T H E S I S

on

THE RELATION OF SUBMERSION TO THE CLEANING OF APPLES AND PEARS BY THE WASHING METHOD

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I N D E X

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THE RELATION OF SUBMERSION TO THE CLEANING OF APPLES AND PEARS BY THE WASHING METHOD.

INTRODUCTION

As a result of experiments on the removal of spray residue from apples and pears in 1926, it became apparent that open-cored fruits (Fig. 1) might offer complications in washing operations. This was especially true since the presence of hydrochloric acid in the core cavities was known to cause core injury and to induce decay from blue mold and other organisms. The problem was of special significance since several concerns were contemplating the building of washing machines employing the submersion principle, where pressure might be a factor in forcing the washing solution through the openings into the receptacles and seed cavities.

There was also some evidence to the effect that in closed-cored fruits (Fig. 2) the pressure from submersion might be sufficient to force the solution into the calyx tube, making effective rinsing impossible and thus endangering keeping quality.

Consequently during the summer of 1927, experiments were planned with the aim of securing data on the following phases of the problem:

1. The prevalence of open cores in the commercial

varieties of apples and pears.

2. The effect of submerging at various depths on the amount of leakage into open-cored fruits.
3. The effects on the fruit of various washing and disinfecting compounds when forced into the core.
4. The effects of submerging at various depths on leakage into the calyx tube of closed-cored fruits.
5. The effects on the fruit of leakage into the calyx tube.

EXPERIMENTAL

I. THE PREVALENCE OF OPEN CORES IN THE COMMERCIAL VARIETIES OF APPLES AND PEARS.

When attempts were made to ascertain the exact percentage of open-cored fruits in apple varieties, it was soon found that no very definite conclusions could be drawn. Some lots within a variety revealed a very high percentage of open cores while other lots of the same variety showed practically no open cored fruits.

The larger sizes usually showed a much higher percentage of open cores than did the smaller sizes. This is shown quite clearly by Tables I and II which show the relation of size to the prevalence of open cores in Tompkin's King and Jonathan apples.

TABLE I

THE RELATION OF SIZE OF FRUIT TO THE PREVALENCE OF OPEN CORES IN TOMPKIN'S KING APPLES.

Sizes	Number of apples examined	Number of open cores	Percent open cores
150 and smaller	250	10	4
150 to 100	360	54	15
100 and larger	140	30	22

TABLE II

THE RELATION OF SIZE OF FRUIT TO THE PREVALENCE OF OPEN CORES IN JONATHAN APPLES.

Sizes	Number of apples examined	Number of open cores	Percent open cores
150 and smaller	161	10	6
150 to 100	235	27	11
100 and larger	94	35	36

Trees with light crops of fruit usually showed more open cores than did the trees bearing full crops. Ortleys, as a rule, showed a very high percentage of open cores. Some lots of Ortley, however, were remarkably free from this trouble. Rome, Winesap, and Yellow Newtown were practically free from open cores. Occasionally an open-cored specimen was found in the larger sizes of these varieties.

In the Milton-Freewater district Jonathan averaged about 30 percent open cores. It is possible that the freeze experienced in that district last spring had something to do with this situation.[1]

These observations on the prevalence of open cores in apples are generally in keeping with those made by other investigators. Fisher found with Spitzenburg, for example, that in some orchards the number of open cores did not exceed 2 percent, while in other Spitzenburg orchards the percentage of open cores often averaged between 25 and 30 percent.[1]

Practically no open cores were found in pears. The commercial varieties of pears apparently are free from the trouble.

II. THE EFFECT OF SUBMERGING AT VARIOUS DEPTHS ON THE AMOUNT OF LEAKAGE INTO OPEN-CORED FRUITS.

To determine the amount of leakage into open-cored fruits, Ortley apples of the "sheepnose" type were used, as these were known to be 100 percent open-cored. These were subjected to submersion in .75 percent hydrochloric acid at depths varying between 0 and 60 inches, the length of the treatment in each case being five minutes.

A tank twelve inches square and 60 inches deep was used in all the submersion tests. The fruit was forced down to the required depths and brought to the surface five times in every treatment. This procedure corresponds with the principle on which the commercial deep submersion machines work.

Following the acid treatment the apples were rinsed in clean water, wrapped wet, and stored in common storage for ten days. At the end of this time the fruit was removed from storage and the specimens were cut open. The amount of leakage resulting from each treatment was determined by noting the prevalence of decay and physiological core injury.

