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EFFECT OF TEMPERATURE ON THE RESISTANCE TO WOUNDING OF CERTAIN SMALL FRUITS AND CHERRIES.[1]

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EXPERIMENTAL WORK.

Precooling, that is, cooling down rapidly to a refrigerating temperature either before or immediately after fruit is placed in cars for shipment, has resulted in appreciable savings in the shipment of perishable fruits.

Powell[2] has shown that the precooling of oranges rendered them less susceptible to decay. He has also shown that fruit even slightly injured is much more liable to fungous infection and decay than sound fruit.

Ramsey[3] comes to much the same conclusion as regards the shipment of red raspberries from the Puyallup Valley.

Stevens and Wilcox,[4] working with strawberries, showed that *Rhizopus nigricans* Ehrenb., which causes much of the decay of this fruit in transit, could not infect unwounded berries and that less infection occurred when the berries were properly cooled and refrigerated until they reached the market.

[1] This bulletin gives the result of a portion of the work carried on under the project "Factors Affecting the Storage Life of Fruits."

[2] Powell et al. The decay of oranges while in transit from California. U. S. Dept. Agr., Bur. Plant Indus. Bul. 123, 79 p., illus. 1908.

[3] Ramsey, H. J. Factors governing the successful shipment of red raspberries from the Puyallup Valley. U. S. Dept. Agr. Bul. 274, 37 p., illus. 1915.

[4] Stevens, Neil E., and Wilcox, R. B. Rhizopus rot of strawberries in transit. U. S. Dept. Agr. Bul. 531, 22 p. Literature cited, p. 21-22. 1917.

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Ridley[1] shows that careful picking and handling, together with the prompt and thorough cooling of strawberries, reduce losses in transit.

Stevens and Wilcox[2] in a later paper showed that picking the fruit in the cool of the day decreased the losses from decay. They also found that washing strawberries picked during the hottest part of the day resulted in less loss from leak caused by *Rhizopus nigricans* than when the fruit was shipped without washing. This was considered to be due to the fact that the berries were cooled by the evaporation of the water from the surface. These writers state that "berries picked in the early morning are cool and less likely to decay than those picked in the heat of the day."

From these investigations it is evident that uninjured fruits are not so liable to decay from fungous infection as those which are injured and that fruit cooled as soon as possible after harvesting or picked when cool is less likely to become infected.

DESCRIPTION OF THE METHOD EMPLOYED.

The present investigation was undertaken to see whether small fruits when cooled were less liable to injury than if picked or handled when they are warm. The small fruits used in the experiment were black raspberries, red raspberries, blackberries, and strawberries. Cherries were also used. Most of the fruit was obtained from Arlington Farm, but for a part of it the writers are indebted to the horticultural department of the Maryland State Agricultural College.

The resistance of the epidermis of the fruit to wounding was determined by means of an apparatus which had been used in measuring the pressure required to puncture the tissue of potatoes.[3] (Fig. 1.) This apparatus consisted of a modified Joly balance. To the lower end of the spring of this balance was attached a metal rod which passed through a short glass tube attached to the upright stand of the instrument. Hair lines on both the tube and rod made it possible to determine the point at which tension on the spring balanced a given weight. At the end of this metal rod a glass rod was attached, to which was cemented a small glass needle with rounded end. The weight of the rod and needle was, of course, within the capacity of the spring. In operating this apparatus the fruit was placed on the stand of the instrument in a suitable holder and the stand was so adjusted that the surface of the fruit was just in contact with the tip of the needle when the two hair lines coincided. The tension on

[1] Ridley, V. W. Factors in transportation of strawberries from the Ozark region. U. S. Dept. Agr., Bur. Markets Doc. 8, 10 p. 6 fig. 1918.

[2] Stevens, Neil E., and Wilcox, R. B. Further studies of the rots of strawberry fruits. U. S. Dept. Agr. Bul. 686, 14 p. 1918.

[3] Hawkins, Lon A., and Harvey, R. B. Physiological study of the parasitism of Pythium debaryanum Hesse on the potato tuber. *In* Jour. Agr. Research, v. 18, no. 5, p. 275–298. 1919.

the spring was released by means of a rack and pinion adjustment until a quick drop in the needle showed that it had penetrated the epidermis of the fruit. The reading on the scale of the instrument was then taken and the weight required to balance this tension on the spring determined. The weight of the glass rod and needle, minus the weight required to balance the tension on the spring, gives the pressure of the needle on the fruit at the time it punctures the epidermis.

