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SPOILAGE OF CRANBERRIES AFTER HARVEST.

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(The work done in Massachusetts was in cooperation with the Massachusetts Agricultural Experiment Station.)

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INTRODUCTION.

IMPORTANCE OF SPOILAGE AFTER HARVEST.

Three million dollars' worth of cranberries are, on the average, produced annually in the United States. Although effective control measures are practiced by many growers, a considerable portion of the crop, certainly not less than 10 per cent, is lost through fungous diseases before the fruit is picked. Large losses also frequently appear after picking. In some respects this spoilage is more troublesome than that which occurs earlier. Fruit which spoils after it is packed and shipped has cost the grower for handling and packing, and further expense is frequently involved in claims for allowances, shipments refused, inspection, and sometimes reseparating at the market. On the average, at least 15 per cent of the crop is estimated to be lost between the field and the consumer.

A less obvious but even more serious effect upon the demand for and sale of cranberries is that produced by marketing spoiled fruit. "Time and again," says Mr. A. U. Chaney (3, p. 30)[1], "have I no-

[1] The serial numbers in parentheses refer to "Literature cited" (p. 20).

ticed that a retailer who has unsound and unattractive fruit in his store has blocked his sale of cranberries." As the trade becomes more and more critical, not only of cranberries but of other fruits, the time is rapidly approaching when (2, p. 30) " growers must recognize the absolute necessity of producing fruit that will be sound when it goes before the consumer."

PLAN OF THE PRESENT WORK.

The senior writer has carried on investigations of the diseases of cranberries since 1901. During the past two years (1916 and 1917), however, the problem has been taken up with special reference to the losses which occur after picking. Field work and storage experiments have been carried on in Massachusetts and New Jersey; laboratory studies of material shipped from these areas and from Wisconsin, Michigan, Oregon, Maine, and West Virginia have been made at Washington, D. C.; fruit has been inspected and studied in most of the important markets east of the Mississippi River; and experimental shipments have been made from cranberry-growing centers to Washington, New York, and Chicago. So far as practicable, the field work in New Jersey and in Massachusetts has been conducted along similar lines, in order to avoid errors due to peculiar local conditions.

The investigations in Massachusetts have been carried on in cooperation with the Massachusetts Agricultural Experiment Station, the work at the State bog at East Wareham being in charge of Dr. H. J. Franklin (4, 5). Prof. F. W. Morse, of the experiment station, has also taken up certain important phases of cranberry respiration in relation to spoilage. While the investigations are not yet complete, the present paper aims to present the more important results and the conclusions thus far obtained in order that they may be immediately available to cranberry growers.

CAUSES OF CRANBERRY SPOILAGE.

The spoilage of cranberries is due in general to one or more of the following causes: Freezing, insect work, bruising, drying out, natural ripening processes, fungous rots, and smothering. The writers propose to employ the term smothering to designate the pathological conditions produced in fruits by sufficient interference with respiration, whatever the cause of this interference.

As the cause of freezing and the means of its prevention are well understood and the work of insects is outside the province of this paper, these two causes of spoilage will not be discussed.

BRUISING.

Loss due to bruising is by no means confined to actual crushing of berries by careless handling or spilling in sorting or packing houses, though this is in itself a cause of considerable loss and should be carefully guarded against.

Very important and more difficult to eliminate are the numerous unnoticed injuries occurring in the processes of harvesting, separating (milling), sorting (hand screening), and packing the fruit. It has been shown that these injuries, while too slight to affect the immediate sale of the fruit, indirectly bring about serious losses by starting decay. This relation of bruising to the starting of fungous rot will be considered later.

Slightly injured berries also dry out and shrivel much more quickly than sound fruit. Shrinkage in storage will be reduced, therefore, by care in harvesting and handling the fruit.

DRYING OUT.

Cranberries held in storage will gradually shrink even though no decay occurs. An experienced observer (6, 1913, p. 20) estimates this shrinkage as high as 10 per cent in the case of Early Black cranberries held in common storage at the bog for late trade. A part of this loss is due to the natural ripening processes mentioned below and part in some cases to the actual loss of water by evaporation. Bruising the fruit increases its rate of drying out and shriveling.

The rate at which water is lost by evaporation depends in part directly on the moistness of the air. In tests made by keeping weighed quantities of cranberries in containers with air of known humidity it was found that for any given temperature the loss in weight increased with the decrease in the humidity of the air. (Table I.)

TABLE I.—*Decrease in the weight of cranberries of the Howe variety held for 36 days in air of different humidities at certain temperatures.*

Air conditions.	Relative humidity (per cent).				
	100	80	65	35	[a] 0
Temperature 5° to 10° C. (41° to 50° F.): Loss in weight.......per cent..	0	4	5	6	9
Temperature 2° to 5° C. (36° to 41° F.): Loss in weight.......do....	.5	1.5	3	4.5	6

[a] Over concentrated sulphuric acid.