Table III gives the data obtained in this test.

TABLE III

THE EFFECT OF SUBMERGING AT VARIOUS DEPTHS ON THE AMOUNT OF LEAKAGE INTO OPEN-CORED FRUITS.

Treatment	Percent physio-logical core injury	Percent decay
Check (no treatment)	0	15
Washed by floatation	0	20
Washed by submerging to depth of 4 inches	0	75
Washed by submerging to depth of 8 inches	0	100
Washed by submerging to depth of 12 inches	0	100
Washed by submerging to depth of 24 inches	0	100
Washed by submerging to depth of 36 inches	0	100
Washed by submerging to depth of 60 inches	0	100

To obtain more information on this point, and also to compare the amount of leakage occuring from submersion with the amount occuring with other methods of washing the following experimental work was undertaken:

A number of Newtown apples were punctured through the calyx tube with a plunger 1/16 of an inch in diameter.

By this procedure it was possible to obtain a large number of fruits, all with the same sized openings into the core.

These fruits were divided into five lots, and were treated with .75 percent hydrochloric acid as follows:

I. Check lot, no treatment.

II. Floatation Treatment.

The apples in this treatment were washed for five minutes in hydrochloric acid. The fruit was floated on the surface with an occasional submersion to a depth of one inch during the treatment to insure results comparable to those obtained with the commercial floatation machines.

III. Sluicing Method.

In this test the apples were floated in the acid solution for one minute during which time the washing solution was poured over the floating fruit from a height of eighteen inches. The apples were turned over in the bath insuring complete exposure to the falling solution.

IV. Spraying Method.

The procedure in this treatment was the same as in the sluicing test, with the exception that the solution was sprayed on the floating fruit. The spray was applied under twelve pounds pressure. A small portable spray can fitted with a disk nozzle giving a moderately fine cone-shaped spray was used. Care was taken to spray each apple for 1/2 a minute, and that the fruit was turned, so all the surface would be exposed to the spray.

V. Shallow Submersion.

The apples in this test were allowed to remain in the washing solution for five minutes with an occasional submersion to a depth of six inches.

After each of the above treatments the fruit was thoroughly washed with clean water, and kept in common storage for ten days. The specimens were then cut open and the amount of core injury and blue mold decay ascertained.

Table IV gives the results obtained in these tests.

TABLE IV

WASHING BY VARIOUS METHODS IN RELATION TO LEAKAGE OF ACID INTO OPEN-CORED APPLES.

Treatment	Number of apples examined	Core injury	Percent blue mold
Check (not washed)	57	none	10.5
Floatation method with occasional submerging to depth of 1 inch. 5 min. .75% HCl.	57	slight	24.2
Sluicing method as in Moe machine. 1 min., .75% HCl.	57	slight	27.3
Spraying method as in Bean machine. ½ min., .75% HCl.	57	slight	25.1
Submersion to a depth of 6 inches. 5 min., .75% HCl.	57	severe	90.0

Obviously, deep submersion results in considerable leakage of acid into the center of open-cored apples. Even at a depth of four to six inches a great deal of leakage occurred (Fig. 3). Apparently some leakage occurs with the sluicing, floatation, and spray methods. The amount of leakage with these methods, however, is much less than that occurring when the submersion method is employed (Fig. 4). Submersion at depths from twelve to sixty inches practically fills the center of every open-cored specimen.

III. THE EFFECT OF VARIOUS WASHING AND DISINFECTING COMPOUNDS WHEN FORCED INTO OPEN-CORED FRUIT.

Experiments were conducted with the aim of obtaining information on the effect on the fruit of various washing and disinfecting compounds when forced into open-cored fruits. Washing and disinfecting compounds were used in the combinations outlined in Tables V and VI. Open-cored Ortley apples were used. These apples were obtained from the Corvallis Orchard Company. They had been graded out, after having been washed with hydrochloric acid solution in a floatation type machine. The fruit was in a firm-ripe to ripe condition, and free from decay, physiological or mechanical injury. Apparently little injury was caused from washing the open-cored apples in this type of washing

TABLE V

THE EFFECT OF VARIOUS WASHING AND DISINFECTING COMPOUNDS WHEN FORCED INTO OPEN-CORED FRUITS

(common storage)

