated with, or are component parts of, the cell walls, and are therefore of special interest in changes involving the softening of fruit. Three classes of pectic substances are considered to be as follows: (1) Pectin, a water-soluble substance which develops during ripening. (2) Protopectin (pectose), an insoluble cell-wall substance which is thought to be changed to pectin during the ripening process. (3) a complex containing pectic acid or a salt of pectic acid, which partially or entirely constitutes the middle lamella, between the cell walls.

By microchemical methods, Carré and Horne[5] demonstrated that in apples the cellulose of the cell wall is intimately associated with protopectin and that the middle lamella is a kind of cement, of a complex containing pectic acid or pectates. They also found numerous globules of a pectic substance accumulating on the walls in the intercellular spaces during the late stages of storage, when the fruit was nearing the final breakdown. These authors concluded that in apples during storage the insoluble protopectin of the cell wall does break down to a soluble form—pectin, which in turn changes to simpler decomposition products. Furthermore, in the later part of the storage period, the pectic acid of the middle lamella is gradually dissolved. They suggest that decomposition of the pectic materials in the cell wall facilitates the outward movement of water, hence the shriveled or wilted condition that often develops in stored fruits.

In melons, which were probably of the cantaloupe type, Mangin states that the cells of the fruit-flesh are held together by short cylindrical connections of pectic substance, which gradually disintegrate, with resultant separation of the cells. Globules of a soluble pectic substance appeared in the intercellular spaces as a result of the disintegration of the cell wall connections.

From the above, it seems that pectic materials are of importance in determining the rigidity of the cell wall, as well as in the cohesion of the cells to each other. The changes which may take place in these materials during ripening and during storage under different conditions, are important in relation to the changes which make the fruit soft, juicy and palatable, and which determine the limits of shipment and storage.

Methods of Determining Pectic Substances.—The pectin, pectic acid and protopectin were determined according to the Carré and Haynes[4] calcium pectate method, with the improvements suggested by Conrad.[7] Samples of 100 grams of freshly ground fruit pulp were placed in flasks, covered with 300 cc of hot 95 per cent alcohol, and heated to the boiling point. Later, the alcohol was filtered off, and the residue washed with more alcohol to remove most of the remaining sugars. After draining thoroughly, practically all of the alcohol was removed by pressing the residue between filter papers. The residue was then ground with sand (several duplicate determinations at this point showed no difference in results if the sample was oven-dried before the water extraction). Seven or eight successive extractions were made with distilled water, bringing the aqueous extract up to 500 cc. Further extractions usually yielded no trace of soluble pectin.

Either 50 or 100 cc aliquot portions of the water extract were used for the determination of water-soluble pectic acid by precipitation as calcium pectate, the $CaCl_2$ solution being added directly to the water extract for this purpose. Similar aliquots were used for determination of the total soluble pectic substances, after hydrolysis with N/1 NaOH. The difference in yield of calcium pectate before and after hydrolysis is taken to be "pectin," though the calcium pectate values have not been multiplied by any factor to convert them to equivalent pectin values, since the true relationship is not exactly known.

The insoluble residue, after the water extraction, was hydrolyzed with HCl, neutralized, extracted with ammonium citrate, and used for determination of insoluble pectic acid and protopectin, as directed by Conrad. It should be pointed out that pectic acid is partly soluble, at least under certain conditions, hence part of it may be obtained in the water extract, part in the residue. This has been overlooked by previous workers, who have considered only the pectic acid in the residue. Conrad(7) and Appleman and Conrad(1) have questioned the common occurrence of pectic acid or its salts in plant tissues, though they examined only the insoluble residue for its occurrence. However, pectic acid was obtained in many samples in the present work both in the water extracts and in the insoluble portion, especially of the cantaloupe. It is an open question if it occurred as such in the fruit tissues, or was formed during preparation of the samples.