It is evident from these results that considerable humidity in the air of the storehouse is desirable to prevent the drying out of the fruit. Under the conditions ordinarily obtaining in cranberry storehouses the humidity is sufficient to prevent any serious loss from drying. In New Jersey the higher temperatures after picking are favorable for drying, and under some conditions of storage fruit kept for a long time may actually shrivel.

It should be mentioned in this connection that in a series of tests extending through both 1916 and 1917, in which cranberries of both the Early Black and the Howe varieties were kept in containers of known humidity, using a method already described by one of the writers (13), no direct relation was found between the humidity of the air and the amount of rot of the fruit. Berries kept as well in very moist air as in drier air unless they were actually wet.

NATURAL RIPENING PROCESSES.

Like other fruits, the cranberry when picked is a living organism, carrying on its vital activities, which may be referred to in general as ripening processes. Of these processes one of the most important is respiration. Under normal conditions the respiration of a fruit is marked by taking in oxygen and giving off carbon dioxid. In this process the living matter of the fruit is broken down and the berry gradually loses weight. If continued long enough this process would end in the destruction of the berry. It has been demonstrated that respiration goes on more rapidly at high than at low temperatures; consequently, the cooler the berries can be kept without freezing the longer they will live and the better will be their condition.

SMOTHERING.

CONDITIONS WHICH CAUSE SMOTHERING.

In a paper published with the report of the Massachusetts Cranberry Station for 1916 (11) the writers called attention to the spoilage of cranberries caused by insufficient ventilation. As pointed out at that time, cranberries kept in tight cans or in an atmosphere of carbon dioxid lose their crispness and bright color, become dull red and flaccid, and taste bitter. Since this kind of spoilage is apparently caused by conditions which check normal respiration, the writers designate it as smothering. Experience has shown that whenever cranberries of good keeping quality are covered with some inert gas, such as carbon dioxid, buried for some time in a big pile of berries, shut up in a tight container, kept under water, or subjected to other conditions which prevent normal respiration, smothering occurs. The exact causes of this spoilage, as well as the nature of the changes brought about in the fruit, are now the subject of investigation by Prof. F. W. Morse, of the Massachusetts Agricultural Experiment Station.

When berries are under water or under carbon dioxid, death due to smothering occurs in a short time, often in one to two weeks, whereas in tight containers or in large piles it results so slowly that if the berries are of inferior keeping quality fungous rot may destroy them before the effect of smothering appears. In case rot-producing fungi are present, they develop rapidly on the weakened berries, and a mass of rotten fruit results.

WATER STORAGE.

Storing cranberries under water is frequently recommended as a means of keeping them for long periods. Berries stored in this way soon die as a result of smothering. They can not, however, wither, nor do they decay, since the growth of rot-producing fungi is prevented. Water-stored berries do not have the bitter taste characteristic of most smothered fruit and are therefore suitable for cooking if used as soon as removed from the water. Such berries are, of course, unsalable.

The effect of storing cranberries in tight packages and under water as compared with storage in ventilated packages was shown by a series of tests made at the State experimental cranberry bog, East Wareham, Mass. In one experiment, uniform lots of apparently sound berries, of both the Early Black and the Howe varieties, were stored dry in closed bottles, under water in bottles, and in ventilated boxes. The results of this test are given in Table II.

TABLE II.—*Results of storing cranberries under different conditions for 36 days.*

Conditions of storage.	Number of berries.			Total spoiled (per cent).
	Total.	Rotten.	Smothered.	
Temperature 3° to 8° C. (37° to 46° F.):				
Under water, in bottle	....	0	All.	[a] 100
In closed bottle, dry	1,054	777	None apparent.	74
In ventilated box	1,364	382	0	28

[a] As explained in the text, these berries were still fit for cooking.

The results shown in Table II are typical of those obtained in other tests, some of which were carried out at much higher temperatures and with other varieties of cranberries, and have been further substantiated on a commercial scale by shipments in various types of packages and by storage tests. These will be considered later.

PREVENTION OF SMOTHERING.

Smothering may be prevented by ventilation. Berries should be stored in ventilated boxes, never in barrels, and the boxes should be so piled as to allow circulation of air through the berries. Cranberry storehouses should be provided with ventilators, which should be opened whenever cold air can be admitted without danger of freezing. Ventilated packages should be used where practicable. These points are also of importance in the control of fungous diseases and are discussed further in that connection.

FUNGI.

IMPORTANCE.

The writers' observations (10) indicate that rot-producing fungi cause at least one-half of all the loss in cranberries after picking. These fungi are, however, by no means of uniform importance in different regions or in different seasons. A study of a number of neighboring bogs during a single year or of a single bog through a series of years can not fail to impress the investigator with the extreme variation in the loss due to decay.