Treatment	Physiological injury	Percent blue mold
Check (no treatment)	none	5
Water (H_2O)	none	15
Water followed by .5% HCl.	slight	70
.5% HCl.	severe	100
.5% HCl plus 2% Formaldehyde	severe	70
2% Formaldehyde	severe	30
5% Boric acid solution	severe	10
5% Boric acid solution followed by .5% HCl.	severe	30
10% Sodium acid carbonate solution	slight	5
10% Sodium acid carbonate solution followed by .5% HCl.	severe	55
10% Sodium shloride solution plus .5% HCl.	severe	100
.2% Sodium hydroxide solution	severe	10

TABLE VI

THE EFFECT OF VARIOUS WASHING AND DISINFECTING COMPOUNDS WHEN FORCED INTO OPEN-CORED FRUITS

(Cold Storage)

Treatment	Physiological injury	Percent blue mold
Check (no treatment)	none	5
Water (H_2O)	slight	15
Water followed by .5% HCl.	severe	85
.5% HCl.	severe	75
.5% HCl. plus 2% Formaldehyde	severe	90
2% Formaldehyde	severe	10
5% Boric acid solution	severe	50
5% Boric acid solution followed by .5% HCl.	severe	50
10% Sodium acid carbonate solution	slight	25
10% Sodium acid carbonate solution followed by .5% HCl.	severe	30
10% Sodium Chloride solution plus .5% HCl.	severe	45
.2% Hydroxide solution	severe	25

machine. The fruit in each case was submerged to a depth of sixty inches, in the same manner as outlined on page two. Following the washing treatment it was rinsed in clean water and wrapped in paper. Half of the fruit from each lot was placed in common storage at a temperature of 65 degrees F. while the remaining portion was stored in cold storage at 40 degrees F. At the end of ten days the fruit from the common storage lots was cut open and examined for physiological injury and decay. The fruit from the cold storage lots was examined twenty-four days after treatment.

Tables V and VI give the data obtained in these tests.

This series of tests showed quite conclusively that serious core injury and blue mold decay nearly always results when hydrochloric acid enters the core of apples.

The injury resulting from the failure to remove the acid from the core cavity was a soft breakdown, much the same in character as the typical blue mold decay. This injury extended to a depth of 1/4 to 1/2 an inch from the core. Unless the acid injury was followed by decay, this injury would not break down the entire apple, but would stop, leaving the soft, watery breakdown at the core (Fig. 3). Cold storage seems to retard these troubles, but does not prevent them. The formaldehyde used alone resulted in no blue mold decay, but was responsible for a great deal of physiological core injury.

This injury was much firmer and darker than the acid injury, and did not extend as deeply into the flesh as the acid injury, but was of sufficient depth to render the fruit unsailable.

Filling the core cavity with water prior to the acid treatment resulted in a slight decrease of core injury and core decay. Filling the core cavity with a 5% solution of boric acid did not prevent blue mold development entirely, this lot of fruit showing approximately fifty percent blue mold decay. Some physiological injury, very similar to the injury caused by the formaldehyde, resulted from the use of boric acid.

Five percent boric acid solution followed by the hydrochloric acid treatment resulted in considerable blue mold decay, and physiological injury.

Sodium acid carbonate alone gave only a small amount of decay and practically no physiological injury. Sodium acid carbonate followed by hydrochloric acid, however, gave a high percentage of blue mold decay, and considerable physiological injury.

Sodium chloride and hydrochloric acid together gave a great deal of blue mold decay and physiological injury.

Sodium hydroxide alone gave only a small amount of blue mold decay, but resulted in a large amount of physiological injury.

The injury caused by blue mold (Penicillium expansum) resulted in the complete breakdown of the fruit. The mold started growth on the surface of the exposed tissue in the core cavity and in ten days had usually worked its way to the surface of the apple (Fig. 5).

Although blue mold started growth upon the introduction of most of the solutions, the growth was greatly accelerated by excessive physiological injury, as shown by the very high percentage of blue mold injury following the acid treatment.

The Effect of .75 percent Hydrochloric Acid on the Growth and Germination of Blue Mold Spores

The following experimental work was undertaken to determine the effect of the acid bath on the time of germination and growth of blue mold spores.