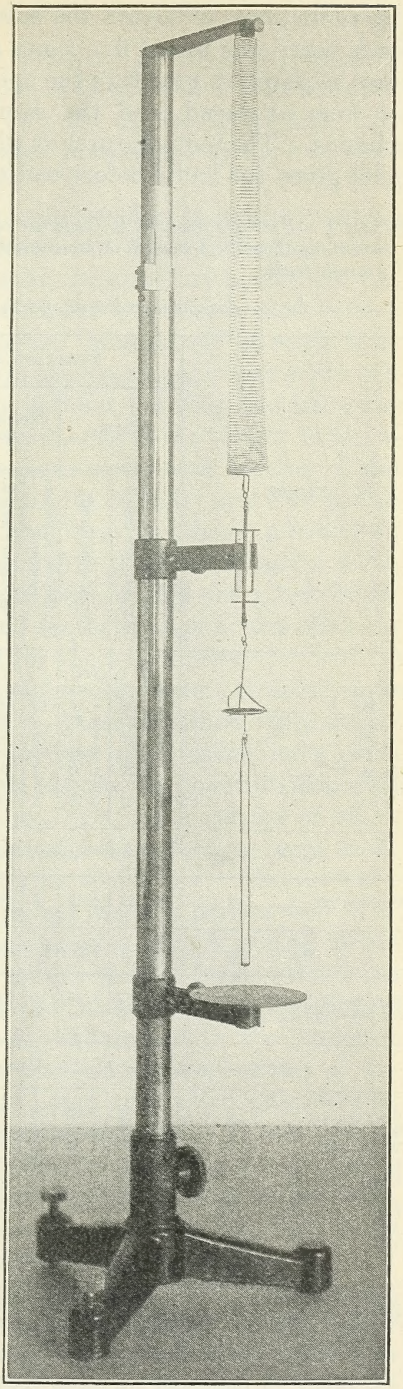

FIG. 1.—Apparatus used in determining the pressure necessary to puncture fruits.

CONDITIONS OF THE TESTS.

Five tests were made on different regions of each fruit, and a number of fruits, varying from 5 to 16, were used in all experiments. The fruit was picked in the morning of the day the determinations were made and tested at room temperature and after being cooled in the ice box. Tests were also made on berries washed in tap water, inasmuch as berries are frequently washed before packing and shipping commercially. As already mentioned, Stevens and Wilcox have shown that the washing of strawberries is beneficial. In a number of cases the fruit was tested the day it was picked, part of it placed in the ice box and tested later, and the remainder allowed to stand in the ice box for 24 hours. It was tested again on being removed from the ice box and later after it had had time to warm to room temperature. The results of these determinations with the different varieties of the fruits are given in Table I. The number of

determinations indicates the number of berries or cherries used. Each berry was tested five times and the tests averaged. The pressures required to puncture the epidermis of the fruit in each separate lot were averaged, and the results are shown in the appropriate columns. The temperatures at which they were tested and the treatment given the fruits before testing are also shown in the table.

TABLE I.—*Pressure required to puncture certain fruits freshly picked and after 24 hours under stated conditions, each determination representing the average of five punctures on a single fruit.*

Sec. A.—STRAWBERRY FRUITS, USING A NEEDLE 636 MICRONS IN DIAMETER.

Variety.	Tested soon after picking.									Tested after 24 hours in ice box.					
	Warm.			Cooled in ice box.			Washed in tap water.			Warmed to room temperature.			Cold.		
	Number of determinations.	Temperature tested.	Pressure required.	Number of determinations.	Temperature tested.	Pressure required.	Number of determinations.	Temperature tested.	Pressure required.	Number of determinations.	Temperature tested.	Pressure required.	Number of determinations.	Temperature tested.	Pressure required.
		° *C.*	*Gms.*		° *C.*	*Gms.*		° *C.*	*Gms.*		° *C.*	*Gms.*		° *C.*	*Gms.*
Cooney	10	26	4.41	....	....	.....	9	26	4.76	10	25	3.64	12	16	6.34
Do	10	29	4.79	10	16	5.57	5	29	4.81	....	....	.....	....	....	.....
Do	9	24	3.87	9	13	5.39	....	....	.....	....	....	.....	8	13	5.18
Do	26	26	4.11	18	16	6.05	....	....	.....	....	....	.....	....	....	.....
Do	7	23	5.06	5	16	6.50	....	....	.....	....	....	.....	....	....	.....
No. 29–5	7	29	4.83	7	16	7.79	....	....	.....	....	....	.....	7	16	6.30
Undetermined	5	30	4.95	6	16	6.79	....	....	.....	....	....	.....	....	....	.....
Do	5	23	5.28	3	13	7.07	....	....	.....	....	....	.....	....	....	.....

Sec. B.—BLACK RASPBERRY FRUITS, USING A NEEDLE 121 MICRONS IN DIAMETER.

Undetermined	10	25	4.45	8	14	6.23	....	....	.....	10	27	4.15	10	13	5.55

Sec. C.—RED RASPBERRY FRUITS, USING A NEEDLE 313 MICRONS IN DIAMETER.

Ranere (*St. Regis*)	12	27	4.86	15	16	6.41	....	....	.....	10	28	3.88	10	13	5.65
Undetermined	9	28	4.93	10	16	6.66	....	....	.....	10	28	3.51	10	13	4.90

Sec. D.—BLACKBERRY FRUITS, USING A NEEDLE 60 MICRONS IN DIAMETER.