Parallel determinations were made on a large number of samples, using the water extract of freshly ground pulp without killing in hot alcohol, for the determination of soluble pectic substances, as was done by Appleman and Conrad(1) in their work on peaches. The samples handled in this way gave about the same as, or somewhat higher results than, the duplicates preserved in alcohol, so far as total content of pectic substances is concerned. But the distribution of the pectic constituents by classes was often different by the two methods. Water-extract of fresh pulp gave a higher yield of soluble pectic acid, while the pectin was usually higher in the extract of pulp killed in alcohol. Also the former samples gave a higher proportion of protopectin to pectic acid in the insoluble fractions, than the latter. The use of fresh materials was finally discarded because it was felt that results obtained by this method were open to question on three points: (1) Greater opportunity for enzyme activity to change the form of the pectic constituents in the ground pulp; (2) interference by the presence of other fruit acids that might form insoluble calcium salts; (3) interference by the large amount of sugars present in the water extract of pulp that had not previously been extracted with alcohol. All results reported in this paper were obtained on samples killed and extracted with alcohol.

TABLE 3

PECTIC SUBSTANCES IN CANTALOUPES AT DIFFERENT STAGES OF RIPENING AND AFTER STORAGE. RESULTS IN PER CENT OF FRESH WEIGHT

Condition of the fruit	Water soluble		Insoluble		Total	Per cent soluble
	Pectin	Pectic acid	Pectic acid	Proto-pectin		
Picked before stem slipped	0.024	0.098	0.054	0.154	0.330	36.9
Picked on half slip	0.056	0.124	0.077	0.085	0.342	52.7
Picked field ripe	0.059	0.133	0.134	0.010	0.336	57.1
Before slip and 7 days storage at 72° F	0.058	0.118	0.136	0.012	0.320	55.0
Half slip and 7 days storage at 72° F	0.000	0.183	0.113	0.008	0.304	60.2

Pectic Substances in Cantaloupes.—Fruits of the Salmon Tint variety were gathered in three stages of maturity on the same day, and sampled immediately for analysis. The following classes of fruit were selected: (1) Those that were full grown, but with no evidence of abscission; the flesh was fully colored and sweet, but too hard to be palatable. (2) Fruit in which the abscission from the stem was begun, but in which the rind was still green; the flesh was still firm but more edible than in (1). (3) Fruit that was "field ripe," i.e., the abscission was complete, the rind yellow, and the flesh soft and juicy. Fruits of the two under-ripe classes were stored at ordinary temperature in a cellar for one week, then sampled for analysis.

After storage, they were as yellow and soft as field-ripened melons; the flesh of those picked before stem-abscission, was now soft, juicy and of fair flavor, while that of the half-slip lot was very soft and slightly overripe. The content of the pectic constituents of the above five lots of fruit is given in table 3. The figures in the table are in terms of calcium pectate, as determined for each constituent.

The total amount of pectic materials in the cantaloupe fruit remains about constant during ripening on the plant, with a slight loss during ripening in storage. There is a very marked change in the form of these materials, however. Protopectin, the insoluble cell wall substance, decreases to almost zero during ripening, both in the field and in the cellar-stored fruit. Conversely, there is a marked increase in the water-soluble fraction, both of pectin and pectic acid. There is also a great increase of the pectic acid in the insoluble fraction. These data bear out the theory that the softening of the fruit is associated with the change of the protopectin of the cell wall, to pectin and pectic acid. In the case of the cantaloupe, it appears that pectic acid constitutes the greater portion of the degradation products of protopectin formed during ripening.

Pectic Substances in Other Melons.—Honey Dews, Casabas and watermelons picked in different stages of maturity, were analyzed for their pectic constituents. A description of these samples is given in the earlier part of this bulletin. The water extract of these three kinds of melons never gave more than a trace of water-soluble pectic acid, either on the extract of fresh pulp, or of pulp killed and extracted with alcohol first. Pectic acid and protopectin were determined separately in the insoluble residue and while the actual amount of pectic acid did not always increase with ripening, the proportion of the pectic acid to protopectin generally did increase, though the change was not regular. Therefore it will avoid confusion to consider the pectic constituents of these melons as simply of two classes, the water-soluble pectin, and the water-insoluble pectic substances (pectic acid and protopectin), in the tables.