In these tests, spores taken from fruit that had been infected with blue mold during the washing treatment were put in a flask containing sterile .75 percent hydrochloric acid solution. The flask was thoroughly shaken to insure wetting the spores and to break up any clumps of spores that might have formed. At regular intervals of two hours one c.c. of the solution charged with the spores was pipetted by means of a sterile pipette onto plates of sterile potato dextrose agar. Enough powdered calcium carbonate was added to each plate to neutralize the acid.

After inoculation each plate was put in the incubator at 80 degrees F. for thirty-six hours. The plates were then examined for mold growth. At the end of the thirty-six hour period every plate had produced a strong growth of blue mold, showing that the spores were not killed by the .75 percent acid in that length of time.

In addition to this work the effect of the acid on the germination of the spores was determined by another method. This was done by charging a sterile solution of .75 percent hydrochloric acid with blue mold spores, and making hanging-drop slides in Van Tiegham cells. These were then examined under the microscope to determine the time and percent of germination by actual count. Checks of pure water and a 5 percent sugar solution were made. The drops were examined every eight hours. At the end of twenty-four hours the spores in the sugar solution had started to germinate. In forty hours sixty percent of the spores in the sugar solutions, and forty-two percent of those in the water had germinated. The spores in the acid solution were examined sixty-eight and seventy-two hours after they were put in the solution, and no germination had started. The test was then discarded because of the evaporation of the hanging-drop in the cells.

This work shows that, although the spores did not germinate while in the acid solution, they germinated and produced a heavy growth when they were removed and placed on a favorable media.

That the acid tanks soon became heavily charged with mold spores was soon apparent. Heald[2] found that the spore count varied from 200 to 12,300 spores per c.c., depending upon the character of the fruit. Fisher[1] found in one machine that was washing ripe windfalls, the spore count reached an average of 1,500 spores per c.c. at the end of a two hour run.

It is apparent that when the spores in the contaminated acid bath are carried into the core cavity with the acid they lie dormant until the acid has been absorbed by the flesh of the fruit. Then, the spores germinate and, following the physiological injury caused by the acid, readily break down the apple.

IV. THE EFFECT OF SUBMERGING AT VARIOUS DEPTHS ON LEAKAGE INTO THE CALYX TUBE OF CLOSED-CORED FRUITS

To obtain information on this phase of the problem, closed-cored apples of the Mann variety were used in the first tests.

An attempt to use several stains in solutions in determining the amount of liquid entering the calyx tube of the fruit was made. Solutions of analin blue, methyl red, methyl green, and gentian violet were used.

Because of the smooth, hard character of the calyx tube, and the spreading of the stains by the juice when the fruit was cut so as to expose the calyx tube, this method was abandoned.

In the second series of tests, closed-cored apples were submerged at depths varying from 0 to 60 inches in a solution of .75 percent hydrochloric acid. The varieties used were Mann, Ben Davis, Yellow Newtown, and Winesap. Following the acid treatment, the apples were thoroughly rinsed in water. The presence or absence of acid in the calyx tube was determined by pressing the tongue firmly against the calyx of each apple as it came from the rinse bath. It was found that the presence of even small amounts of acid could be detected in this manner.

The results of this test showed quite clear that submersion tends to force the washing solution into the calyx tube of closed-cored apples. It is clear, also, that rinsing, no matter how thoroughly done, cannot remove the acid that has been forced deep into the calyx tube. Apparently the deeper the submersion the greater the amount of acid that is forced into the calyx tube.

Several lots of fruit were treated with water before they were submerged in the acid, as outlined in part II. Passing the fruit through a water bath prior to the acid treatment did not remedy this trouble entirely.

V. THE EFFECTS ON THE FRUIT OF LEAKAGE INTO THE CALYX TUBE

Data on this phase of the problem was obtained by submerging apples at various depths in .75 percent hydrochloric acid and then noting the effects of the treatment during the storage period. Mann and Ben Davis apples were washed by the floatation method, and by the submersion method in depths varying from four to sixty inches. The methods used are outlined on page 10. Tables VII and VIII give the results obtained in these tests.

Winesap and Newtown apples were submerged in 66 percent hydrochloric acid at depths of one inch and sixty inches.

The results obtained are shown in table IX.