Erie	15	26	5.60	16	13	6.36	15	26	5.46	12	27	5.62	15	13	7.16
Lawton	15	28	5.45	15	13	6.50	15	28	5.53	15	28	5.69	15	13	6.35
Wachusett	14	26	6.52	15	16	8.47	15	26	6.30	5	26	7.36	5	13	8.18
Lawton	14	25	5.59	15	13	6.83	....	....	.....	....	....	.....	....	....	.....
Unknown	16	26	6.00	14	13	8.11	15	26	6.24	....	....	.....	....	....	.....
Do	15	26	7.92	15	12	9.06	....	....	.....	....	....	.....	....	....	.....
Erie	10	27	7.94	10	13	8.98	....	....	.....	5	26	6.93	5	13	9.59

Sec. E.—CHERRY FRUITS, USING A NEEDLE 68 MICRONS IN DIAMETER.

Montmorency	15	27	5.08	15	16	6.46	....	....	.....	....	....	.....	....	....	.....
Do	16	29	5.65	16	13	6.88	....	....	.....	....	....	.....	10	13	7.10

DISCUSSION OF RESULTS.

Table I shows that the average pressure required to puncture berries that have been cooled is considerably more than that required for warm berries. This is true not only for the freshly picked fruit but also holds for the berries that were maintained at ice-box temperature (about 16° C.) for 24 hours.

Section A of Table I shows the average pressure in grams required to puncture strawberries freshly picked and treated in various ways. With the freshly picked fruit the pressures required (with a 636-micron needle) are from 0.76 to 2.96 grams higher with the cooled berries than with fruit from the same lots tested immediately at room temperature. This is a marked increase in the resistance of the epidermis to puncture. Washing in tap water without lowering the temperature did not apparently increase the resistance of the berries to puncture, as is shown by the 14 determinations under that heading in the table. Berries maintained in the ice box for 24 hours and then tested as soon as they were removed and after they had been warmed to room temperature gave results comparable to those obtained when freshly picked berries were tested and then cooled for a few hours and tested again; that is, the pressure required to puncture the cold fruit was greater than that required for the warm fruit.

The results with black and red raspberries, shown in sections B and C of Table I, were very similar to those obtained with strawberries. With black raspberries an average of 1.2 grams more pressure was required, with a 121-micron needle, to puncture the cold berries than those at room temperature. Only one variety of black raspberries was tested. Two varieties of red raspberries were used, the Ranere (*St. Regis*) and an undetermined variety. The pressure necessary to puncture the freshly picked Ranere berries was 1.55 grams less than that required for the same lot of fruit cooled in the ice box. A 313-micron needle was used with this fruit. With the undetermined variety the difference was 1.73 grams, or practically the same as for the Ranere. Similar differences in the pressure required for puncturing these berries were observed in berries of the same lots cooled in the ice box for 24 hours and tested immediately on removal and after warming to room temperature. It was noticeable, however, that the pressures required to puncture the epidermis after the 24-hour period in the ice box were not so high as with the freshly picked fruit. It is possible that the storing of this fruit tends to make the epidermis tender and more easily ruptured.

Experiments were carried out with four varieties of blackberries, the Erie, Lawton, Wachusett, and one undetermined variety. The results of the determinations were very similar to those obtained in the work with the other berries. The average increase in pressure necessary to puncture the freshly picked cooled fruit over that required

for the same lots at room temperature ranged from 0.76 to 2.11 grams with a 60-micron needle. Similar differences in the pressure required to puncture the warm and cold fruits were obtained when the fruit was allowed to remain in the ice box 24 hours. Washing the berries in tap water did not appreciably affect their resistance to puncture one way or the other. This may be due to the fact that the berries were tested immediately on removal from the water, which would preclude any appreciable cooling effect from evaporation.

The results with Montmorency cherries were practically the same as those with berries. Cooling the fruit increased its resistance to puncture.

From these results it is evident that the fruits used in the work are much less easily punctured when cool than when warm. It seems probable that this increase in the resistance of the skin to mechanical injury is an important factor in the results obtained by Ramsey, Stevens and Wilcox, and Ridley in their work on the prompt cooling and refrigeration of berries. It would seem also that the picking of berries in the early morning when they are cool, as is quite commonly practiced in some regions, would be decidedly advantageous, in spite of the fact that at that time the berries are frequently wet with dew, as no evidence was obtained that moist berries were more susceptible to injury than dry fruits.

No attempt was made to determine the reason for this increase in resistance to puncture due to cooling. A possible explanation of this phenomenon, which occurred to the writers, was that the surface of the fruit might be covered with a wax which softened at the higher temperatures but became harder and more resistant when cooled. Another purely mechanical explanation is that the walls of the drupelets or of the external cells of the fruits have a lower coefficient of expansion than their contents. If this were the case, at higher temperatures the walls would be under greater strain and would, therefore, puncture more easily. This point deserves further investigation.

In conclusion, it has been shown in this work with strawberries, blackberries, black and red raspberries, and cherries that cooling the fruit renders the epidermis more resistant to mechanical injury.

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