An illustration of the variation in the amount of rot over a considerable area in different seasons is found in the annual reports of the board of inspectors of the New England Cranberry Sales Co. for the last five years, as given by the chairman, Mr. H. S. Griffith (6). The crop of 1913 was described as "remarkably free from fungous disease"; in 1914 and in 1915 there was a large percentage of unsound fruit; the crop for 1916 was unusually sound up to November 1, after which a noticeable, though not very serious, amount of end-rot developed; the crop for 1917 was in general of good keeping quality, with a small amount of fungous disease. As these inspectors determine the brand of the crops from representative bogs over much of the Massachusetts cranberry area, their reports, no doubt, represent fairly well the condition for the entire region.

The prevalence of rot in some seasons seems to be associated with weather conditions which would favor the growth and spread of fungi. Our knowledge of these relations is too slight, however, to permit of very definite conclusions. Differences in the amount of rot on different bogs or on various portions of one bog are often related either to lack of vigor or to excessive growth of the vines, due to various causes. These relations will be considered later.

PRINCIPAL CRANBERRY FUNGI WHICH CAUSE FRUIT ROTS.

The fungi which cause the decay of cranberries after they are picked are in a large part those which attack the fruit on the vines. The molds which cause decay of such perishable fruits as strawberries and raspberries are rarely found on cranberries and are, therefore, of slight importance.

Among the diseases which are the principal causes of losses of cranberries in storage are early-rot (8), caused by *Guignardia vaccinii* Shear, which is also the cause of scald and blast, and which is especially destructive to fruit on the vines and early in the season in New Jersey; end-rot (9), caused by *Fusicoccum putrefaciens Shear*, common on fruit in storage, especially late in the season and in the northern cranberry regions; bitter-rot, caused by *Glomerella cingulata vaccinii* Shear; ripe-rot, caused by *Sporonema oxycocci* Shear; and blotch-rot, caused by *Acanthorhynchus vaccinii* Shear. Soft-rot, caused by *Penicillium* spp., is rather common on fruit held late in storage, but is usually associated with other rots, and is not of great importance. Ripe-rot develops at a lower temperature than any of the other rots, except end-rot, and is most frequent in Massachusetts.

CONTROL OF FUNGOUS DISEASES.

Bog Management.

Since all the fungi which cause important storage rots of cranberries are found on the bogs and in large part gain entrance to the berries before they are picked, control measures should begin with the bog. Not all of the factors which determine the abundance of fungi are understood at present; in fact, it sometimes seems as if a bog is free from rot-producing fungi in spite of the treatment it receives rather than because of its management. Certain phases of bog management seem, however, to have a direct relation to the keeping quality of the fruit produced. An excessive growth of vines, whether produced by too much nitrogenous plant food or some other cause, generally results in diseased fruit.

Many cranberry growers believe that frequent flooding to prevent injury from early frosts in the fall seriously affects the keeping quality of the fruit, although this is not uniformly the case. The writers had under observation one bog which during the fall of 1917 was completely submerged on 12 nights, and the fruit still showed exceptional keeping quality.

If the water is held for a considerable period continuously, however, the result is very likely to be disastrous. Cranberries of the Early Black variety on the Massachusetts State bog, which had been submerged for two weeks after the bulk of the crop was harvested, showed a great increase in the rot of the flooded fruit as compared with the fruit harvested before the flooding. In this case, indeed, a serious infection of *Sporonema oxycocci* (ripe-rot) occurred on the berries which had been submerged. Only a few of the berries picked before this flooding were found to be infected with this fungus. In northern cranberry regions during cold periods bogs are sometimes flooded and the water held so long that the fruit may be actually smothered. This practice is certain to injure the fruit.

The holding of winter flowage until mid-July, thus sacrificing one season's crop, is occasionally practiced in both Massachusetts and New Jersey as a means of reducing pests; this is one of the treatments recommended by Franklin (4) and by Scammell (7) for the reduction of several destructive insects. During the year following this treatment a large crop of berries of excellent keeping quality is said to be obtained, and the benefits, both in the reduction of field rot and in the improvement of keeping quality, are frequently said to persist for several years.

Spraying.

Thorough spraying has been found in all localities to reduce rot and improve the keeping quality of the fruit. In New Jersey and on Long Island, where there is always considerable loss from fungous disease before picking and where spraying has been practiced in some cases for 10 years, thorough spraying has been found profitable and no injury to the vines has been observed.

Experiments were conducted with the Early Black variety at Whitesbog, N. J., during 1917 to determine the times at which Bordeaux mixture should be applied in order to control fungous diseases most effectively and economically. Blast, early-rot, and a storage rot, all due to *Guignardia vaccinii* Shear, were the principal causes of loss on this bog during the year. Bordeaux mixture of the formula 4–4–50, with about 1 pound of resin-fishoil soap, was used throughout the experiments.