TABLE VII

THE EFFECT OF LEAKAGE INTO THE CALYX TUBE OF

MANN APPLES

Treatment	Percent calyx injury	Percent calyx decay
Check (no treatment)	0	0
Washed by floatation method	0	5
Submerged 4 inches	5	10
Submerged 8 inches	10	5
Submerged 12 inches	10	10
Submerged 18 inches	0	10
Submerged 24 inches	15	10
Submerged 48 inches	5	10
Submerged 60 inches	15	20

TABLE VIII

THE EFFECT OF LEAKAGE INTO THE CALYX TUBE

OF BEN DAVIS APPLES

Treatment	Percent calyx injury	Percent calyx decay
Check (no treatment)	0	0
Washed by floatation	10	10
Submerged 4 inches	10	5
Submerged 8 inches	45	20
Submerged 12 inches	15	10
Submerged 18 inches	15	15
Submerged 24 inches	25	10
Submerged 36 inches	40	35
Submerged 48 inches	45	15
Submerged 60 inches	35	20

TABLE IX

THE EFFECTS OF LEAKAGE INTO THE CALYX TUBE

OF WINESAP AND NEWTOWN APPLES

Variety	Treatment	Percent Calyx Injury	Percent Calyx Decay
Newtown	Submerged 1 inch in .60% HCl.	0	3.1
Newtown	Submerged 60 inches in .60% HCl.	31.0	27.5
Winesap	Submerged 1 inch in .60% HCl.	8.0	8.0
Winesap	Submerged 60 inches in .60% HCl.	13.0	27.1

The injury resulting from the failure to remove the acid from the calyx tube was, in general, of two kinds: (1) that caused by the hydrochloric acid, and (2) that caused by the growth of molds.

The injury from the hydrochloric acid, when visible from the outside, appeared as tan-colored areas involving the calyx tube and surrounding tissue (Fig. 6). A large number of specimens were cut in two, exposing the calyx tube; and it was found that the injury usually started just below the calyx tubes, or on the lobes themselves.

With continued storage the injured areas became much darker in color, but if the injury was not followed by mold growth it did not spread throughout the apple.

As is shown in tables VII, VIII, and IX, a high percentage of the apples were injured by calyx decay. This decay was usually caused by blue mold, although occasionally they became infected with perennial canker (Glaeosporium perennans). The blue mold growth generally started in the same region as the hydrochloric acid injury.

Within ten days time the blue mold would have rotted the entire area around the calyx tube, resulting in the characteristic light colored soft decay (Fig. 7).

The decay resulting from perennial canker was much darker, resulting in a firm, dry, rot, which slowly consumed the fruit (Fig. 8).

Obviously deep submersion results in an increased amount of both calyx injury and calyx decay. It seems that any depth greater than from 6 to 8 inches is sufficient to force the acid solution below the calyx lobes and deep enough into the calyx tube to make it impossible to rinse out, and that when the acid is left in the calyx end, physiological injury or decay usually results.

Observations from Commercial Washing Operations

The experimental data obtained in the course of these experiments corroborate very closely the observations made from commercial washing operations.

Early in 1927 several firms contemplated manufacturing a deep submersion type of machine, and two firms did manufacture and offer for sale this type of fruit washer. The principle on which these machines work is that the fruit is carried from the surface to a depth of about five feet and then allowed to come to the surface again. This is repeated four times during the five minutes the fruit is left in the acid compartment. From the acid bath it is conveyed to a rinsing tank where it is subjected to a similar treatment in fresh water, and then conveyed to the dryer.

This type of machine had several advantages: it was simple in regard to construction, eliminating the necessity for pumps, pipes, screens, or rapidly moving parts. By submerging, it was possible to keep the fruit in the acid for five minutes, which was necessary if disinfectants were to be used and still keep the fruit in motion which is necessary in order to break up local concentrations of arsenic laden acid, without using a large amount of valuable floor space. This economy of floor space and simple construction was a large factor in the selling of this machine.

Thirty-two of these machines were installed, principally in Hood River, with a few at Mosier, Milton-Freewater, Roseburg, Medford, and White Salmon. This represented an investment of about $40,000 for the cost of the machines. The amount for the cost of spoiled fruit cannot be accurately estimated, but it is safe to say that it amounted to $100,000 or more.

The first machine was installed about August 1st, 1927, at Medford, Oregon. Forty thousand boxes of pears were washed with no report of injury. Sodium chloride was used to cause the pears to float.

Following this, a machine was set up at Hood River. The first fruit to be washed in the North with this machine was five cars of Gravenstine apples. A weak acid solution was used and no injury was reported.