Table 4 shows that the total pectic content of Honey Dews and Casabas decreases slightly as the fruit becomes riper, thus agreeing with the results obtained by Carré[3] on apples and by Appleman and Conrad[1] on peaches. The total pectic content of watermelons is very much lower than in other kinds of melons, and no well-marked changes in the pectic constituents of the watermelon during ripening are apparent. In the Honey Dew and Casaba varieties, there is a regular and considerable increase in the soluble pectin content, at the expense of the insoluble fraction, as the fruit becomes riper and its flesh becomes softer and more palatable. This change is shown in the last column of table 4, which gives the per cent of the total pectic constituents which were in water-soluble form. There was about three times as much pectin in the ripe fruit, at the last sampling, as in the hard immature fruit at the first sampling.

TABLE 4

THE PECTIC SUBSTANCES OF MELONS DURING RIPENING ON THE PLANT, EXPRESSED AS PER CENT OF THE FRESH WEIGHT OF THE FLESH

Sample	Quality	Pectin	Insoluble pectic substances	Total	Per cent soluble
HONEY DEW					
Picked Aug. 29	Inedible	.055	.253	.308	17.9
Picked Sept. 3	Inedible	.065	.238	.303	21.5
Picked Sept. 8	Inedible	.078	.155	.233	33.5
Picked Sept. 15	Firm, edible	.101	.128	.229	44.1
Picked Sept. 22	Soft, edible	.130	.106	.235	55.3
CASABA					
Picked Aug. 29	Hard, inedible	.049	.281	.330	14.8
Picked Sept. 3	Hard, inedible	.050	.289	.339	14.7
Picked Sept. 8	Barely edible	.102	.199	.301	33.9
Picked Sept. 15	Barely edible	.122	.175	.297	41.1
Picked Sept. 22	Firm, edible	.137	.134	.271	50.6
Picked Oct. 6	Soft, juicy	.152	.138	.290	52.4
WATERMELON					
Picked very immature		.024	.064	.088	27.3
Picked immature		.012	.072	.084	14.3
Picked ripe		.017	.081	.098	17.3
Picked overripe		.017	.070	.087	19.5

CHANGES DURING STORAGE IN FRUIT HARVESTED IMMATURE

From the practical point of view, the nature of the changes occurring in fruit after removal from the plant are of great importance, for they determine the edibility and marketability of the fruit after its long journey from field to consuming center. Knowledge of the probable course of changes within the fruit when it is harvested immature is especially significant, because under present commercial practices most of the melons shipped to market are harvested before full ripeness is attained. It is generally recognized that shipping quality and eating quality are more or less opposed. The work which has been done here is intended to show how far one of these qualities can be attained without sacrificing the other. Because of the importance of oxidation in ripening processes of fruit, it was considered advisable to test treatments which prevent access of air to the fruit flesh. Oiling was one treatment of this kind which was tried. The fruit which was oiled received a light coat of Frutol (Standard Oil Co.), before placing in storage. This is a clear, colorless mineral oil. It did not appear to penetrate into the flesh.

Sugars in Cantaloupes During Storage.—Fruit picked on the half-slip was stored at 38°F for ten days, then for three days in a cellar at 72°F. During the cold storage period, there was no softening, the flesh remaining firm and sweet, but softening occurred during the subsequent period at higher temperature. The rind, green at first, yellowed somewhat during cold storage. The oiled fruits were of good edibility when removed from cold storage, but at the end of three days at the higher temperature they developed a slightly strong or sour flavor. Oiled fruits stored at 73°F for a week, without previous cold storage, developed this undesirable flavor to a marked degree. It may be ascribed to the accumulation of the products of incomplete respiration, owing to the reduction in gas exchange by the oil coating. Table 5 gives the sugar content of the fruit before and after storage in this experiment.