A single thorough application of Bordeaux mixture after the blossom buds had begun to open increased the total yield by more than 10 per cent (from 173 to 192 bushels per acre) by controlling blossom blast. Two applications before blossoming were no more effective than one. An application immediately before the spring reflow showed no effect in the control of fungi. No trace of the spray was observed on the vines when the water was removed. The applications before blossoming had no effect in reducing the rotting of the fruit after picking.

Protection of the berries from infection during the first month of their growth resulted in very satisfactory control of both field and storage rots. This was accomplished by two thorough applications, one near the close of the blossoming period (before all the petals had fallen) and another two weeks later. By these applications alone the total yield was increased, the rot at picking time was reduced from more than 20 per cent to less than 2 per cent, and storage rot from 6.7 per cent to 1.9 per cent. These two sprays applied at the proper time effected a saving of 44 bushels of marketable cranberries per acre, or one-fourth of the crop. Any delay in making the first application after blossoming resulted in a marked increase in both field rot and storage rot.

A third application after blossoming was of no increased benefit in these experiments. It must be repeated, however, that early-rot was the only fungous trouble of importance on this bog; furthermore, the berries were picked before the middle of September. It is doubtful whether two applications after blossoming will give satisfactory control with all varieties or where other diseases, such as bitter-rot, are concerned. A similar series of experiments with cranberries of the Centennial variety in New Jersey during 1917 gave unsatisfactory and unreliable results because of severe frost injury. Further experiments along this line are necessary and are in prospect.

The use of Bordeaux mixture with resin-fishoil soap, which has been found to be the most effective fungicide for cranberries, is recommended. One application should be made just after the blossoms begin to open and should be repeated every two weeks until August 15.

In Massachusetts small plats of berries on the State bog which were sprayed with Bordeaux mixture for several years in succession have shown some injury to the vines. More experiments are necessary in order to determine the cause of this injury. As no injury of this kind has been observed in New Jersey or on Long Island, the writers feel that where losses from rot either before or after picking are heavy the benefit from spraying will more than offset any probable injury.

Dry Picking.

Experiments conducted on a number of bogs in New England have indicated that cranberries should be picked dry. The results shown in Table III are summarized from tests made in 1917. In each case from 4 to 10 bushels of berries were picked early in the morning while still wet with dew and an equal quantity taken from an adjacent portion of the bog as soon as the berries were thoroughly dry.

TABLE III.—*Comparative results of storing cranberries that were picked wet and dry in 1917.*

Variety.	Locality.	Days in storage.	Percentage of rotten cranberries.	
			Picked dry.	Picked wet.
Early Black	East Wareham, Mass.	56	32	51
Howe	do	44	13	40
Early Black	South Wareham, Mass.	24	[a]17	[a]20
Cherry	Madrid, Me.	60	2.4	6.0

[a] Contained about 10 per cent of rotten berries when picked.

That the inferior keeping quality is due to the fact that the berries were wet and not to any injury received in picking is indicated by the fact that similar deterioration in keeping quality followed where boxes of berries which had been picked dry were wet with clean water.

During the latter part of the shipping season cranberries are sometimes removed from a cool storage house to a warm room for sorting and packing. If the humidity of the air is high, moisture frequently condenses on the berries to such an extent that they become wet and sticky. This is injurious to their keeping quality and should be carefully avoided. Cranberries should never be barreled or shipped in this condition. The desirability of packing and, if possible, sorting in cool rooms, which will prevent wetting the fruit by condensation from the air, is further considered under the next topic.

Low Temperature.

A study of the temperature relations of many of the fungi which cause fruit rots of cranberries (14, pp. 524 and 525) has shown that most of them grow very slowly, if at all, below 10° C. (50° F.). The only conspicuous exception is the end-rot fungus, which grows somewhat even at 0° C. (32° F.). The rate of growth of all these fungi, and consequently of the rot which they cause, increases rapidly with rise of temperature above 10° C. (50° F.). As already mentioned, the ripening processes which result in the death of the cranberry itself also go on more rapidly as temperature rises.

As an illustration of the effect of temperature on the keeping quality of cranberries, the results of temperature tests conducted at Washington, D. C., during 1916 and 1917 may be cited (Table IV). Equal quantities of apparently sound cranberries from uniform lots were kept at different temperatures in the refrigeration apparatus described by Brooks and Cooley (1).

TABLE IV.—*Effect of temperature on the keeping quality of cranberries as shown by tests made at Washington, D. C., in 1916 and 1917.*

Variety.	Days in storage.	Percentage of cranberries spoiled in storage at temperatures—[1]				
		0° C. (32° F.).	5° C. (41° F.).	10° C (50° F.).	15° C. (59° F.).	20° C. (68° F.).
Early Black	28	2	4	5	12	19
Do	28	1	1.5	3.5	9	13
Howe	25	2.5	5	8	15.5	19
Early Black	60	16	27	....	48	72
Do	60	20	27	....	51	66
Do	56	39	43	....	92	99
Howe	67	8	27	....	48	76

[1] This includes smothering and all forms of fungous rot.