By this time, it had been determined that this machine could not be used on varieties which had very open calyx tubes, or calyx tubes opening into the core cavity, but it was thought that it would be satisfactory for most commercial varieties, and that no great injury would result.

The first indication of real trouble was reported

October 15th, when it was found that 19 cars of Jonathans washed by one of these machines at Milton-Freewater, Oregon, were arriving at eastern markets in bad condition. The fruit showed a great deal of Blue Mold decay, some cars running as high as 60 percent. The apples also showed a high percentage of calyx injury.

The next report was from Mosier. Delicious apples which had been washed and put in common storage were so badly injured that they had to be repacked in ten days after they were washed. Then the same trouble started to show up in the Spitzenburg, Delicious, and Jonathans at Hood River, Oregon.

When this positive injury was seen, the machines were converted into the paddle wheel floatation type of washer which proved to be satisfactory under commercial conditions.

Practical Applications

The results of the experimental work, together with the observations made from commercial washing operations bring out the following factors in regard to the commercial cleaning of fruit by the washing methods.

1. That submersion to any depth greater than a few inches will result in a high percentage of injury.
2. That submerging the fruit in solutions before they are subjected to the acid treatment is not practical as it does not lower the amount of injury to any great degree.
3. That injury from penetration occurs when both acid and alkali solutions are used as solvents.
4. That injury from penetration varies considerably with the kinds and varieties of fruits.

Summary and Conclusions

1. It was found that there was a wide variation in the prevalence of open-cored apples within a given variety, the number of open-cored fruits increasing in the larger sizes. Some varieties were almost all close-cored, while other varieties would run as high as 30 percent open cores.

2. Deep submersion results in considerable leakage of acid into the open-cored apples. Apparently some leakage occurs with sluicing, floatation, and spray methods, but it is much less than when submersion is employed. Submersion at four inches resulted in a great deal of leakage, and depths below twelve inches practically filled the center of every open-cored specimen.

3. Serious core injury resulted when hydrochloric acid entered the core of the apple. Filling the core with different solutions prior to the acid treatment resulted in only a slight decrease in core injury and decay.

4. It is quite clear that submersion forces the washing solutions into the calyx tube of close-cored fruits, and that the deeper the submersion the greater the amount of acid is forced into the calyx tube. This

acid could not be rinsed out. The entrance of acid solution into the calyx tube resulted in a high percentage of physiological injury and mold decay.

LITERATURE CITED

Fisher, D. F., Report of Washington Hort. Soc., 1927.

Heald, F. D., Report of Washington Hort. Soc., 1927.