TABLE 5

SUGAR CONTENT AFTER STORAGE, OF CANTALOUPES PICKED AT HALF SLIP. EXPRESSED IN PER CENT OF THE FRESH WEIGHT

Treatment	Condition of fruit	Total solids	Brix reading on juice	Reducing sugars	Sucrose	Total sugar	Hydrolyzable polysaccharides
At time of picking		12.19	11.5	2.43	5.52	8.24	0.32
Stored 10 days at 38° F	Firm, sweet, good	11.10	11.2	2.47	5.20	7.88	0.27
Same, after 3 days at 72° F	Slightly soft, overripe	10.84	11.8	2.53	4.61	7.38	0.24
Oiled, stored 10 days at 38° F.	Firm, sweet, good	11.15	11.5	2.57	5.07	7.91	0.26
Same, after 3 days at 73° F	Firm, abnormal taste	11.30	11.3	2.70	5.60	8.51	0.24

The total sugar content apparently decreases slightly during cold storage, and in the untreated melons it decreases still more after removal to higher temperature. The latter change is much reduced in the oiled melons, probably because the utilization of sugars in respiration is retarded by the oil coating. The ratio of reducing sugars to sucrose remains about the same in the stored fruit. Thus, there can be no improvement in sugar content or in sweetness of cantaloupes picked immature, during storage or shipment. These results agree with those obtained on cantaloupes by Chase, Church and Denny.[6] Softening and loss of sugar by respiration are reduced by either cold storage or by oiling the surface of the fruit, but treatments of the latter type are likely to result in a product of undesirable flavor, in spite of the higher sugar content.

TABLE 6

CHANGES IN SOLIDS AND IN SUGAR CONTENT OF MELONS DURING STORAGE AT 20°–22°C. EXPRESSED AS PER CENT OF FRESH WEIGHT OF FLESH

Treatment	Quality	Total solids	Soluble solids	Reducing sugar	Sucrose	Total sugar
HONEY DEW (Series A)						
Picked Sept. 3	Hard, inedible	8.38	78.8	5.48	0.86	6.38
In ethylene 5 days	Rind yellowish, flesh soft, juicy	8.31	84.3	3.62	3.25	7.00
Cellar 5 days	Rind greenish, hard, flesh hard, inedible	8.12	82.4	4.87	1.71	6.60
Ethylene 5 days and cellar 7 days	Rind full yellow, flesh soft, juicy	8.49	85.6	2.93	4.06	7.20
Cellar 12 days	Rind greenish, hard, flesh firm, barely edible	7.76	79.4	3.95	2.18	6.20
Ethylene 5 days and cellar 14 days	Rind yellow, soft, flesh soft, overripe	8.16	81.9	2.66	3.80	6.60
Cellar 19 days	Rind greenish, hard, flesh edible, insipid	7.40	81.7	4.01	2.06	6.10
CASABA (Series B)						
Picked Sept. 3	Rind greenish, inedible	7.45	74.4	4.58	0.78	5.40
Ethylene 5 days	Rind bright yellow, flesh soft, edible	7.41	76.7	3.62	1.84	5.56
Cellar 5 days	Rind greenish, hard, flesh firm, barely edible	7.46	74.9	4.58	0.79	5.41
Ethylene 5 days and cellar 7 days	Rind yellow, soft, flesh mushy, insipid	6.72	71.8	2.82	1.41	4.30
Cellar 12 days	Rind partly yellow, flesh firm, barely edible	6.92	71.0	3.93	0.90	4.88
Cellar 19 days	Rind partly yellow, flesh slightly soft	6.69	72.9	3.78	1.00	4.83
Cellar 32 days	Rind pale yellow, flesh firm, edible	5.52	70.1	3.10	0.68	3.82
CASABA (series C)						
Picked Sept. 26	Rind partly yellow, flesh firm, barely edible	8.56	81.7	4.01	3.37	7.56
Ethylene 2½ days	Rind orange-yellow, flesh soft, juicy, good	8.70	81.0	3.18	3.87	7.26
Cellar 2½ days	Rind partly yellow, flesh firm, barely edible	9.15	83.1	3.23	4.21	7.66
Ethylene 2½ days and cellar 7½ days	Rind deep orange, flesh soft, overripe	8.58	77.9	2.37	4.44	7.05
Cellar 10 days	Rind mostly yellow, slightly soft, good	8.84	78.8	3.12	3.66	6.97