In the course of the first three tests, the results of which are given in Table IV, it was observed that cranberries color more rapidly at relatively low temperatures (5° C., 41° F.). It is, then, desirable from every point of view for cranberries to be kept as cool as practicable.

When cranberries are picked they are usually at a temperature considerably warmer than that of the air, and the sooner they are cooled the better. To this end it is desirable that cranberries should be removed from the bog as soon as practicable and placed in the shade. They should be stored in ventilated boxes, never in barrels, and the boxes should be so piled as to permit free circulation of air among the boxes.

The storehouse in which cranberries are held should be kept as cool as is possible without danger of freezing the fruit. This can be done most economically by having the house provided with adequate ventilators to admit air at the bottom of the building. These ventilators should be open during cool weather and closed when the temperature of the outside air rises above that of the storehouse.

As already stated, cranberries which are held in the chaff and shipped during cold weather are frequently brought from a cold to a warm room for sorting. In order that sorters may work comfortably and efficiently the room in which the work is done must be at a temperature of at least 15° C. (60° F.), while the fruit in storage is often at a much lower temperature. If cool cranberries are held in a warmer room long enough for proper screening, their temperature is considerably raised, and if they are barreled in this room the higher temperature may be maintained long enough to affect their keeping quality seriously. As an instance of the injury to keeping quality which may result from such treatment, a test made in the fall of 1916 may be cited. Equal quantities of Early Black cranberries were taken from a barrel which had been kept for some time at a temperature of 7° to 10° C. (45° to 50° F.). One portion was taken to a warm room, about 24° C. (75° F.), and carefully hand sorted, the process taking in all about 40 minutes, after which the sound berries were returned to the original temperature. An equal portion was sorted in the cool room. At the end of 10 days the two lots were again sorted, with the results shown in Table V.

Table V.—*Comparative results of sorting cranberries in warm and in cool rooms, in the autumn of 1916.*

Treatment.	Number of berries.	Berries rotten 10 days after sorting.	
		Number.	Per cent.
Sorted in a warm room	973	153	17
Sorted in a cool room	968	88	

To avoid loss from this source and from wetting the fruit by condensation from the air, berries should not be sorted in a heated room unless necessary. When weather conditions make this imperative they should be removed from the warm room as soon as possible and should not be packed in the sorting room. Packing in a warm room means including in the barrel a quantity of warm air, which in a tight package retains its heat for a considerable time.

Perhaps the most efficient means of overcoming this difficulty is one that can be readily arranged where sorting belts are used. This method is used by at least two growers, one in Massachusetts and the other in New Jersey. The separators and packers are in a large room which is kept at the temperature of the fruit, while the belts carrying the fruit to be sorted pass through a smaller inside room which is kept at a higher temperature and in which the sorters work. With such a system, using belts 30 feet long, no berry is exposed to warm air for more than 1 minute and the air in which the berries are packed is as cool as that in which they were stored. Careful temperature tests made in such a sorting house in Massachusetts showed that with the temperature of the berries at 7° C. (45° F.) and that of the sorting room at 18° C. (65° F.), the temperature of the berries was raised not more than 1 degree centigrade in sorting.

Ventilation.

Adequate ventilation of the cranberry storehouse is necessary first of all as a means of lowering the temperature of the fruit as soon as possible after it is picked. Its importance is not by any means confined to the effect on temperature, however, for, as pointed out earlier, improper ventilation results in smothering and sometimes in increased decay. In order to obtain the best results, cranberries should be stored in ventilated boxes which are so piled as to permit a free circulation of air among the berries.

The same principle may well be extended to the packages in which cranberries are shipped, particularly for the early shipments, which are frequently made during very warm weather. In this connection, the writers carried on experiments during both 1916 and 1917, in which berries were shipped in containers of different types. The results of these experiments are summarized in Table VI. In general it may be stated that the fruit in the smaller, well-ventilated containers kept better than that in the barrels. Of these containers the ventilated half-barrel box is perhaps the most satisfactory.

Ventilated barrels in which there are from 28 to 32 small openings (every other stave having two notches in each side) offer a convenient substitute for the tight barrel and one which may be introduced at slight expense and without the delay and effort incident to introducing a new package to the trade. Such barrels are now in use for early shipments by at least one large grower. While the writers have as yet been unable to carry out satisfactory comparative tests of ventilated and tight barrels, in a simple shipment of Early Black cranberries from Massachusetts the berries in the ventilated barrels appeared drier than those in the tight barrels. It is hoped that next season it will be possible to make shipping tests of a size sufficient to settle the question as to the amount of advantage derived from using ventilated barrels.