FIGURE 1

DIAGRAM OF AN OPEN-CORED APPLE

FIGURE 2

DIAGRAM OF A CLOSED-CORED APPLE

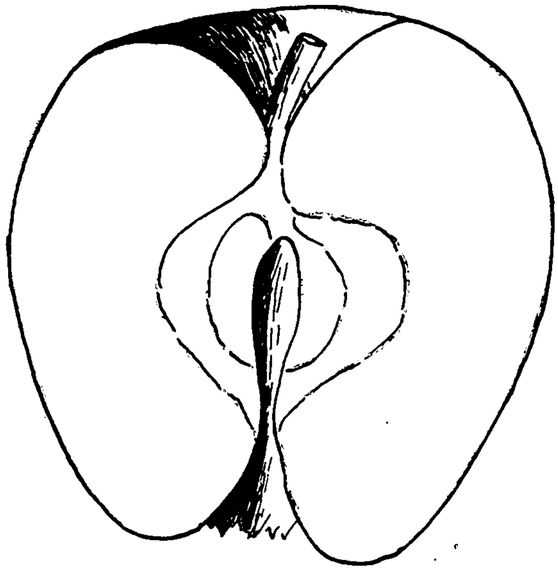

Fig. 1

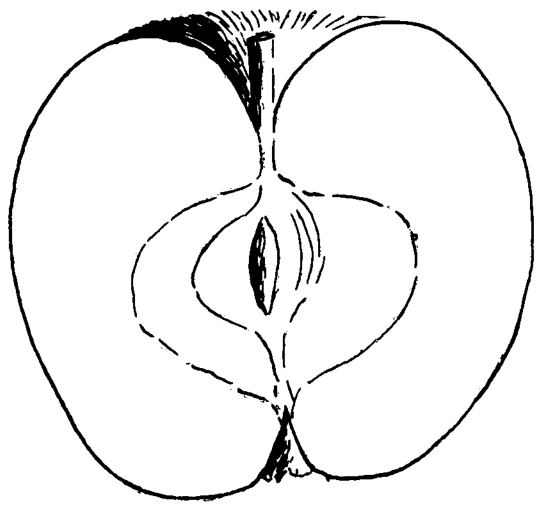

Fig. 2

FIGURE 3

INJURY OCCURRING IN OPEN-CORED

APPLES SUBMERGED TO A DEPTH OF SIX INCHES

Fig. 3

FIGURE 4

INJURY OCCURRING IN OPEN-CORED APPLES

WASHED BY THE FLOATATION METHOD

Fig. 4

FIGURE 5