Sugars in Other Melons During Storage.—Honey Dew and Casaba melons were harvested on September 3, the fruit being respectively 54 and 51 days old from date of setting. The fruit was hard and the flesh inedible at this time. It was realized that the sugar content was probably much lower than it would be in normally ripened fruit, but it was thought advisable to study the changes during storage, of fruit that was picked unripe. The storage was in a cellar at 70° to 75°F. Since ethylene has been found to have a marked effect upon ripening processes of some other fruits, certain of the stored lots of melons were treated with this substance. The fruits of each variety were divided into two lots, and one lot was placed in a special chamber to which ethylene gas was added once each day for 5 days. After this period the ethylene-treated fruit was stored in the same room as the untreated. The concentration of ethylene used was 1 part to 2000 of air. The room was ventilated each day before adding the new charge of gas. Samples were taken for analysis from both treated and untreated fruit at the end of the 5-day period, and at intervals of 7 days thereafter. The changes in sugar content and in the color and texture of the fruit is given in table 6.

In the Honey Dews and in the Casabas of Series B, after 5 days' treatment with ethylene, the green color of the rind had completely disappeared, the former becoming creamy yellow and the latter bright yellow in color. At this time, the untreated fruits were about as green as when harvested. The flesh of the treated fruit was much softer than when picked, and could be classed as edible, although lacking in sweetness and flavor. The flesh of untreated fruit was still hard.

At the time of the later samplings, ethylene-treated fruit showed progressive softening, but with little improvement in flavor. They finally became so soft that the Honey Dews were classed as overripe 14 days after removal from the ethylene chamber, while the Casabas were overripe after 7 days. The untreated fruits remained firm a much longer time and though the changes in color and texture noted in the ethylene-treated fruit occurred in the untreated also, the changes were very much slower in the latter.

With regard to total sugar content, the samples taken at the 5- and 12-day periods after harvest show about the same amount as the freshly picked fruit. Samples taken still later show a marked decrease in the amount of total sugars, due no doubt to losses by respiration. There is a decrease in reducing sugars and corresponding increase in sucrose during storage of the Honey Dew and Casaba melons picked unripe, however. This change in form of sugar was also found to characterize the ripening process of fruits attached to the plant. The data also show that the change of reducing sugars to sucrose was much more rapid, and greater in amount, in the fruit of both varieties which was treated with ethylene, than in untreated fruit. This change may cause a somewhat sweeter taste in ethylene-treated melons.

Attention should now be called to the Casabas of Series C, in table 6. These were commercially picked fruits that from external appearances were about the same as the 53-day old fruit picked September 15 and discussed in table 2. In other words, these melons were in the stage considered "commercially mature" and suitable for shipment, though the rind was still hard and the flesh too firm to be palatable. Fruit of this series treated with ethylene at the rate of one part to 4000 of air, for 2½ days, was fully colored, with soft, juicy flesh of good eating quality. These melons had 40 per cent more sugar than those used in Series B, and this factor together with the rapid change in color and texture caused by the ethylene, gave them good eating quality. The fruit harvested at the same time, but untreated, also developed a high degree of edibility after 10 days' storage.

TABLE 7

PECTIC SUBSTANCES OF MELONS DURING STORAGE, EXPRESSED IN PERCENTAGE OF THE FRESH WEIGHT

Variety and treatment	Quality	Pectin	Insoluble pectic substances	Total	Per cent soluble
HONEY DEW (Series A)					
Picked Sept. 3	Hard, inedible	0.065	0.238	0.303	21.5
Ethylene 5 days	Soft, juicy	0.141	0.115	0.256	55.1
Cellar 5 days	Hard, inedible	0.067	0.202	0.269	24.9
Ethylene 5 days and cellar 7 days	Soft, juicy, fair flavor	0.175	0.075	0.250	70.0
Cellar 12 days	Firm, barely edible	0.114	0.146	0.260	43.8
Ethylene 5 days and cellar 14 days	Overripe	0.149	0.118	0.267	55.8
Cellar 19 days	Firm, edible	0.107	0.139	0.246	43.5
CASABA (Series B)					
Picked Sept. 3	Hard, inedible	0.050	0.289	0.339	14.7
Ethylene 5 days	Soft, edible	0.152	0.109	0.261	58.2
Cellar 5 days	Firm, barely edible	0.128	0.214	0.342	37.4
Ethylene 5 days and cellar 7 days	Mushy, insipid	0.123	0.194	0.317	38.8
Cellar 12 days	Firm, barely edible	0.128	0.177	0.305	42.0
Cellar 19 days	Slightly soft	0.148	0.176	0.324	45.7
CASABA (Series C)					
Picked Sept. 26	Firm, barely edible	0.105	0.162	0.267	39.3
Ethylene 2½ days	Soft, juicy	0.190	0.110	0.300	63.3
Cellar 2½ days	Firm, barely edible	0.120	0.135	0.255	47.0
Ethylene 2½ days and cellar 7½ days	Soft, overripe	0.196	0.093	0.289	67.8
Cellar 10 days	Slightly soft, good	0.143	0.127	0.270	53.0