TABLE VI.—*Shipping tests of cranberries in different types of containers during 1916 and 1917.*

Variety.	Year.	Point of shipment.	Point of receipt and examination.	Percentage of spoilage.	
				In tight barrel.	In ventilated crate.
Early Black	1916	East Wareham, Mass.	Washington, D. C.	38	29
Do	1916	South Wareham, Mass.	Livermore Falls, Me.	23	16
Howe	1916	East Wareham, Mass.	Washington, D. C.	21	11
Do	1917	do	Chicago	22	[a] 18
Do	917	Wareham, Mass.	New York	13	9

[a] Ventilated half-barrel box.

In this connection it may be noted that cranberries color better in well-ventilated containers.

Careful Handling.

DECAY INCREASED BY BRUISING.

Bruises caused in harvesting, separating, or sorting cranberries form, as already stated, an important cause of increased decay. This was strikingly shown by a test made at Whitesbog, N. J., in 1916, using Centennial cranberries immediately after harvesting, before they had been separated or sorted. Each berry in a 10-pound sample was examined critically for the presence of scratches, bruises, or other blemishes which were so slight as not to be noticed in a casual inspection or picked out by the most careful sorter. Nearly one-fourth of the berries were found to be so injured; all of them were marketable and, to the inspector, apparently sound; they showed no signs of fungous decay. The injured and uninjured berries were placed in separate ventilated corrugated paper boxes and left in the storage house for two months. At the end of that time they were reexamined and the results noted, as shown in Table VII.

TABLE VII.—*Relation of slight injuries to the keeping quality of cranberries, as shown by a test made at Whitesbog, N. J., in 1916.*

Condition before storage.	Number of berries.	Rotten after being stored two months.	
		Number.	Per cent.
Sound	2,171	97	4.5
Slightly injured, but marketable	697	316	45.3

Table VII shows that after two months in storage there was ten times as much rot among the previously bruised berries as in the sound ones. Many of these unnoticed injuries occur in each process of handling the fruit. This emphasizes the need of care and of improvement when possible in methods of harvesting, separating, sorting, and packing cranberries.

HARVESTING.

Careful experiments in which the keeping quality of hand-picked cranberries was compared with that of scooped berries have not shown any very decided advantage in favor of either method, provided the scoopers were not allowed to pick up dropped berries from the ground.

A series of tests in New Jersey in the fall of 1916 showed that the keeping quality of these dropped berries was much inferior to that of berries picked or scooped from the vines. The results of these tests are summarized in Table VIII. The experiment with Early Black cranberries was conducted by Mr. Franklin S. Chambers. Adjacent similar plats of each variety were marked on the bog; then the berries from half the plats were picked by hand by experienced pickers and the remainder harvested by experienced scoopers. All berries were stored for two months in ventilated 1-bushel boxes in adjacent piles in a ventilated storage house.

TABLE VIII.—*Effect of different methods of harvesting upon the keeping quality of cranberries, as shown by tests made in New Jersey in 1916.*

Variety.	Method of harvesting.	Total weight (pounds).	Condition noted (per cent).			
			Immediately after harvesting.		Rotten after being stored 2 months.	Rot developed in storage.
			Slightly bruised.	Rotten.		
Early Black	Picked	1,168	(1)	(1)	12	....
Do	Scooped	1,054	(1)	(1)	14	....
Centennial	Picked	171	12	6	17	11
Do	Scooped	164	18	5	12	7
Do	Picked up after scoopers	38	34	6	25	19
Howe	Picked	425	....	−1	4.5	3.5
Do	Scooped	384	....	−1	4.2	3.2
Do	Picked up after scoopers	41	....	−1	18.1	17.1

[1] Not determined.

Berries picked up from the ground after scooping, as Table VIII shows, bore a much higher percentage of the slight injuries mentioned above than did any of the other fruit, and, as was to be expected, this was the cause of their poor keeping quality. It seems from this evidence that if dropped fruit is picked up from the ground it should be kept separate, in order not to lower the grade or keeping quality of all the berries.

It is probable that neither method of harvesting can be said to be best under all conditions, but that factors other than keeping quality, such as length and uniformity of pine growth, will influence or determine the method to be preferred in any particular locality.

SEPARATING AND SORTING.

Very important and difficult to eliminate are the numerous unnoticed injuries caused in the processes of separating, sorting, and packing the fruit. Franklin (4, p. 21) has published data which show that the bruising caused by running berries through the separator and by dropping them into a barrel markedly increases the amount of rot. The results of the investigation of the writers fully substantiate these conclusions. Great injury is also caused by squeezing the berries in sorting. In this process the decayed berries are often detected by touch even more than by sight, and much sound fruit is thus squeezed or pressed unnecessarily. The resulting bruises, while imperceptible, frequently serve to start decay.