BLUE MOLD DECAY FOLLOWING DEEP

SUBMERSION OF ORTLEY APPLES

Fig. 5

FIGURE 6

ACID INJURY FOLLOWING DEEP SUBMERSION OF CLOSED-CORED APPLES

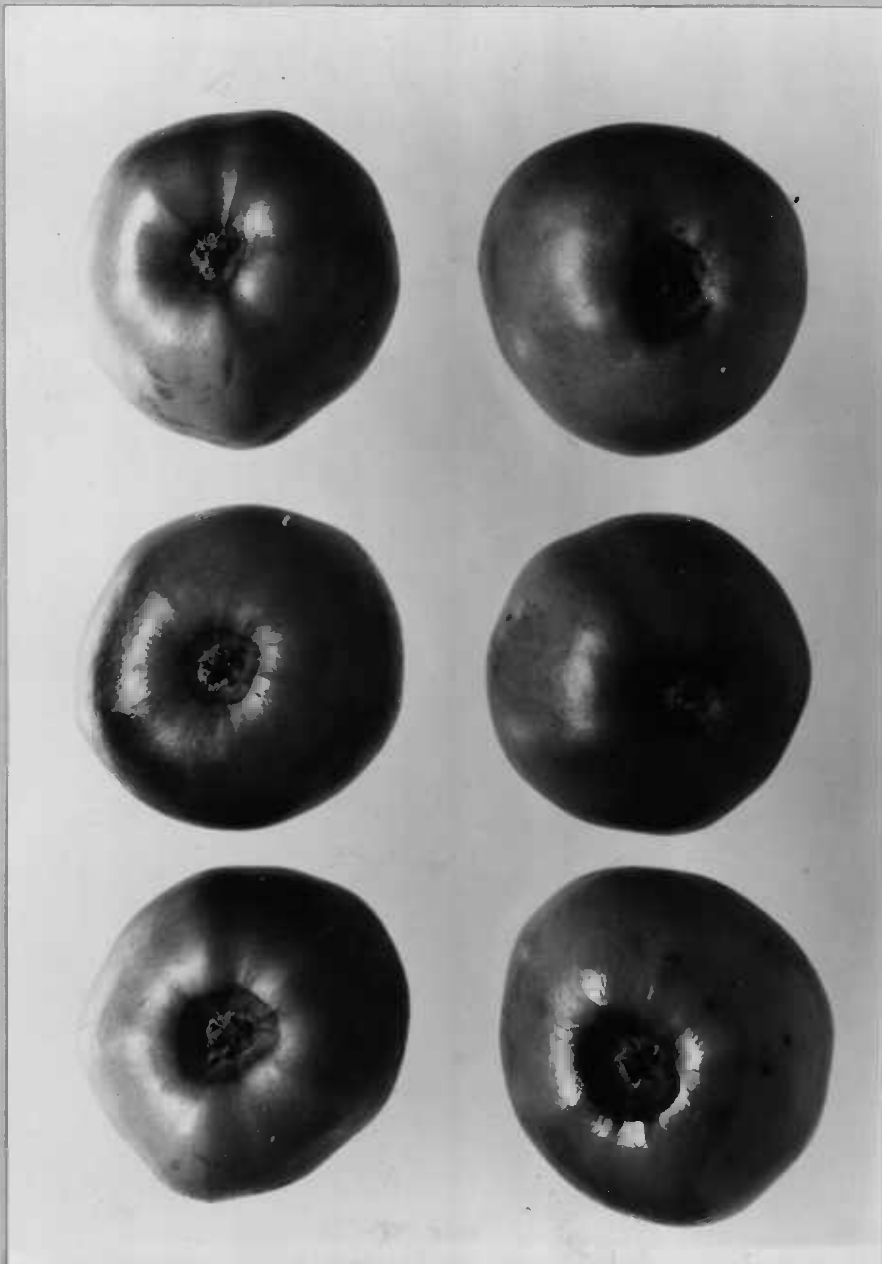

Fig. 6

FIGURE 7

BLUE MOLD DECAY FOLLOWING DEEP

SUBMERSION OF CLOSED-CORED APPLES

Fig. 7

FIGURE 8

PERENNIAL CANKER FOLLOWING DEEP SUBMERSION OF CLOSED-CORED APPLES

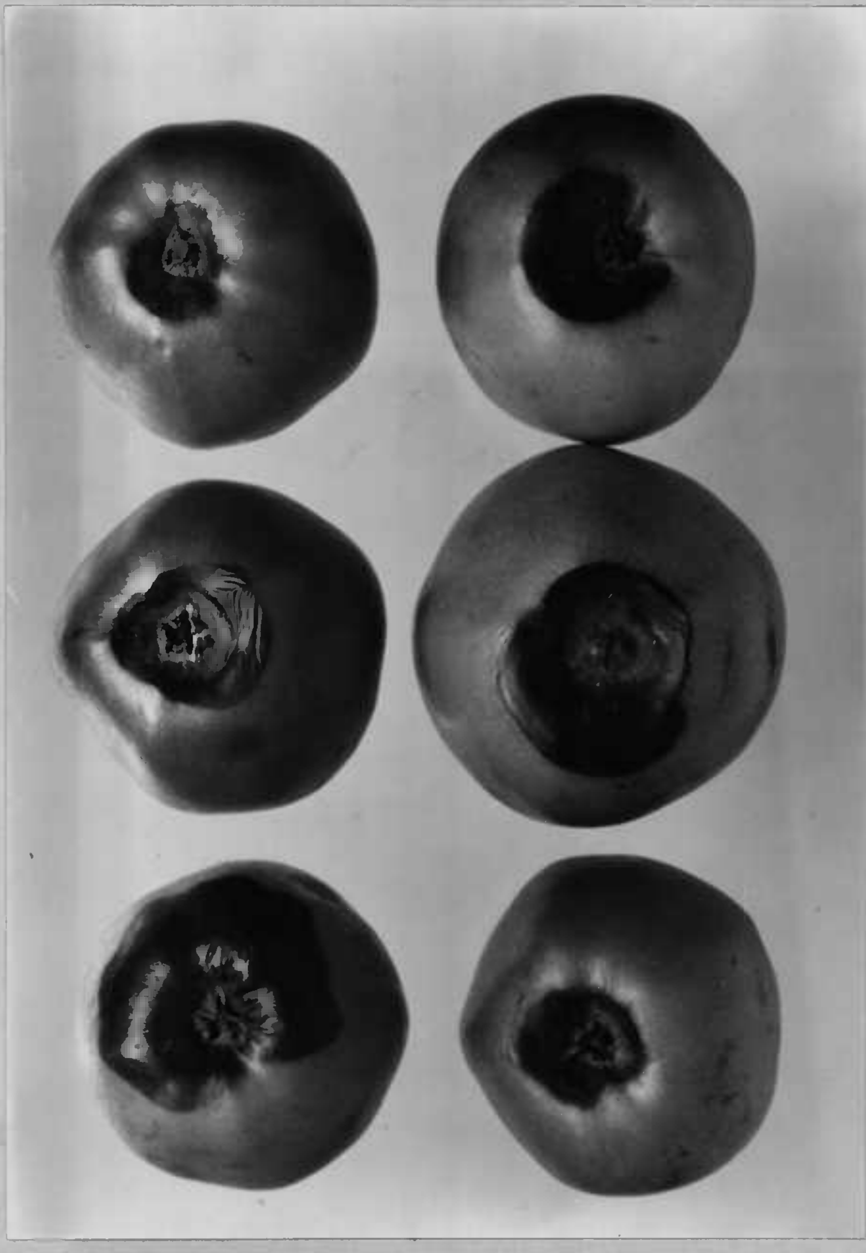

Fig. 8