Pectic Substances During Storage.—Samples from the same melons described in table 6 were also used for determination of pectic constituents, and the results are given in table 7. Here again the results are given in terms of "pectin" in the water-soluble portion, and "insoluble pectic substances," the pectic acid and protopectin of the insoluble part of the sample.

During storage, fruit picked immature loses the green pigment of the rind, and the flesh becomes progressively softer and more juicy. It is seen from table 7 that the total of the pectic substances decreases slightly during storage, and that the pectin increases markedly at the expense of the insoluble fraction. The change to pectin from protopectin is in all cases much more marked in the fruit treated with ethylene than in the untreated. The rate and amount of this change appears to parallel the degree of softening of the fruit-flesh.

DISCUSSION OF THE EFFECTS OF ETHYLENE GAS

Tables 6 and 7 showed certain differences in the composition during storage of melons treated with ethylene and those untreated. Comparing fruit which had been in storage for the same number of days, ethylene treatment hastened removal of green pigment from the rind, and caused the flesh to become softer and more juicy. Ethylene also affected the normal rate of change in form of sugar and pectic substances. The course of these changes is shown in figures 3 and 4, for the fruit which was picked September 3, in a decidedly immature condition.

Figure 3 shows that the amount of total sugars may increase slightly during the first few days of storage, but remains nearly constant for the remainder of the storage period, with a slight tendency downward. The per cent of sucrose, however, increases markedly during storage, and this increase is more rapid and greater in final amount, in ethylene-treated fruit. The divergence of the curves for sucrose is most marked during the first period of 5 days during which the fruit was actually exposed to ethylene. In the next period, of 7 days, the increase of sucrose continues, but at a reduced rate, in both treated and non-treated fruit. The effect of the ethylene on conversion of reducing sugars to sucrose, seems to carry over beyond the period during which the fruit is actually exposed to the gas.

Figure 4 shows that while the total amount of pectic substances in the fruit decreases gradually during storage, the amount occurring in soluble form, as pectin, increases. As with sucrose, the increase in pectin is much greater in the early part of the storage period, when the fruit is treated with ethylene.

Since the change of protopectin to pectin in the fruit is supposedly due to the activity of the enzyme proto-pectinase, it is probable that the influence of ethylene upon this change in form of pectic materials, and upon the softening of the fruit, is due to the increased activation of this enzyme.