An illustration of the relation of bruises received in separating and sorting to the development of decay in storage is found in the results of a test made at Whitesbog, N. J., in the fall of 1917, in which 75 bushels of Early Black cranberries were picked on September 14 from plats which had been thoroughly sprayed during the summer. On September 21 the berries from each plat were divided into three representative parts. One part was then set aside in the storage house without further handling. The second part was sorted by hand on stationary sorting tables by commercial sorters, the percentage of unsound fruit noted, and the sound berries placed in the storage house. The berries remaining were then separated by machine and finally by hand in the usual commercial manner, the percentage of unsound fruit noted, and the apparently sound berries placed in storage. In this last method practically all unsound berries were removed by the machines, and the berries therefore suffered very little by handling during the final process of hand sorting.

All the berries were stored for nearly six weeks in ventilated storage boxes of 1-bushel capacity in a house in which the temperature varied from 15° C. to 7° C. during the season. For purposes of further comparison, 32 bushels of the Early Black variety that were picked on the same day (Sept. 14) from unsprayed plats on the same bog were divided, handled, and stored at the same time and in the same manner as those from the sprayed plats. Berries of good keeping quality (sprayed) were thus compared with those of poor keeping quality (unsprayed) as to the effect upon them of separating or sorting before storage.

On October 31 all the berries were removed from storage, sorted by commercial sorters, and the percentage of unsound fruit noted. The results are summarized in Table IX.

TABLE IX.—*Increase in amount of rot due to separating or sorting cranberries, as shown by tests made at Whitesbog, N. J., in 1917.*

Conditions of test.	Results noted (per cent).			
	Rotten Sept. 21 (1 week after picking).	Total rotten on Oct. 31 (after 6 weeks in storage).	Rot developed in storage.	Increase of storage rot due to previous handling.
Berries of good keeping quality (sprayed):				
Hand sorted before storage	1.6	5.9	4.2	1.9
Separated and sorted before storage		5.7	4.1	1.8
Not handled before storage		3.9	2.3	
Berries of poor keeping quality (unsprayed):				
Hand sorted before storage	21.6	30.4	8.8	7.8
Separated and sorted before storage		28.3	6.7	5.7
Not handled before storage		22.6	1.0	

Table IX shows that even with berries of excellent keeping quality the amount of decay developed in storage was nearly doubled by a previous sorting either by hand or by machine and that the effect of hand sorting was at least as severe as that of machine separating. On berries of potentially poor keeping quality the effect was similar but very much more marked. It appears that these berries did not decay in storage any faster than the sprayed berries unless they had been bruised previously by sorting, but that when so bruised the rot developed rapidly and in large amount. Here, again, hand sorting alone proved slightly more injurious than separating by machine.

This experiment indicates that the berries should be handled as little as possible and as late as possible before disposal, especially in the case of fruit of bad or doubtful keeping quality.

As another example of the increase in the amount of decay which is caused by hand sorting, the results of a test made at Wareham, Mass., in the fall of 1917 may be cited. Ten bushel boxes of Early Black cranberries were scooped on September 12 in such a way that two boxes came from each of five different regions of the bog, the two boxes from each region being as nearly alike as possible. All the berries were stored with abundant ventilation at a temperature which varied from 15° to 5° C. (59° to 41° F.) as the season advanced. Five boxes, one of each pair, were carefully hand sorted on October 3 and the good berries replaced in the boxes and held until November 6, when all the berries were sorted. The results, summarized in Table X, indicate that the sorting on October 3 more than doubled the amount of rot during the following month.

TABLE X.—*Increase in rot due to the sorting of cranberries, as shown by a test made at Wareham, Mass., in 1917.*

Treatment.	Condition noted (per cent).		
	Rotten on Oct. 3.	Rotten on Nov. 6.	Total rot.
Sorted once during storage	4.3	15.8	20.1
Not sorted during storage	....	11.0	11.0

To avoid such losses as have been cited, all berries, especially those of doubtful keeping quality, should be handled as little as possible, they should be cleaned as near the time of shipping as possible, and in sorting care should be exercised not to touch or bruise the berries unnecessarily. It is possible that separating machines may be devised which will injure the fruit less than those at present in use. Improvement can certainly be made in the methods of hand sorting. The most thorough sorting is not necessarily the best if it is accompanied by too much handling of the berries. Sorting belts in which the berries pass from the separator over a slowly moving belt which carries them in front of the sorters and deposits those not removed in a box or barrel at the end have the advantage of making it unnecessary for sorters to handle the fruit roughly, provided there is some device for turning the berries on the belt. An easer[1] of some kind should be used to prevent bruising when berries drop into a barrel or other container.

SHIPPING IN THE CHAFF.

When berries come from the bog they have more or less leaves, broken vines, or other foreign matter mixed with them. Fruit in this condition is said to be "in the chaff."

As a result of the knowledge of the fact that the processes of cleaning cranberries increase their tendency to decay and that it is advantageous to place them before the consumer as soon as possible after cleaning, some growers have attempted shipping berries in the chaff and having them cleaned at destination. For berries particularly subject to decay after sorting this plan is apparently to be recommended.