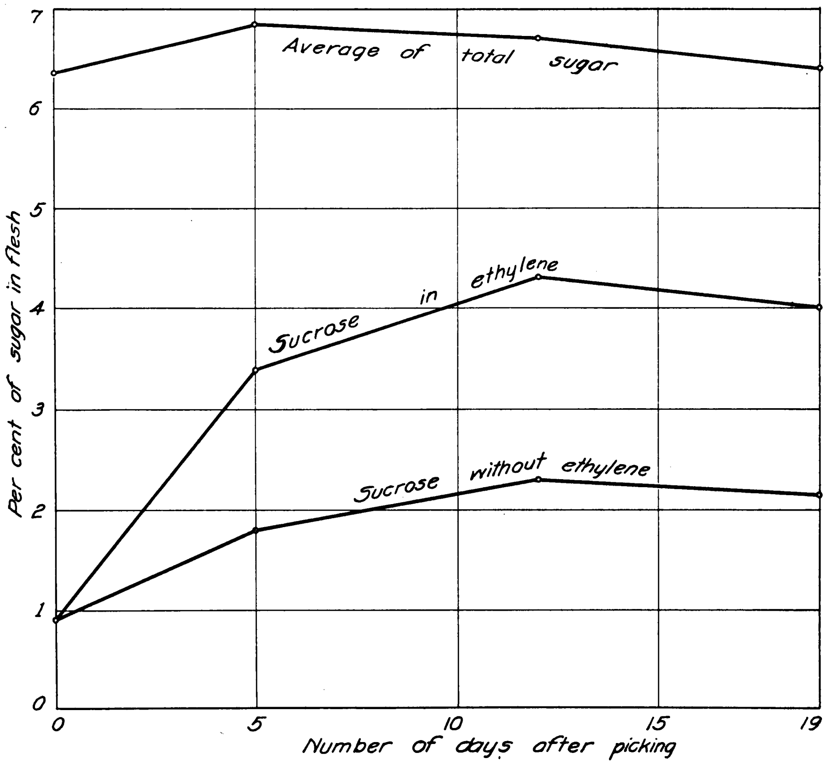

Fig. 3.—Sucrose content in Honey Dew melons during storage at 72°F, with and without 5 days ethylene treatment, compared to the average amount of total sugars in the two lots. (Compare with table 6.)

So far as the commercial utilization of ethylene on melons is concerned, it appears that it may well be used to hasten the softening, and to improve the edibility of melons picked in the commercially-mature stage, when these fruits are desired for immediate consumption. This means that its use will be limited to the grower who sells on local markets, rather than to the shipper. It is possible, too, that the receiver of California melons in eastern markets, can make use of the treatment, when the fruit arrives at destination in too green and hard condition for immediate use. The use of ethylene will also be limited to Honey Dews and Casabas; there is no object in treating cantaloupes, for the types of changes accelerated by ethylene occur so rapidly in cantaloupes naturally, that nothing is to be gained by treating them. It should also be emphasized that while melons picked very immature may be softened, they are not given good edible quality by the ethylene treatment.

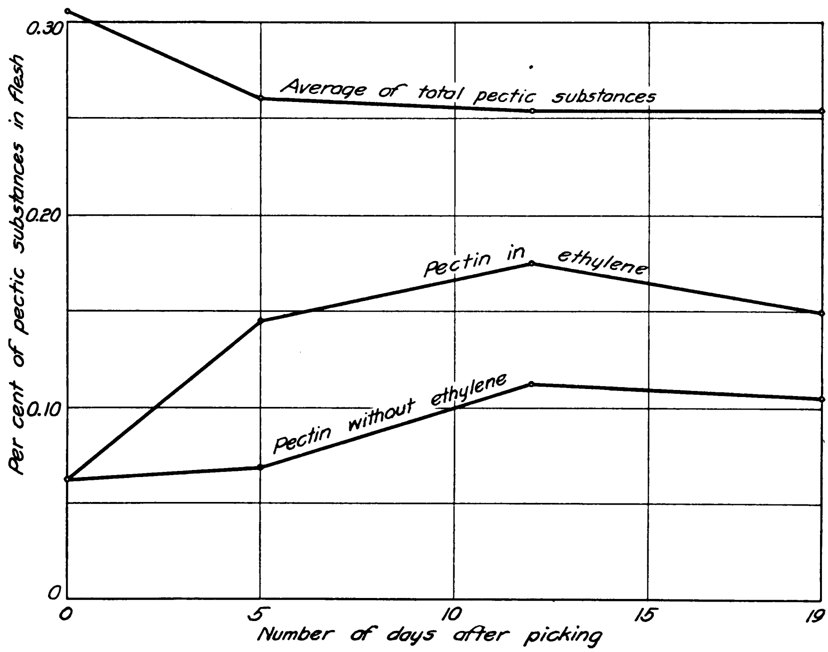

Fig. 4.—Changes in pectic substances in Honey Dew melons during storage, showing the relative increases in amount of pectin in fruit without ethylene and with 5 days ethylene treatment. (Compare with table 7.)