The writers have had the opportunity to test this method in only one instance, a shipment of berries from a bog in Wareham, Mass., to Chicago, Ill. Two varieties were used in the experiment, and equal quantities of berries as uniform as could be secured were chosen. Half of each lot was carefully separated and sorted before shipment and the shrinkage noted; the other half was shipped in the chaff. At destination all lots were run through a separator and the shrinkage again noted. The berries were packed in Wareham on

[1] Easer is a term the writers apply to any device for breaking the fall to prevent bruising.

October 26 and examined in Chicago on November 15, 1917. The results are given in Table XI.

TABLE XI.—*Comparative results of shipping cranberries before and after cleaning, as shown by tests made in 1917.*

Variety.	Condition when shipped.	Shrinkage noted (per cent).		
		In first cleaning.	In separating at Chicago.	Total.
McFarlin[1]	In chaff		28.7	28.7
Do	Separated and sorted	20	10.2	30.2
Middleboro	In chaff		27.0	27.0
Do	Separated and sorted	20	15.5	35.5

[1] Contained more than 10 per cent of frozen berries.

It will be noted that with both varieties the total loss of berries was greater with those cleaned before than with those cleaned after shipment. This is particularly marked in the case of the Middleboro variety, which contained no frosted berries and therefore gave a more accurate test.

Shipping in the chaff naturally involves the extra expense of freight charges and containers for the chaff and decayed berries which would be taken out in cleaning. On the other hand, if fruit is shipped in the chaff it may be held in storage and run through a separator as sold. Under these conditions hand sorting will not be necessary and the cost of preparing for sale is materially reduced. In deciding whether to attempt shipping in the chaff each grower will have to take into consideration his own expense of separating and sorting, the probable keeping quality of his berries, and whether the consignee has adequate facilities for separating the fruit. Shipping in the chaff will then be confined to consignments to large dealers and will be most profitable in the case of fancy fruit of relatively poor keeping quality.

SUMMARY.

Recent observations and investigations have shown that about 15 per cent of the cranberry crop is lost between the field and the consumer. The losses are due in part to fungous rots and in part to smothering.

Bruising of the fruit occurs in the operations of picking, separating, sorting, and packing. Such injury is not only a direct cause of spoilage, but renders the fruit much more liable to decay. Much more rot has been found in roughly handled or bruised fruit than in carefully handled fruit.

No direct relation has been found between the humidity of the air in which the fruit is kept and the amount of rot which develops. Death and spoilage of cranberries will finally result from natural ripening of the fruit. This process is hastened by high temperatures and reduced by low temperatures.

Cranberries kept in tight packages which do not permit ventilation soon die from smothering and are of little value for food. Such fruit is soft and the tissues are discolored. Spoilage by smothering may be caused by keeping the berries in large piles, by having them too closely crowded in unventilated storerooms, or by flooding for too long a period, especially in warm weather.

Extended investigations indicate that at least one-half of the spoilage of cranberries after picking is due to fungous rots. These vary much in prevalence and destructiveness in different seasons and localities, depending upon a variety of factors.

The chief rots which develop after picking are early-rot, caused by *Guignardia vaccinii;* end-rot, caused by *Fusicoccum putrefaciens;* bitter-rot, caused by *Glomerella cingulata vaccinii;* ripe-rot, caused by *Sporonema oxycocci;* blotch-rot, caused by *Acanthorhynchus vaccinii;* and soft-rot caused by species of Penicillium. The fungous rots which develop after picking, as well as before, may be largely prevented by spraying with Bordeaux mixture to reduce infection. Improved bog management also increases the vigor of the vines and tends to reduce rot.

Cranberries picked and stored or packed wet show more rot than those picked and packed dry; when cooled as soon as practicable after picking and kept at low temperatures they show a great reduction in the amount of rot. The most favorable temperature for keeping berries is 32° F. Temperatures above 50° F. produced rapid increase in the development of rots. Berries warmed by being kept in a heated room while being sorted showed an increase in the amount of rot.

Ventilated barrels or other ventilated packages used in distribution gave less rot and other spoilage than tight packages.

A comparison of different methods of harvesting the fruit showed but slight differences in its keeping quality.

A study of the effect of separating fruit by machines and by hand sorting showed but little difference in the result. All lots developed much more rot than the check. The results indicate that separating and sorting should be delayed until the fruit is to be shipped.

Cranberries shipped in the chaff, that is, without cleaning or sorting, and separated and sorted at destination, showed less loss from rot than those separated and sorted before shipment.

PRACTICAL SUGGESTIONS.

Spray thoroughly to prevent fungous infection.

Pick and handle the fruit with great care to avoid bruising.

Cool the berries as quickly as possible after picking and keep them cool until they are shipped.

Store and handle the fruit in a cool, well-ventilated building, and use ventilated packages, especially for early shipments.

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