SUMMARY AND CONCLUSIONS

The late stages of development and the ripening process in cantaloupes, Honey Dews, Casabas, and watermelons, are characterized by the following changes when the fruits remain attached to the plant:

1. Progressive increase in per cent of total solids (dry matter), in total sugar content, in soluble solids, and in specific gravity of the juice.

2. Reducing sugars, which consist of approximately equal proportions of levulose and dextrose, decrease in amount during ripening, being partly used in respiration, and partly changed to sucrose.

3. Sucrose increases more rapidly than reducing sugars decrease, showing that sugars are moving into the fruit until the full-ripe stage is reached.

4. The total amount of pectic substances remains about the same, but the amount of protopectin, high in unripe melons, decreases rapidly during ripening, with a corresponding increase of pectin and probably also of pectic acid. The proportion of pectic substances in soluble form increases during ripening, suggesting that partial disintegration of cell walls is an important part of the ripening process.

5. The flesh becomes progressively sweeter and softer, and the rind turns from green to yellow.

Fruits which are picked from the plants in the immature condition show the following changes during the storage at ordinary temperatures (70°–75°F):

1. Little or no increase in sugar content, in the early part of the storage period, and generally a small decrease in sugars, during the latter part of storage, due to the losses occasioned by respiration.

2. Honey Dews and Casabas, during storage show the same change in form of sugars as do fruits attached to the plant, i.e., decrease in reducing sugar and increase in sucrose.

3. The total content of pectic substances decreases slightly, and protopectin is changed to pectin, just as in fruit attached to the plant.

4. The flesh becomes softer, but does not gain appreciably in sweetness, hence melons picked very immature, while the sugar content is low, upon artificial ripening become soft and to some extent juicy, but do not attain good flavor because of the lack of sugar.

Fruits of Honey Dew and Casaba picked slightly unripe and exposed to ethylene at the rate of 1 part to 2000 of air, or 1 part to 4000 of air, for 2 to 5 days, show no increase in sugar content, but do show a marked acceleration in the rate of softening, in change from green to yellow color of the rind, and in conversion of reducing sugars to sucrose, compared to similar fruit stored without ethylene treatment. These changes do not result in palatable quality, if the fruit is picked so immature that its sugar content is low. But if the fruit is in the stage described in this paper as ''commercially mature,'' the treatment results in good eating quality in a much shorter time than is the case with fruit of the same stage of maturity not treated with ethylene.

The effects of ethylene upon the ripening process are believed to be due to activation of enzymatic reactions, and hence bring about changes in a short time that would ordinarily require a longer period for their accomplishment.

Pectic acid was found in the water extract of cantaloupes but not in that of Honey Dews or Casabas. Its occurrence in the cantaloupe only, may be due to the presence of an enzyme (pectase) in large amounts in that variety, resulting in rapid conversion of pectin to pectic acid during ripening or during the process of preparing the samples. This, together with the observed slower rate of ripening in storage of the Honey Dews and Casaba, suggest that these varieties differ markedly from cantaloupes in their enzyme activity, especially with regard to protopectin and pectin-hydrolyzing enzymes. With this difference in enzyme activity, it is possible that long-keeping varieties of cantaloupes can be developed by the plant breeder.

Both pectic acid and protopectin were found in the insoluble residue of the four kinds of melons examined. However, the relation of these substances to each other was not constant, and did not show a consistent relation to the ripening process.

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The titles of the Technical Papers of the California Agricultural Experiment Station, Nos. 1 to 20, which HILGARDIA replaces, and copies of which may be had on application to the Publication Secretary, Agricultural Experiment Station, Berkeley, are as follows:

1. The Removal of Sodium Carbonate from Soils, by Walter P. Kelley and Edward E. Thomas. January, 1923.
3. The Formation of Sodium Carbonate in Soils, by Arthur B. Cummins and Walter P. Kelley. March, 1923.
4. Effect of Sodium Chlorid and Calcium Chlorid upon the Growth and Composition of Young Orange Trees, by H. S. Reed and A. R. C. Haas. April, 1923.
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